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Training Manual

Sustaining River Basin Ecosystems in Hydropower Development

Network for Sustainable Hydropower Development in the Mekong Countries (NSHD-M)

Training Manual

Sustaining River Basin Ecosystems in Hydropower Development

PREFACE

Intergovernmental co-operation between countries that share the Mekong River and its tributaries commenced in 1957 when the United Nations founded the Mekong River Committee. The Mekong was then one of the world's largest unregulated rivers, and the Committee was to capitalise on the river's economic potential. In 1995 a new Mekong Agreement established the Mekong River Commission (MRC), with a more holistic mandate: 'to promote and co-ordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well-being by implementing strategic programmes and activities and providing scientific information and policy advice'. The 1995 Mekong Agreement also placed the MRC under the direct responsibility of its four member states: Thailand, Laos, Cambodia and Vietnam. The MRC also engages with two important upstream partners,, China and Myanmar, on its shared water courses.

The development of the Mekong's water resources have included the establishment of a number of large dams, on both the river's main stem and tributaries, in all four member countries. These dams were constructed for a variety of purposes, including flood protection, irrigation and hydropower. These dams have been controversial, due to their negative effects on natural and social environments—to the extent that some member countries, such as Thailand, have ceased building dams altogether.

In 2000, the World Commission on Dams (WCD) published *Dams and Development: A New Framework for Decision-Making*. In the report WCD proposed an approach based on the recognition of rights and the assessment of risks, particularly taking into account the core values of equity, efficiency, participatory decision-making, sustainability and accountability, when building dams. In addition, the report identified seven strategic priorities, associated principles, and twenty-six guidelines for the way forward.

On completion of its mandate, the WCD was disbanded. To maintain the WCD's momentum, the United Nations Environment Programme (UNEP), as a neutral entity to disseminate the WCD report and facilitate inclusive, multi-stakeholder dialogues at national and local levels, reviewing the WCD's recommendations, agreed to host a follow-up initiative: the Dams and Development Project (DDP). One of the outputs of the DDP process was *A Compendium of Relevant Practices for Improved Decision-Making on Dams and their Alternatives*.

Against the backdrop of previous water resource development projects, with their many negative legacies, the German Development Cooperation, through GIZ, agreed to promote the sustainable development of the Mekong's water resources, by facilitating learning among member countries, to minimize adverse effects and optimise the benefits of new projects. GIZ recognised developmental challenges, faced by emerging economies worldwide; in particular, an ever-increasing need for sustainable, renewable energy (in particular, hydropower in the Mekong region). This led to the establishment of the Network for Sustainable Hydropower Development in the Mekong Countries (NSHD-M), including academics and researchers from MRC member states and China. Key functions of the NSHD-M are human resource development and advanced training, as well as dialogue and regional networking to share information and good practices.

These objectives will be achieved through the sharing of information on six key topics:

- Dealing with Social Aspects

- Sustaining River Basin Ecosystems
- Comprehensive Options Assessment
- Hydropower and Economic Development
- Hydropower Development on Transboundary Rivers
- Hydropower and Climate Change

It is intended that these topics will be addressed in six respective training manuals, supported by country-specific case studies, developed by academics and researchers from MRC member states and China. This training manual covers ‘Sustaining River Basin Ecosystems’ .

Each of the training manuals is being developed in three phases: the development of generic manuals of sufficient scope and depth, the adaptation of these generic manuals to align with Mekong basin states' country-specific legal and institutional frameworks and socio-economic conditions, and further adaptations as may be required, including the translation of the training manuals into local languages.

GIZ promotes and supports participatory learning and adopts a ‘Participatory Adult Learning Approach’ (PALA). Participatory adult education is founded on the belief that people have a right to influence the decisions that affect their lives and that adult learners come with particular goals and ideas about education. Thus, participatory education programs involve learners in making decisions about their own learning, particularly through activities chosen or created by the learners theselves. This, in turn, validates learners’ knowledge and needs, enhances academic achievement, and shapes the extent to which participants can exercise control in the classroom, their lives, and communities. According to adult education scholars, the purposes of participatory education are to enhance learners’ autonomy, critical thinking, leadership, and active citizenship.

It is important that what is taught is applicable to real life situations. A workshop will, therefore, provide an opportunity for adult learners to apply what has been learned to real-life situations and job requirements. Learners will be encouraged to share their experiences and possible solutions, turning workshops into learning cooperatives.

Adults have different experiences throughout life, which lead to the accumulation of knowledge. Some experiences are based on past learning, others on everyday community life and work. All of these are significant resources from which to draw on during the learning process and to share with others. It is important to establish what learners’ existing knowledge is and to encourage them to share what they’ve accumulated with others.

Participants learn more by listening and actively participating than by taking detailed notes. Learners must actively participate in order to satisfy their learning needs. In participatory learning, learners actively participate to determine what and how they learn. This may include the objectives, knowledge, skills and attitudes or actual teaching methods. Traditionally, a teacher delivers information; however, in participatory learning, a student learns by doing.

While a participatory approach is encouraged, at times information must still be presented. Examples include: giving instructions, giving advice or suggestions, summarizing, giving explanations or demonstrations. The challenge is to provide necessary information without learners becoming bored.

Other ways in which participatory learning can be implemented include: group work, group discussions, brainstorming, role play, field work, and questions and answers.

From this manual, the trainings are intended to be participatory in nature, optimising the benefits of the 'Participatory Adult Learning Approach'.

Applying modern adult learning methods at the Trainer-of-Trainers Workshop in Hoa Binh, March 2013

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Abbreviations and Acronyms

ACTEW	Australian Capital Territory Electricity and Water Corporation
ADB	Asian Development Bank
AIC	Appreciation-Influence-Control
BOOT	Build, Own, Operate and Transfer)
BS	British Standard
BWP	Berg Water Project
CCAI	Climate Change and Adaptation Initiative
CD	Compact Disc
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DDP	Dams and Development Project
DEFRA	Department of the Environment, Food and Rural Affairs (UK)
DMR	Department of Mineral Resources
ECO	Environmental Control Officer
EMC	Environmental Monitoring Committee
ECSHD	Environmental Considerations for Sustainable Hydropower Development
EIA	Environmental Impact Assessment
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
ESIA	Environmental and Social Impact Assessment
EU	European Union
FERC	Federal Energy Regulatory Commission
FPIC	Free, Prior and Informed Consent
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HIA	Health Impact Assessment
I&AP	Interested and Affected Party
IBA	Important Bird Area
ICRA	International Centre for Development-oriented Research in Agriculture)

IFC	International Finance Corporation
IFR	In-stream Flow Requirement
IHA	International Hydropower Association
IPCC	Intergovernmental Panel on Climate Change
ISGWES	Information Centre for Water and Energy Systems.
ISH	Initiative on Sustainable Hydropower
ISO	International Standards Organisation
IUCN	International Union for Conservation of Nature
IWRD	Integrated Water Resources Development
IWRM	Integrated Water Resources Management
LHWP	Lesotho Highlands Water Project
LMB	Lower Mekong Basin
MDG	Millennium Development Goals
MIS	Management Information System
MRC	Mekong River Commission
MSP	Multi-stakeholder Platform
NAPA	National Adaptation Program of Action to Climate Change
NEAP	National Environmental Action Plan
NGO	Non-government Organisation
SHD-Network	Network for Sustainable Hydropower Development in the Mekong Countries
PALA	Participatory Adult Learning Approach
PES	Payment for Ecosystem Services
QA	Quality Assurance
REDD	Reducing Emissions from Deforestation and Forest Degradation
RoD	Record of Decision
RAP	Resettlement Action Plan / Relocation Action Plan
RP	Resettlement Plan
RRP	Rescue and Relocation Plan
RSAT	Rapid basin-wide Hydropower Sustainability Assessment Tool
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SEA	Strategic Environmental Assessment
SHD	Sustainable Hydropower Development

SIA	Social Impact Assessment
TCTA	Trans-Caledon Tunnel Authority
TEEB	The Economics of Ecosystems and Biodiversity
TOT	Training of Trainers
TSECS	Tuvalu Solar Electric Cooperative Society
TVA	Tennessee Valley Authority
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
WANI	Water and Nature Initiative
WB	World Bank
WCD	World Commission on Dams
WCED	World Commission on Environment and Development
WQ	Water Quality
WSSD	World Summit on Sustainable Development
WWF	World Wide Fund for Nature / World Wildlife Fund
ZOPP	Objectives-Oriented Project Planning

Units

^{o}C	degree Celsius
ha	hectare
kg	kilogramme
km	kilometre
m	metre
MW	megawatt
M m^3	million cubic metres
s	second
t	tonne
yr	year

Structure of Manual

The learning material in this manual has three major elements divided into 10 'modules':

- Introductory material (Overview, General Concepts).
- Technical material (Biodiversity Conservation, Fisheries, Watershed Management, Climate Change, and Mitigation – as this focuses on environmental flows).
- Procedural material and tools (EIAs, EMPs, Compliance and Monitoring).

Eight of the 10 modules were authored by James Ramsay (JR) and two by Brian Hollingworth (BH) ,with subsequent editing by JR, as noted below:

Module	Author
1 Overview of the Dams and Hydropower Debate	BH
2 General Concepts	JR
3 Biodiversity Conservation	JR
4 Fisheries	JR
5 Watershed Management & Reservoir Sedimentation	JR
6 Climate Change	JR
7 Mitigation and Compensation	JR
8 Introduction to EIA	JR
9 Environmental Management Plans	BH
10 Compliance and Monitoring	JR

As far as possible, each module is a stand-alone training course, divided into sessions covering different topics. However, to avoid repetition, there is some cross-referencing.

The scope of each of the modules and its sessions is given in a box at the beginning of each chapter.

Structure of Sessions

Each session comprise a standard set of items (table below). The Key Aspects are highlighted at the beginning of each session, together with training aids: 'Purpose of Session, Learning Objectives and Key Reading'. The Discussion Topics, Exercises and Additional Reading are listed in another training aids table at the end of each session, followed by the Case Studies.

Session Structure	
Item	**Description**
Key Aspects	A brief list of the most important points in the session
Training aids	
Purpose of Session	Statement of purpose of session
Learning Objectives	Brief statement of the knowledge and skills the trainee should have at the end of the session
Key Reading	A list of key readings
Content	The content of the session, as text, lists, tables etc.
Training aids	
Discussion Topics	Suggestions for the trainer
Exercises	Suggestions for the trainer
Additional Reading and Resources	Additional reading and resources to help the trainee expand his/her knowledge
Case Studies	Short case studies presented as boxes.

Sources

This manual is based on information from many different sources. As far as possible, citations are given for all quotations and all sources are referenced in footnotes. The authors welcome notification of errors and omissions.

1 OVERVIEW OF THE LARGE DAMS AND HYDROPOWER DEBATE

MODULE 1: OVERVIEW OF THE LARGE DAMS AND HYDROPOWER DEBATE		
Scope	**Session/Sub-Topic**	**Scope**
Overview of the hydropower and sustainability debate	**Session 1.1: Background to Hydropower and Sustainability**	
	Environment and development	NEPA; WCED; the Earth Summits; the MDGs
	Concept of sustainability	WCED; definitions; principles
	Session 1.2: New Ethical and Industry Standards	
	World Commission on Dams	WCD
	Dams and Development Project	WCD Uptake; UNEP and the DDP
	Industry Response to WCD	IHA; the Hydropower Sustainability Assessment Protocol
	Water Alternatives special issue	WCD+10, Water Alternatives special issue
	Session 1.3: The Mekong River Basin	
	Hydropower in the LMB	Overview of hydropower - existing and planned
	MRC task forces and tools	ECSHD; RSAT; ISH
	Integrated Basin Development Strategy	Overview; strategic priorities for basin development and basin management; strategy implementation and status

1.1 The Background to Hydropower and Sustainability

Key aspects	• The debate on large dams and hydropower can be traced over several decades through international initiatives and the resulting normative frameworks concerning environmental and social safeguards and human rights, including: o United Nations Conference on the Human Environment, 1972; o Brundtland Commission, 1987; o UN Conference on Environment and Development, 1992; o The Millennium Report, 2000; o World Summit on Sustainable Development, 2002; and o The Rio +20 conference, 2012.

TRAINING AIDS	
Purpose of session	The purpose of the session is to introduce and review the evolution of the environment and development debate and the concepts of 'sustainability' and 'sustainable development'.
Learning objectives	• To understand the origin and evolution of the debate. • To be aware of the many stakeholders that have been involved. • To understand the core principles of 'sustainability'.
Preparatory reading	1) IISD. 2002. Introduction to Sustainable Development. http://www.iisd.org/pdf/2011/intro_to_sd.pdf 2) IISD. 2009. Sustainable Development Timeline. http://www.iisd.org/pdf/2009/sd_timeline_2009.pdf 3) Club of Rome online presentation on 'Limits to Growth', at http://www.clubofrome.org/?p=326

1.1.1 Environment and Development

In the post-World War II industrial boom, consciousness of the negative impacts of unfettered technological development first emerged in the United States. In 1962, publication of *Silent Spring*,[1] a review of the ecological damage caused by pesticides especially DDT, triggered major national and international debates. In 1969, the US promulgated the National

[1] Rachel Carson. 1962. Silent Spring. Houghton Mifflin, Boston, USA.

Environmental Policy Act (NEPA). This was the first national legislation that mandated environmental assessment and required the results to be published in a detailed environmental statement. It prompted extensive research into the methods needed to comply with NEPA and environmental assessment.

The US approach provided the catalyst for broader international initiatives. In 1972 at the United Nations Conference on the Human Environment, the United Nations Environment Programme (UNEP) was launched. In the same year, the Club of Rome[2] published the controversial future modelling scenarios in the book "Limits to Growth", highlighting the concepts of **'ecological footprin**t' (the area of and needed to sustain one human being) and **'overshoot'** (when the global ecological footprint is exceeded, inevitably resulting in subsequent collapse; this transition is considered to have happened in the 1980s[3]).

In 1987, the World Commission on Environment and Development (WCED, commonly called the Brundtland Commission) published its report, Our Common Future. It called for development that met the needs of the present generation without compromising the ability of future generations to meet their own needs, and prompted the use of the term "sustainable development". By the start of the 1990s, three major instruments of international environmental law existed, namely the International Framework Convention on Climate Change, the International Convention on Biodiversity and the Montreal Protocol on Ozone.

There have been three major conferences ("Earth Summits") focusing on environment and development, in 1992 (Rio), 2002 (Rio+10) and 2012 (Rio+20):

- **1992**: **UN Conference on Environment and Development (UNCED):** this was held in Rio de Janeiro. It discussed a wide range of environmental issues. Discussions focused on finding possible solutions to issues of global importance such as poverty, war and the ever-increasing divide between developed and developing countries. A key point highlighted was that of sustainable development, which stressed the heavy dependence of social and economic development on conservation of the natural resource base, with effective methods and processes to avoid environmental degradation. The meeting resulted in the emergence of the **Rio Declaration**, a set of 27 principles aimed at binding the governments of participating countries to the need for environmental protection and responsible development. **Agenda 21** was also developed at the Earth Summit - the environmental agenda for the 21st century - and has since formed the cornerstone for sustainability and sustainable development strategies. Chapter 18 of the Agenda deals with water resources, and paragraph 40 of Chapter 18 calls for the development of national and international legal instruments that may be required to protect the quality of water resources, including for environmental impact assessment.

- **2002: World Summit on Sustainable Development (WSSD):** this meeting took place in Johannesburg, to evaluate progress in implementation of the results of the

[2] The Club of Rome was founded in 1968 as an informal association of independent leading personalities from politics, business and science, men and women who are long-term thinkers interested in contributing in a systemic interdisciplinary and holistic manner to a better world. The Club of Rome members share a common concern for the future of humanity and the planet.

[3] See Club of Rome website: http://www.clubofrome.org/

Rio Summit and identify new challenges which had developed since 1992. Significantly, one topic not addressed during this meeting was that of population growth. The meeting reaffirmed the international community's commitment to Agenda 21. Paragraph 19 of the Johannesburg Plan of Implementation called on all states to:

> *"encourage relevant authorities at all levels to take sustainable development considerations into account in decision-making, including on national and local development planning, investment in infrastructure, business development and public procurement. This would include actions at all levels to:*
>
> *(a) …….*
>
> *(e) Use environmental impact assessment procedures".*

- **2012: United Nations Conference on Sustainable Development (Rio+20):** in 2012, Rio de Janeiro again hosted an Earth Summit, where the concept of sustainability was emphasised and discussed. Three processes or 'pillars' emerged as the basis for sustainable development: strengthening, reforming and integrating. The issue of energy provision was addressed, with participating member countries proposing to build on the Sustainable Energy for All initiative (SE4ALL: see **Box 1-1**), which was started by the UN Secretary General. This initiative incorporates a number of objectives, including the provision of worldwide access to basic, lowest level of modern energy services for the purpose of consumption and production by 2030, and promoting the development and use of renewable energy sources and technologies in every country.

Box 1-1: Sustainable Energy for All: 2012 report by UN Secretary General

2012 was the International Year of Sustainable Energy for All (SE4ALL), and the Secretary General of the UN reported[4] (emphasis by author):

> *"5 .... Without access to modern energy services, it is not possible to achieve the Millennium Development Goals.*
>
> *6. The availability of adequate, affordable and reliable energy services is essential for alleviating poverty, improving human welfare, raising living standards and, ultimately, achieving* ***sustainable development****. Adequate sustainable energy services are critical inputs in providing for human health, education, transport, telecommunications and water availability and sanitation.*
>
> *7. Achieving* ***sustainable energy*** *for all involves the development of systems that support the optimal use of energy resources in an equitable and socially inclusive manner while minimizing environmental impacts. Integrated national and regional infrastructures for energy supply, efficient transmission and distribution systems and demand programmes that emphasize energy efficiency are necessary for sustainable energy systems."*

At the meeting the international community again reaffirmed the principles developed in the preceding conferences. The Heads of State expressed their determination to:

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[4] United Nations. 2012. *International Year of Sustainable Energy for All, 2012: Report of the Secretary General*. Report A/67/314. 16 August 2012

> *"reinvigorate political will and to raise the level of commitment by the international community to move the sustainable development agenda forward" and "to eradicate poverty and promote empowerment of the poor and people in vulnerable situations".*

Leaders also noted:

> *"We acknowledge that climate change is a cross-cutting and persistent crisis, and express our concern that the scale and gravity of the negative impacts of climate change affect all countries and undermine the ability of all countries, in particular, developing countries, to achieve sustainable development and the Millennium Development Goals, and threaten the viability and survival of nations" and "We underscore that broad public participation and access to information and judicial and administrative proceedings are essential to the promotion of sustainable development".*

The Rio +20 Declaration also introduced the "green economy" and a set of guidelines to the debate[5].

An important milestone during this series of Earth Summits was the development of the **Millennium Development Goals:** in 2000, leaders from around the world gathered at the UN in New York to adopt the UN Millennium Declaration. The Report of the Secretary General of the United Nations (The Millennium Report) stated:

> *The ecological crises we confront have many causes. They include poverty, negligence and greed - and above all, failures of governance. These crises do not admit of easy or uniform solutions.*

Countries at the 2002 MDG meeting committed to a new global partnership, aimed at decreasing the severe levels of poverty experienced at a global scale and introducing a timeline (a deadline of 2015) for the meeting of predetermined targets now known as the Millennium Development Goals (MDGs). Eight MDGs were listed, with the 7th being that of ensuring environmental sustainability. Under this goal is the integration of principles of sustainable development into the policies and procedures of countries and the reversal of the loss of natural resources.

Apart from proposing the MDGs, the report called for the "*building of a new ethic of global stewardship*". It held that effective environmental policy must be based on sound scientific information and called for governments to create and enforce environmental regulations.

[5] United Nations. *The future we want*. Resolution adopted by the General Assembly A/RES/66/288, 123rd plenary meeting. 27 July 2012

1.1.2 The Concept of Sustainability

Left alone, the earth is a sustainable system. The accumulated impacts of human activity over the past 150 years or so are now threatening this continued well-being. 'Sustainability' and 'sustainable development' are now used universally, but what do these words mean?

Sustainable development ties together concern for the carrying capacity of natural systems with the social challenges faced by humanity. As early as the 1970s, "sustainability" was employed to describe an economy "in equilibrium with basic ecological support systems."

The concept of 'sustainable development' was crystallised by the World Commission on Environment and Development (WCED) in 1987. It is development that meets *“the needs of the present generation without compromising the ability of future generations to meet their own needs”.* A brief history of 'sustainable development' to 2002 is given in **Box 1-2**.

It is now generally accepted that the concept incorporates an integration of the three dimensions of sustainable development: **economic**, **social** and **environmental** (with the social dimension now often broken down into political and cultural sustainability). In addition, it needs rights-based, equitable and inclusive processes to enhance sustainability at global, regional, national and local levels.

The UNESCO[6] website states: “*All sustainable development programmes must consider the four dimensions of sustainability - environment, society, culture and economy. Since the local context has a great influence on these dimensions, sustainable development takes many forms around the world. The ideals and principles behind sustainability include broad concepts such as intergenerational equity, gender equity, social tolerance, poverty alleviation, environmental preservation and restoration, natural resource conservation, and building just and peaceful societies*."

Box 1-2: A Very Brief History of Sustainable Development

The concept of **sustainable development** emerged from the post-War environmental movement, which recognised the negative impacts of human growth and development on the environment and communities.

1972: Limits to Growth: Commissioned by the **Club of Rome**, Limits to Growth attempts to model the consequences of a growing human population in a world of finite resources, concluding that current patterns of growth cannot be sustained indefinitely.

1987: Our Common Future: The term sustainable development came to prominence through the United Nations **Brundtland Commission**. The commission’s 1987 report, Our Common Future defined sustainable development as “*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*”.

1992: Rio conference: The concept received further attention at the **United Nations Conference on Environment and Development** in Rio de Janeiro in 1992, the first international attempt to develop strategies for a more sustainable pattern of development.

Representatives of 178 national governments, including more than 100 heads of state, and many organizations representing civil society attended the conference. The world had never previously witnessed a

[6] Principles of Sustainable Development. Available online at: http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/sustainable-development/principles/

larger gathering of national leaders. At the summit, governments around the world committed to sustainable development.

2002: Johannesburg summit: The World Summit on Sustainable Development (WSSD) took place in Johannesburg from 26 August to 4 September 2002. The summit delivered three outcomes: a political declaration, the Johannesburg Plan of Implementation, and the establishment of numerous partnership initiatives. Key commitments covered sustainable consumption and production, water and sanitation, and energy. The outcomes complemented the Millennium Development Goals, reinforced Doha and Monterrey agreements, and set challenging global goals and targets on accessing water, sanitation and modern energy services; increasing energy efficiency and use of renewable energy; sustainable fisheries and forests; reducing biodiversity loss on land and in our oceans; chemicals management; and decoupling environmental degradation from economic growth - that is, achieving sustainable patterns of consumption and production.

Source: UK DEFRA website, accessed 03 Feb. 2013

The 1992 Rio Declaration on Environment and Development set out 27 principles of sustainability.

These principles can guide the efforts of governments, communities and organizations to define sustainability goals and create programmes to help achieve those goals. Some of the principles are:

- People are entitled to a healthy and productive life in harmony with nature;
- The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations;
- Eradicating poverty and reducing disparities in living standards in different parts of the world are essential to sustainable development;
- Environmental protection is an integral part of the development process and cannot be considered in isolation;
- International actions in the field of environment and development should also address the interests and needs of all countries;
- To achieve sustainable development and a higher quality of life for all people, countries should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies;
- Women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainable development;
- Warfare is inherently destructive to sustainable development. Peace, development and environmental protection are interdependent and indivisible.

Importantly, sustainable development involves the following important issues: (i) inter-generational and intra-generational equity, (ii) precautionary or risk aversion strategies, and (iii) conservation of biodiversity[7]. The equity and precautionary principles are defined below:

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[7] Darwish Al Gobaisi (undated). International Study Group for Water and Energy System (ISGWES), Information Center for Water and Energy System (ICWES). Basic Concepts of Sustainability. Available online at: http://www.exergy.se/goran/hig/ses/pdfs/algobaisi1.pdf

- **Inter-generational equity** is the principle of equity between people alive today and future generations. The implication is that unsustainable production and consumption in today's society will degrade the ecological, social, and economic basis for tomorrow's society, whereas sustainability involves ensuring that future generations will have the means to achieve a quality of life equal to or better than today's.
- **Intra-generational equity** is the principle of equity between different groups of people alive today. Similar to inter-generational equity, intra-generational equity implies that consumption and production in one community should not undermine the ecological, social, and economic basis for other communities to maintain or improve their quality of life.
- **Precautionary principle:** a principle of sustainability, which implies that where there are threats of serious or irreversible damage, the lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
- **Biodiversity** (or '**natural capital**' including ecosystem functions) must be maintained because the functions it performs cannot be duplicated by manufactured capital (see Section 2.1.3).

An important part of the debate, often overlooked, is the carrying capacity of natural systems on a global scale. Are there really "Limits to Growth"?[8] Can economic development be sustained, physically? Do we need a more fundamental "sustainability revolution"?

In the water sector, six central principles of sustainability have been identified (Princen, 2003)[9]:

1. Equitable utilisation.
2. Prevention of significant harm.
3. Obligation to notify and inform other parties.
4. Obligation to share data among parties.
5. Cooperative management of international rivers.
6. Obligation to resolve disputes peacefully.

TRAINING AIDS	
Discussion topics	***1)*** In today's world, is there still a place for the view that "if some people suffer, that is OK as long as more people are benefitting"? ***2)*** Principle 15 of the Rio Declaration states: "*In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irre-*

[8] Published by the Club of Rome: available at http://www.clubofrome.org/?p=326

[9] Global Environmental Politics 3:1, February 2003 © 2003 by the Massachusetts Institute of Technology. http://www.nicholas.duke.edu/solutions/documents/PrinciplesForSustainability.pdf

	versible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." How could this principle be applied to large hydropower dams? ***3)*** Is continued economic growth physically possible? Or morally necessary? And what are the alternatives?
Exercises	***1)*** What is the population of your country? And the area? Grow this population geometrically at, say, 2%. How many years before there is 1 person per square metre?
Additional Reading	***1)*** Darwish Al Gobasi (year unknown). International Study Group for Water and Energy System (ISGWES), Information Center for Water and Energy System (ICWES). *Basic Concepts of Sustainability*. http://www.exergy.se/goran/hig/ses/pdfs/algobaisi1.pdf ***2)*** Wikipedia. *Sustainable Development*. Accessed Feb 3, 2013. http://en.wikipedia.org/wiki/Sustainable_development ***3)*** *Principles of Sustainable Development*. http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development/sustainable-development/principles/ ***4)*** *Limits to Growth: The 30 Year Update*. http://clubofrome.at/archive/limits.html ***5)*** Jared Diamond. 2005. *Collapse: how societies choose to fail or succeed*. Penguin Group, NY. 575 p ***6)*** Clive Ponting. 2007. *A new green history of the world: the environment and the collapse of great civilizations*. Penguin, NY. 464 p ***7)*** Darwish Al Gobaisi. 1998. *Sustainable Use of Our Planetary Natural Capital for Life Support on the Earth*. IEEE Systems, Man and Cybernetics Conference, Tunisia. ***8)*** Moffatt, I. 1996. *Sustainable Development - Principles, Analysis and Policies.* Parthenon Publishing Group. ***9)*** IUCN/UNEP/WWF. 1991. *Caring for the Earth: A Strategy for Sustainable Living.* IUCN, UNEP and WWF, Gland, Switzerland. ***10)*** Tyler Miller Jr., G. 1996. *Sustaining the Earth - An Integrated Approach*. Second Ed.: Wadsworth Publishing Co. ***11)*** Ismail Serageldin. 1998. *Expanding the Measure of Wealth – Indicators of Environmentally Sustainable Development*. Environment Department, World Bank, Washington, DC.

Case Studies

Collapse of the Angkor Civilisation

Angkor is the scene of one of the greatest vanishing acts of all time. The Khmer kingdom lasted from the ninth to the 15th centuries, and at its height dominated a wide swath of Southeast Asia, from Myanmar (Burma) in the west to Vietnam in the east. As many as 750,000 people lived in Angkor, its capital, which sprawled across an area the size of New York City's five boroughs, making it the most extensive urban complex of the preindustrial world. By the late 16th century, when Portuguese missionaries came upon the lotus-shaped towers of Angkor Wat - the most elaborate of the city's temples and the world's largest religious monument - the once resplendent capital of the empire was in its death throes.

Scholars have come up with a long list of suspected causes, including rapacious invaders, a religious change of heart, and a shift to maritime trade that condemned an inland city. It's mostly guesswork: Roughly 1,300 inscriptions survive on temple doorjambs and freestanding stelae, but the people of Angkor left not a single word explaining their kingdom's collapse.

Recent excavations, not of the temples but of the infrastructure that made the vast city possible, are converging on a new answer. Angkor, it appears, was doomed by the very ingenuity that transformed a collection of minor fiefdoms into an empire. The civilization learned how to tame Southeast Asia's seasonal deluges—then faded as its control of water, the most vital of resources, slipped away.

Angkor became a medieval powerhouse, thanks to a sophisticated system of canals and reservoirs, which enabled the city to hoard scarce water in dry months and disperse excess water during the rainy season. Forces beyond Angkor's control threw this exquisitely tuned machine into disarray. Right at Angkor's zenith, one of its reservoirs apparently went dry for a time. Any deterioration of the waterworks would have left Angkor vulnerable to a natural phenomenon no engineer of that day could have anticipated.

Sets of constricted growth rings in long-lived *po mu* trees showed that the trees had endured back-to-back mega-droughts, from 1362 to 1392 and from 1415 to 1440. During these periods the monsoon was weak or delayed, and in some years it may have failed completely. In other years, megamonsoons lashed the region. To a tottering kingdom, extreme weather could have been the coup de grâce.

Source: extracted from National Geographic website article http://ngm.nationalgeographic.com/2009/07/angkor/stone-text

1.2 New Ethical and Industry Standards

Key aspects	• In 2000, the World Commission on Dams (WCD) proposed an approach to dams, based on the recognition of rights and assessment of risks, five core values, seven strategic priorities and twenty-six guidelines. • The WCD's recommendations were endorsed by civil society and some governments, partially endorsed by the industry, and rejected by some major stakeholders. • The UNEP Dams and Development Project (UNEP-DDP) followed up the WCD to disseminate the WCD Report, and to facilitate a review of its recommendations at national and local levels through inclusive multi-stakeholder dialogues. • The dam industry, under the umbrella of the International Hydropower Association, has developed a Hydropower Sustainability Assessment Protocol; the latest version (2011) has achieved some consensus.

TRAINING AIDS	
Purpose of session	To introduce and review the debate that has developed in the international community about large dams, and specifically hydropower.
Learning objectives	• To understand the origin and extent of the debate. • To be aware of the many stakeholders involved in the debate. • To be aware of the core issues in the debate. • To appreciate the volume of the body of knowledge.
Key reading	1) World Commission on Dams. 2000. *Dams and Development a New Framework for Decision-making*. The Chairman's and Commissioner's Forewords. pubs.iied.org/pdfs/9126IIED.pdf 2) UNEP, Dams and Development Project. 2007. *A Compendium of relevant practices for improved decision-making on dams and their alternatives*. The Executive Summary. https://gc21.giz.de/ibt/gc21/area=gc21/style=liny/paint=bizyb/en/usr/modules/gc21/ws-FLEXportal-NRM-Net/info/ibt/downloads/swid/DDP-Compendium.pdf 3) IHA. 2010. Leaflet introducing *Hydropower Sustainability Assessment Protocol.* Available at: http://www.hydrosustainability.org/Home.aspx

1.2.1 The World Commission on Dams

For years, governments, civil society organisations, development officials, industry associations and private sector proponents have debated the costs and benefits of large dams. In recent years, the building of any dam has drawn environmental, social or political controversy. The 1990s saw an escalation of these conflicts. Proponents pointed to the social and economic development benefits that dams make possible, such as providing electric power, irrigation and water supply. Critics argued that project funding, whether public and/or private, systematically downplays the adverse environmental, social and economic impacts of dams and exaggerates the benefits. By the mid-1990s, an estimated 800,000 dams existed worldwide, with some 40-80 million people displaced and impoverished by them, and raging international controversy over the merits of further large water infrastructure projects.

In April 1997, IUCN and the World Bank sponsored a small but significant workshop in Gland, Switzerland. Representatives of diverse interests came together to discuss the highly controversial issues associated with large dams. To the surprise of participants, deep-seated differences on the development benefits of large dams did not prevent a consensus emerging that a new way forward was needed, which led to the formation of a multi-stakeholder World Commission on Dams (WCD).

The WCD was established in February 1998 and began its work under the chair of Professor Kader Asmal. Its 12 members were chosen through a global search process to reflect regional diversity, expertise and varying stakeholder perspectives. The Commission was independent, with members serving in individual capacities, and not as representatives of an institution or a country.

The Commission began by consolidating worldwide knowledge and experience with large dams. To give its analysis and conclusions a solid foundation, the WCD commissioned, organised or accepted:

- In-depth case studies of large dams on five continents, together with two country papers.
- A cross-check survey targeted at 150 large dams in 56 countries.
- 17 thematic reviews, grouped into five dimensions of the debate.
- Four regional consultations.
- Inputs submitted by interested individuals, groups and institutions.

In November 2000, the WCD Report, ‘Dams and Development: A New Framework for Decision-Making’, was published. The WCD Report has a number of elements: a summary report, a main report, and the knowledge base, all of which are available online (http://www.dams.org/) and on CD. Together, they present more than 4,000 pages of collective wisdom on dams.

Analysis of the knowledge base confirmed that while some dams have been successful, many large dam projects have fallen short of their physical and economic targets, have led to irreversible damage to river ecosystems, and have had serious negative effects within their communities.

To create a different future, the Commission proposed a way forward characterised by an approach to dam planning and implementation based on the recognition of rights and assessment of risks; five core values, seven strategic priorities, and 26 guidelines **(Box 1-3).**

Following the fulfilling of its mandate, the Commission then dissolved with the words:

"We have told our story. What happens next is up to you."

Box 1-3: WCD Approach: Rights and Risks, Core Values, Strategic Priorities, and Guidelines

WCD Approach

- An approach to dam planning and implementation based on the **recognition of rights and assessment of risks**;
- Five **core values**:
  - equity
  - efficiency
  - participatory decision-making
  - sustainability
  - accountability
- Seven **strategic priorities**:
  - gaining public acceptance,
  - comprehensive options assessment
  - addressing existing dams
  - sustaining rivers and livelihoods
  - recognising entitlements and sharing benefits
  - ensuring compliance
  - sharing rivers for peace, development and security
- Twenty-six **guidelines** for implementing the strategic priorities.

1.2.2 WCD Uptake, the DDP and the Compendium

Initial reaction to the Commission's report varied. Whilst embraced by civil society and some governments as a new way of doing business that would avoid the mistakes of the past, other governments and industry stakeholders were less welcoming. In particular, the Commission's recommendations for an inclusive and transparent planning process were criticised as being impractical in the 'real world'. Nevertheless, as the 'gold standard' framework for dam projects the WCD's recommendations were taken up by some national water and energy authorities (e.g. Mexico's National Water Commission), international development agencies (e.g. GIZ), and international legal frameworks (e.g. the EU's carbon market).

To maintain the momentum created by the WCD, and as a neutral entity to disseminate and facilitate a review of the WCD Report, through national and local multi-stakeholder dialogues, UNEP agreed to host a follow-up initiative called the Dams and Development Project (DDP). The DDP had four key elements:

- Promoting national, regional and global multi-stakeholder dialogues.
- Detailing non-prescriptive practical tools.
- Networking and communication.
- Disseminating information.

The objectives of the DDP's second and final phase (2005-2007) were to:

- Su Support multi-stakeholder dialogues at country, regional and global levels for improving decision-making on dams and their alternatives, with the aim of engaging all stakeholders, particularly governments.
- Produce non-prescriptive tools to help decision-makers, by drawing on all relevant existing criteria and guidelines for the planning and management of dams and their alternatives.

One outcome of the second phase was the publication of *A Compendium of Relevant Practices for Improved Decision-Making on Dams and their Alternatives*. The Compendium is an information tool to assist policy makers, decision makers, professionals and other stakeholders in the planning and management of dams and their alternatives. It deals with a set of key environmental and social topics ("Key Issues" - **Box 1-4**) which were prioritised by the DDP process, and gives examples of relevant practices, which have actually been implemented.

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Box 1-4: Key Issues in DDP Compendium

Key Issues dealt with by the Compendium

- Identification of options (Chapter 2)
- Stakeholder participation (mechanisms) (Chapter 3)
- Social impact assessment and addressing outstanding social issues (Chapter 4)
- Compensation policy and benefit-sharing mechanisms (Chapter 5)
- Environmental management plans (Chapter 6)
- Compliance (Chapter 7)
- International policy on shared rivers (Chapter 8)

Source: UNEP-DDP (2007): A Compendium of Relevant Practices for Improved Decision-Making on Dams and their Alternatives.

1.2.3 The Hydropower Sector Response

Disclaimer: This material is only intended to convey the nature and purpose of the IHA Protocol and does not in any way constitute training in the actual use of the Protocol.

As the DDP process unfolded the International Hydropower Association (IHA, an industry group established in 1995) launched its own initiative to influence dam planning. The Association's accepted the WCD Report's core values core values, but not all of its strategic priorities or guidelines. In 2004 IHA published its own Sustainability Guidelines, followed in 2006 by an initial version of a Sustainability Assessment Protocol. These first attempts were dismissed by some elements of civil society as a biased view of the hydropower industry, and the guidelines and protocol failed to gain much credibility.

In response, in 2007 the IHA launched a new initiative to improve the Protocol, working through a self-selected forum of stakeholders as part of its governance system. The 14 forum members included representatives of governments of developed and developing countries, commercial and development banks, some large social and environmental NGOs (most notably Transparency International, Oxfam, WWF and The Nature Conservancy), and the hydropower sector[10]. After two-and-a-half years of work, the revised Protocol was published in 2010. The principles incorporated into the revised Protocol are shown in **Box 1-5**.

Box 1-5: Hydropower Sustainability Assessment Protocol: Principles

Hydropower Sustainability Assessment Protocol Principles
The Hydropower Sustainability Assessment Protocol is a sustainability assessment framework for hydropower development and operation. The principles incorporated into the Protocol are: • Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. • Sustainable development embodies reducing poverty, respecting human rights, changing unsustainable patterns of production and consumption, long-term economic viability, protecting and managing the natural resource base, and responsible environmental management. • Sustainable development calls for considering synergies and trade-offs amongst economic, social and environmental values. This balance should be achieved and ensured in a transparent and accountable manner, taking advantage of expanding knowledge, multiple perspectives, and innovation. • Social responsibility, transparency, and accountability are core sustainability principles. • Hydropower, developed and managed sustainably, can provide national, regional, and local benefits, and has the potential to play an important role in enabling communities to meet sustainable development objectives.
Source: International Hydropower Association. 2010. Hydropower Sustainability Assessment Protocol: Background Document.

The Protocol is governed by the Hydropower Sustainability Assessment Council. A Charter, which sets out rules concerning the formation and decision-making of the Council, and Terms and Conditions for Use of the Protocol were adopted in June 2011. These key documents are available on www.hydrosustainability.org.

[10] International Hydropower Association. 2010. *Hydropower Sustainability Assessment Protocol: Background Document*.

The Protocol allows for the production of a sustainability profile for a project, through assessing its performance on certain criteria. To reflect the different stages of hydropower development, the Protocol includes four sections, each of which has been designed as a standalone document. Through an evaluation of basic and advanced expectations, the Early Stage tool may be used for risk assessment and initial dialogue, prior to advancing to detailed planning. The remaining three documents—Preparation, Implementation and Operation—set out a graded spectrum of practice, calibrated against statements of basic good practice and proven best practice. The graded performance within each sustainability topic also provides the opportunity to promote structured, continuous improvement.

Assessments rely on objective evidence to support a score for each topic, which is factual, reproducible, objective and verifiable. The system provides for accreditation by independent assessors. The Protocol will be most effective when embedded into business systems and processes. Assessment results may be used to inform decisions, to prioritize future work and/or to assist in external dialogue.

The new Protocol is widely regarded by concerned NGOs as an attempt to 'greenwash' the industry and sideline the WCD's report. Criticisms range from the exclusion of southern civil society organisations and dam-affected people, during the Protocol's development, to the lack of objectivity in the assessments, weak language, lack of requirements to respect national laws, exclusion of major topics such as human rights, lack of requirements to consult with affected people, and the tight control exerted over the entire process by the industry[11]. In conclusion:

> *"The IHA Protocol is a voluntary scorecard for dam builders that allows the hydropower industry to control the assessment of its own projects without any mandatory bottom-lines. It could easily be used to legitimize unsustainable and irresponsible practices in the dam industry, against which local communities continue to struggle".* (International Rivers, 2010).

It remains to be seen whether the Protocol, backed by industry, gains a foothold in dam planning, or whether the WCD's recommendations and other well-established procedures and criteria, such as those of the World Bank and IFC, will remain dominant.

1.2.4 Water Alternatives special issue: WCD + 10

In 2010, Water Alternatives, an on-line interdisciplinary journal addressing the issues that water raises in contemporary societies, published a special edition styled "WCD+10". Its purpose was to provide an opportunity, ten years after the WCD, to take stock of the evolution in thinking about the complex and diverse issues that still surround decisions about dams and development. The special issue included a snapshot survey of WCD uptake since 2000.

Perhaps the most dramatic finding presented in the journal is the figure of **472 million river-dependent people living downstream and affected by large dams** (Lehner *et al.*, 2010). This is some 7% of the entire global population.

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[11] See http://www.internationalrivers.org/resources/voluntary-approach-will-not-resolve-dam-conflicts-4286

In their review of the papers in the issue, the editors detected the following trends[12]:

- Perspectives differ on the impact of the WCD Report and process.
- Water and energy demands continue to rise and drive dam development.
- Climate change is now a greater driver of hydropower expansion.
- New financiers are changing the loci and framework for decision-making processes.
- Negative consequences of dams on the environment and livelihoods of dam-affected communities remain critical issues.
- The quest for new decision-making tools and approaches continues, from assessment protocols to economic analysis.
- How can participation, compliance, accountability, and performance be ensured?
- Multi-stakeholder platforms (MSPs) continue to show promise for informing and shaping negotiated agreements that result in better sharing of the resources, benefits, and costs associated with dams.

The editors conclude that the papers demonstrate the need for a renewed multi-stakeholder dialogue at multiple levels. "*This would not be a redo of the WCD, but rather a rekindling and redesigning of processes and forums where mutual understanding, information-sharing, and norm-setting can occur*."

[12] Moore, D.; Dore, J. and Gyawali, D. 2010. *The World Commission on Dams + 10: Revisiting the large dam controversy*. Water Alternatives 3(2): 3-13. www.water-alternatives.org

TRAINING AIDS	
Discussion topics	1) The WCD and DDP ended when they had achieved their mandate. Is there an argument for having a permanent institution to guide dams and development? 2) Can an industry police itself, or is genuine independence and transparency necessary for effective monitoring?
Exercises	1) Draw a time line of the most important events in the "dams and development" debate. 2) List large water infrastructure projects in your country that are controversial or have under-performed technically, economically, environmentally or socially.
Additional reading and resources	1) World Commission on Dams. 2000. *Dams and Development a New Framework for Decision-making*. 2) UNEP, Dams and Development Project. 2007. *A Compendium of relevant practices for improved decision-making on dams and their alternatives*. 3) IHA. 2010. *Hydropower Sustainability Assessment Protocol*. http://www.hydrosustainability.org/IHAHydro4Life/media/PDFs/Protocol/hydropower-sustainability-assessment-protocol_web.pdf 4) IR. 2010. *NGO critique of the IHA protocol*. Available at http://www.internationalrivers.org/files/attached-files/ngo_critique_final_iha_protocol.pdf 5) Moore, D.; Dore, J. and Gyawali, D. 2010. The World Commission on Dams + 10: Revisiting the large dam controversy. *Water Alternatives* 3(2): 3-13. www.water-alternatives.org 6) Johnston, B.R. 2010. Chixoy dam legacies: The struggle to secure reparation and the right to remedy in Guatemala. *Water Alternatives* 3(2): 341-361. www.water-alternatives.org 7) Global dams and reservoirs database: Lehner, B., R-Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P. et al.2011. High resolution mapping of the world's reservoirs and dams for sustainable river flow management. *Frontiers in Ecology and the Environment*. Source: GWSP Digital Water Atlas (2011). Map 81: GRanD Database (V1.1). Available online at http://atlas.gwsp.org.

Case Studies

The following case study concerns major human rights violations associated with the Chixoy Dam project in Guatemala, as well as legal and moral responsibilities of the international agencies funding the project. The Chixoy Dam became—and remains—a *cause celebre* to illustrate the need for new, sensitive approaches to water and power infrastructure planning and development.

The Chixoy Dam and the Rio Negro Massacres

In 1978, in the face of civil war, the Guatemalan government proceeded with its economic development programme, including the construction of the Chixoy hydroelectric dam. Financed in large part by the World Bank and the Inter-American Development Bank, the Chixoy Dam was built in Rabinal, a region of the department of Baja Verapaz, historically populated by the Maya Achi indigenous people. To complete construction, the government undertook both voluntary and forced relocations of dam-affected communities from the fertile agricultural valleys to the harsher surrounding highlands.

When hundreds of residents refused to relocate, or returned after realizing the conditions of resettlement villages were not what the government had promised; these men, women, and children were kidnapped, raped, and massacred by paramilitary and military officials. More than 440 Maya Achi were killed in the village of Río Negro alone, and the string of extrajudicial killings that claimed up to 5,000 lives between 1980 and 1982 became known as the Río Negro Massacres.

The government officially declared the acts to be counterinsurgency activities - although local church workers, journalists and the survivors of Rio Negro deny that the town ever saw any organized guerrilla activity. After news of the massacres emerged, the international banks continued to finance the project.

In 2004, the Geneva-based international human rights NGO Centre on Housing Rights and Evictions (COHRE) filed a petition before the Inter-American Commission on Human Rights against both Guatemala and the countries comprising the directorial boards of the banks involved in funding the Chixoy Dam project. One argument presented in the petition suggests these States cannot ignore or violate their human rights obligations simply by using banks as agents. A second argument posited by the Petition asserts that the World Bank, as a specialized agency, may be legally bound to uphold the principles of the UN Charter, including respect and preservation of human rights. However, the Bank's charter claims legal immunity for itself and its employees. COHRE argues that such immunity is only for acts within the scope of the World Banks' operations, and human rights violations clearly lie outside of that scope. It is still unclear whether the Bank can be held liable.

As of May 2013 former dictator Efraín Ríos Montt is undergoing trial for genocide, but the survivors of the Chixoy massacre have still not received reparations.

Sources: extracted from Wikipedia http://en.wikipedia.org/wiki/R%C3%ADo_Negro_Massacre and the Guardian Weekly Poverty Matters Blog http://www.guardian.co.uk/global-development/poverty-matters/2012/dec/10/guatemala-chixoy-dam-development-terror

1.3 Mekong River Basin

Key aspects	• Dam-building in the Mekong River Basin and elsewhere in the region is widespread, with many more dams planned. • In the Lower Mekong Basin the MRC has: o established an Initiative on Sustainable Hydropower; o developed a Rapid Basin-wide Hydropower Sustainability Assessment Tool; o prepared a Basin Development Strategy.

TRAINING AIDS	
Purpose of session	To review the scale of planned developments in the Basin and basin-wide planning in the LMB.
Learning objectives	• To understand the scale of planned developments in the Basin. • To have an overview of basin planning responses.
Key reading	1) ICEM. 2010. Executive Summary of *SEA of Hydropower on the Mekong Mainstream*. MRC.

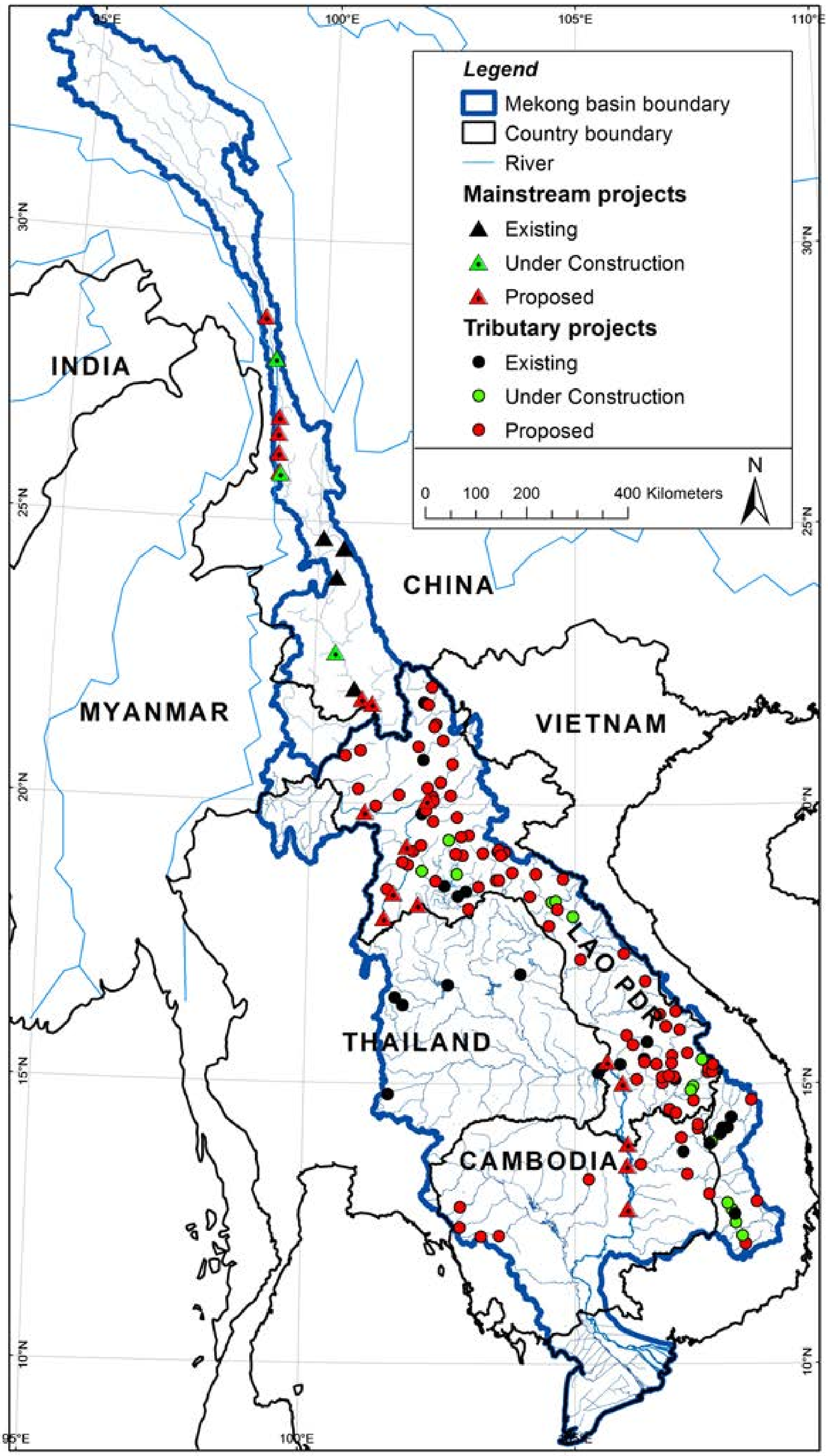
1.3.1 Hydropower in the Lower Mekong River Basin

The Lower Mekong Basin (LMB) covers an area of approximately 606,000 km^2 within the countries of Cambodia, Laos, Thailand, and Vietnam. Hydropower is gaining importance in the LMB as riparian countries attempt to meet the increasing demand for energy and provide an alternative to fossil fuels (an important aspect of sustainable development). Cambodia, Laos, Thailand and Vietnam, member countries of the Mekong River Commission (MRC), aim to utilise hydropower to encourage socio-economic development and welfare in the region. A number of hydropower projects exist or have been proposed for the LMB mainstream (**Figure 1.1**), while additional hydropower developments for the LMB tributaries are anticipated in the future.

1.3.2 MRC Task Forces and Tools

In 2006, the Asian Development Bank (ADB), the Mekong River Commission and the World Wide Fund for Nature (WWF) established a task force to drive an initiative on **Environmental Considerations for Sustainable Hydropower Development** (ECSHD). The purpose was to develop tools that will assist decision making for sustainable hydropower development in the Mekong River Basin.

Figure 1-1: Existing and Planned Hydropower Facilities in the Mekong Basin



Source: Mekong Flows website [**http://www.mekongriver.info/hydropower**](http://www.mekongriver.info/hydropower) Map design: University of Canterbury, Data source: MRC Hydropower database.

In 2010, ECSHD and further partners published the **Rapid Basin-wide Hydropower Sustainability Assessment Tool** (RSAT)[13]. The tool was designed to target the most important issues necessary for a basin-wide approach to sustainable hydropower development. This differs from the IHA's Hydropower Sustainability Assessment Protocol in that the protocol is designed for individual projects, whilst RSAT takes a basin or sub-basin approach.

The primary aims of RSAT are:

- To provide a common basis for dialogue and collaboration on sustainable hydropower between key players;
- To highlight and prioritise areas of hydropower sustainability risk and opportunity in a particular basin or sub-basin for more detailed study; and
- To identify capacity building needs in the basin.

The key themes within the assessment are:

- Continuous improvement.
- Basin-wide understanding and protection of values.
- Integration between basin planning and hydropower development regulatory and management frameworks.
- Co-operation between different countries sharing a river basin.
- Balance of social and environmental criteria with economic and technical criteria in decision-making processes.
- Consistency in approaches across a river basin.
- Informed participation of stakeholder in decision-making and broad community support.
- Climate change – a cross-cutting issue.
- The topics and criteria used in the assessment.

The MRC has established an **Initiative on Sustainable Hydropower** (ISH), which focuses on advancing regional cooperation for sustainable planning and management of the growing number of hydropower projects from a basin-wide perspective[14]. Through the Initiative, the MRC assists its Member Countries in relating decisions on hydropower management and development to basin-wide integrated water resources management perspectives.

The four main outcomes planned for the ISH are a direct response to the objectives of the MRC Strategic Plan (2011 - 2015):

- Outcome 1: Combining awareness raising and multi-stakeholder dialogue.
- Outcome 2: Knowledge management and capacity building.

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[13] MRC. 2010. Rapid Basin-wide Hydropower Sustainability Assessment Tool (RSAT). MRC.

[14] MRC. 2010. Initiative on Sustainable Hydropower (ISH), 2011-2015 Document. MRC.

- Outcome 3: Embedding sustainable hydropower considerations in regional planning and regulatory systems.
- Outcome 4: Sustainability assessment and adoption of good practice.

These outcomes are in line with the 1995 Mekong Agreement, and have also led to the SHD-M, which aims to support each of the four outcomes listed above.

A number of development cooperation agencies are assisting the MRC and other partners involved in water resources development in the LMB, for example (i) GIZ, which has sponsored an *Assessment of RBO-Level Mechanisms for Sustainable Hydropower Development and Management* based on five international case studies of trans-boundary cooperation in river basins, and (ii) the ADB, which has commissioned a study of *Ensuring Sustainability of GMS Regional Power Development*.

1.3.3 Integrated Basin Development Strategy for the LMB

1.3.3.1 Overview

The MRC's Integrated Water Resources Development (IWRD)-based Basin Development Strategy[15] provides initial directions for cooperative and sustainable Lower Mekong Basin development and management. The strategy is:

- The Mekong River Commission's main tool for achieving the objective of the 1995 Agreement for the Cooperation for the Sustainable Development of the Mekong River Basin Agreement as stated in Article 1: 'to cooperate in all fields of sustainable development, utilization, management and conservation of the water and related resources of the Mekong River Basin'.
- The MRC's primary response to Article 2, which calls for 'the formulation of a basin development plan…to identify, categorize and prioritize the projects and programs…'.

The strategy defines an agreed 'rolling' basin development planning process, which connects regional LMB plans, made possible through transboundary cooperation, with national LMB plans. The strategy is subject to review and updating by the MRC every five years.

The LMB and the Mekong River are undergoing significant change. Economic growth and poverty reduction in the LMB require developing water resources for multiple purposes, including power, agriculture, fisheries production and navigation. These also require the management of the river and its life- and livelihood-giving ecosystems, for long-term sustainability, throughout demographic, economic and climate change. Developments in the Lancang-Upper Mekong Basin in China, as well as the LMB, are now changing the Mekong's flow regime. To meet growing demand for goods and services, the private sector is actively seeking investment opportunities, which the river can provide. This strategy is an essential, deliberate, and comprehensive response to these rapid investments.

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[15] MRC. 2011. Basin Development Strategy. Available at http://www.mrcmekong.org/publications/topic/basin-planning

There are many LMB development opportunities that could bring significant benefits at national and, through cooperation, at regional levels. These opportunities also have significant risks and costs, which must be managed and mitigated, both at the national level, and where relevant, through cooperation at transboundary level. The strategy identifies the following **opportunities** and **risks**:

- Considerable potential for further hydropower development in the tributaries of the Mekong River, particularly in Laos and Cambodia, requiring sound social and environmental standards to ensure sustainability.
- Major potential to expand and intensify irrigated agricultural production and to combat delta saline intrusion, subject to cooperation with China in the operation of the Lancang - Upper Mekong hydropower dams, to ensure increased, regulated and reliable dry season flows.
- Potential opportunity for main stem hydropower development, provided that the many uncertainties and risks are fully addressed, and transboundary approval processes are followed. While potential benefits are high, so are potential costs, including transboundary impacts.
- The need to define other priority water-related opportunities (for example, fisheries, navigation, flood management, tourism, and environment and ecosystem management), as well as those that go beyond the water sector (for example, other power generation options).

1.3.3.2 Strategic Priorities for Basin Development

The strategy defines a process to move from opportunities to implementation and sustainable development, including the definition of **Strategic Priorities for Basin *Development***:

- Essential knowledge acquired to address uncertainty and minimize risks of identified development opportunities, including knowledge on migration and adaptation of fish; trapping and transport of sediments and nutrients; loss of biodiversity; and social and livelihoods impacts.
- Opportunities and risks of current developments (to 2015), including: cooperation with China to ensure increased low flows; LMB mainstream baseline low-flow agreements, and the management of risks arising from projects already committed.
- Options identified for sharing development benefits and risks.
- The expansion and intensification of irrigated agriculture for food security and poverty alleviation.
- Environmental and social sustainability of hydropower development greatly enhanced.
- Climate change adaptation options identified and implementation initiated.
- Basin planning considerations integrated into national planning and regulatory systems.

1.3.3.3 Strategic Priorities for Basin Management

The Strategy also defines **Strategic Priorities for Basin *Management***, an essential companion to basin development to ensure sustainability, as follows:

- Rigorous basin-wide ‘environmental and social objectives’ and ’baseline indicators’ need to be defined.
- Clearly defined basin objectives and management strategies for water-related sectors, including fisheries and navigation, must be set.
- National-level basic water resources management processes must be strengthened, including water resources monitoring, water use licensing, and data and information management.
- Basin-level water resources and related management processes must be strengthened, including the implementation of MRC procedures, state of basin monitoring and reporting, project cycle monitoring, and enhancing stakeholder participation.
- A water resources management capacity building programme must be implemented, linked to MRC’s overall initiatives and complementary to national capacity building activities.

1.3.3.4 Implementation of the Strategy

The strategy defines a clear road map—setting out priority actions, timeframes and outcomes. An early action in the road map is the preparation of LMB Regional and National Action Plans that define activities, responsibilities, deliverables and costs. The MRC will lead the preparation of the Regional Action Plan; implemented will come through the MRC Strategic Plan 2011-2015. The National Action Plans will be integrated, to the extent possible, within national long- and short-term economic and sectoral plans, and implemented as a core priority. A comprehensive monitoring programme of strategy activities and outcomes will be developed during the first three months of implementation.

1.3.3.5 Status of the Strategy

The strategy is a product of the MRC Member Countries of Cambodia, Laos, Thailand and Vietnam, and will be implemented by them, facilitated by the MRC and with financial support of its key development partners. Active and transparent involvement of all Mekong stakeholders is required to achieve the ambitious goals for of cooperative and sustainable LMB management and development, for the shared benefit of all those living in the LMB, particularly the poor and vulnerable.

TRAINING AIDS	
Discussion topics	1) Should countries develop independent energy policies or combine with others to optimise solutions? 2) Could any other investment strategy than hydropower provide the same energy benefits?
Exercises	Form groups of 4 to 6; randomly divide into imaginary "upstream" and "downstream" countries; list the arguments you would use to (i) defend the right of upstream countries to independently dam the river; (ii) defend the right of downstream countries for a veto on upstream development.
Additional reading and re-sources	1) MRC. 2011. *Basin Development Strategy*. Available at http://www.mrcmekong.org/publications/topic/basin-planning 2) MRC. 2010. *Initiative on Sustainable Hydropower (ISH), 2011-2015 Document*. MRC. 3) MRC. 2010. *Rapid Basin-wide Hydropower Sustainability Assessment Tool (RSAT).* MRC. 4) http://www.iucn.org/news_homepage/all_news_by_region/news_from_asia/?11712/Students-face-to-face-with-dam-development

2 GENERAL CONCEPTS

MODULE 2: GENERAL CONCEPTS		
Scope	**Session/Sub-Topic**	**Scope**
General concepts of ecology and ecosystems, hydropower impacts and the international governance framework in relation to "sustaining river basin ecosystems"	**Session 2.1: Ecosystems**	
	Biodiversity	Introduction to "biodiversity" - types, scales.
	Ecosystems	Introduction to ecosystems; focus on freshwater; spatial aspects (e.g. fish migrations).
	Ecosystem services	Introduction to ecosystem services - regulating, provisioning, etc., focusing on freshwater and wetlands.
	Session 2.2: Hydropower Impacts	
	Principles	Definitions; history of concept; moral basis; practical basis; precautionary principle.
	Impacts of hydropower projects	A quick review of typical hydro impacts in relation to freshwater ecosystems.
	Session 2.3: International Framework	
	UN	The major conventions.
	Other international law & agreements	Introduction to the normative frameworks at various scales.
	Major tools in relation to water resources development	Introduction to e.g. IWRM, WCD, IHA (more details in later modules (Mitigation, EIAs, EMPs)).

2.1 Ecosystems

Key aspects	• Three levels of biodiversity: o Species o Genetic o Ecosystem • Ecosystems: interacting and inter-dependent biological systems and their physical habitat, at different scales. • Ecosystem services: multiple services in four main categories—regulating, provisioning, cultural and supporting.

TRAINING AIDS	
Purpose of session	To introduce/refresh the trainee on basic ecological concepts.
Learning objectives	By the end of the session, the trainee will be able to: • Define an ecosystem and understand the importance of ecosystem integrity and complexity. • Understand the range and importance of ecosystem services provided by intact ecosystems.
Key readings	1) What is ecological integrity http://www.pc.gc.ca/apprendre-learn/prof/itm1-con/on/eco/eco1_e.asp 2) The encyclopaedia of Earth http://www.eoearth.org/article/Ecosystem 3) What are Ecosystem Services. http://www.fao.org/es/esa/pesal/aboutPES1.html

2.1.1 Biodiversity

Biodiversity is a contraction of 'biological diversity'. A definition from IUCN is given in **Box 2-1**. Three levels of biodiversity form the complexity of life: **species diversity**, **genetic diversity** and **ecosystem (or habitat) diversity**.

- **Species diversity** refers to the number of the different species and the number of individuals of each species within any one community.
- **Genetic diversity** refers to the genetic variability within a species. A more genetically diverse species generally has more adaptability and is more likely to survive environmental changes.
- **Ecosystem or habitat diversity** refers to the diversity of habitats or ecosystems within an area. As different species typically require different habitats, a greater

diversity of habitats usually provides conditions for the greater diversity of species.

Box 2-1: Biodiversity Glossary

Biodiversity glossary
Biodiversity: the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.
An ecosystem: a community of plants, animals and smaller organisms that live, feed, reproduce and interact in the same area or environment.
An ecosystem service: a service people obtain from the environment. Ecosystem services are the transformation of natural assets (soil, plants and animals, air and water) into things that we value. They can be viewed as provisioning such as food and water; regulating, for example, flood and disease control; cultural such as spiritual, recreational, and cultural benefits; or supporting like nutrient cycling that maintain the conditions for life on Earth. Ecosystem 'goods' include food, medicinal plants, construction materials, tourism and recreation, and wild genes for domestic plants and animals. Source: IUCN: http://www.iucn.org/what/biodiversity/about/?gclid=CO-ajpT3tbUCFW5V4godrAUABQ

As stated by IUCN[16], biodiversity is the foundation of life on Earth. It is crucial for the functioning of ecosystems, which provide us with products and services necessary for life. Oxygen, food, fresh water, fertile soil, medicines, shelter, protection from storms and floods, stable climate and recreation - all have their source in nature and healthy ecosystems. But biodiversity gives us much more than this. We depend on it for our security and health; it strongly affects our social relations and gives us freedom and choice.

Biodiversity is extremely complex, dynamic, and varied—like no other feature on Earth. Its innumerable plants, animals and microbes physically and chemically unite the atmosphere (the mixture of gases around the Earth), geosphere (the solid part of the Earth), and hydrosphere (the Earth's water, ice and water vapour) into one environmental system, which makes it possible for millions of species, including people, to exist.

At the same time, no other feature of the Earth has been so dramatically influenced by man's activities. By changing biodiversity, we strongly affect human well-being and the well-being of every other living creature.

There are many measures of biodiversity. **Species richness** (the number of species in a given area) represents a single but important metric that is valuable as the common currency of the diversity of life - but to fully capture biodiversity, it must be integrated with other metrics (measurements).

[16] http://www.iucn.org/what/biodiversity/about/?gclid=CO-ajpT3tbUCFW5V4godrAUABQ

According to the Freshwater Biodiversity Unit of IUCN's Species Programme, an estimated 126,000 described species rely on freshwater habitats, including species of fishes, molluscs, reptiles, insects, plants, and mammals[17]. With the inclusion of undescribed species, this number could rise to over one million. Species richness in relation to area of habitat is extremely high in many freshwater groups. Freshwater fishes comprise almost 45% of all fishes and freshwater molluscs about 25% of all molluscs. An estimated 15,000 fish (including brackish water species), 4,300 amphibians, 5,600 Odonata (dragonflies and damselflies), and 5,000 mollusc species depend on freshwater habitats. Other major groups dependent upon freshwater include reptiles, insects, plants, and mammals.

Of the world's 5,494 mammals, 78 are Extinct or Extinct in the Wild, with 191 Critically Endangered, 447 Endangered and 496 Vulnerable[18]. 1,910 of the planet's 6,312 amphibians are in danger of extinction, making them the most threatened group of species known to date. Freshwater fish are the most endangered group of animals on the planet, with more than a third threatened with extinction: of the approximately 15,000 species of freshwater fish so far discovered, 5,685 have had their status assessed and of these, 36% are threatened to some degree[19].

Threats to biodiversity are numerous. Human activity is responsible for most of them[20]:

- **Habitat loss and degradation** affects 86% of all threatened birds, 86% of the threatened mammals assessed and 88% of the threatened amphibians.
- Introducing **invasive alien species,** which establish and spread outside their normal distribution. Some of the most threatening invasive species include cats and rats, green crabs, zebra mussels, the African tulip tree, and the brown tree snake. Introductions of alien species can happen deliberately or unintentionally; for example, by organisms “hitch-hiking” in containers, ships, cars or soil.
- **Over-exploitation of natural resources**. Resource extraction, hunting, and fishing for food, pets, and medicine.
- **Pollution and diseases**. For example, excessive fertilizer use leads to excessive levels of nutrients in soil and water.
- **Human-induced climate change**. For example, climate change is altering migratory species patterns, and increasing coral bleaching.

[17] http://www.iucnredlist.org/initiatives/freshwater

[18] For an explanation of these categories, see the IUCN Red List website page http://www.iucnredlist.org/technical-documents/categories-and-criteria

[19] http://www.telegraph.co.uk/earth/wildlife/8672417/Third-of-freshwater-fish-threatened-with-extinction.html

[20] http://www.iucn.org/what/biodiversity/about/biodiversity_crisis/

2.1.2 Ecosystems

The word **'ecology'** is derived from the Greek words for 'study' and 'home'. Ecology is the study of the home of organisms. An **'ecosystem'** is a community of organisms; with physical components of its environment interacting as a complex system, such that the whole is greater than the sum of its parts. The living and non-living components of the ecosystem are linked through nutrient and energy flows.

Ecosystems can be defined at different scales, from a single pond up to the entire planet, but typically are described at biome or bioregion level - a forest, a freshwater ecosystem, or major lake.

Key ecological concepts include food chains, trophic levels, integrity, resilience and connectivity.

Food chain and tropic level: all food chains (

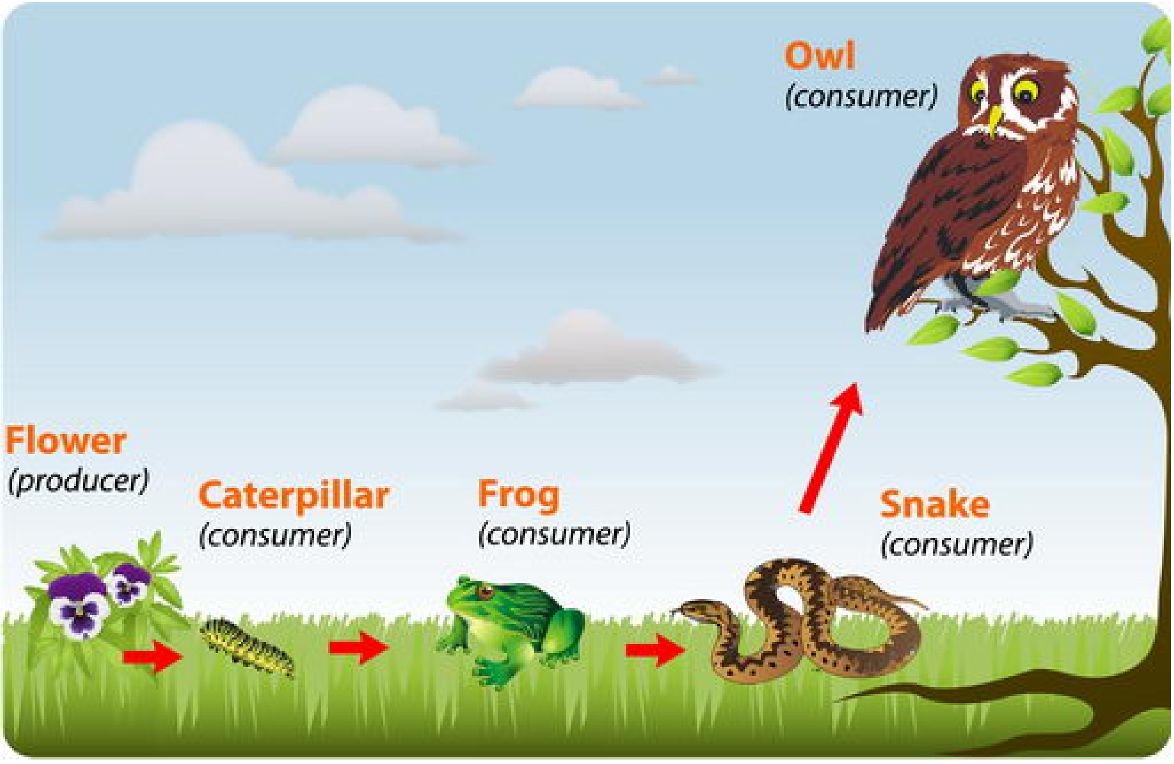
Figure 2-1) start with a **producer**, an organism, which captures solar energy by photosynthesis to create starch; this is the first **trophic level**. Producers are consumed by a sequence of **consumers**, typically a **herbivore,** then one to three, or more levels, of **carnivore**. These are the higher trophic levels. In practice, almost all ecosystems are built from **food webs** (

Figure 2-2), complex networks of food chains.

The **biomass** (literally, mass of living organisms) at each trophic level can be considered an **ecological pyramid** (

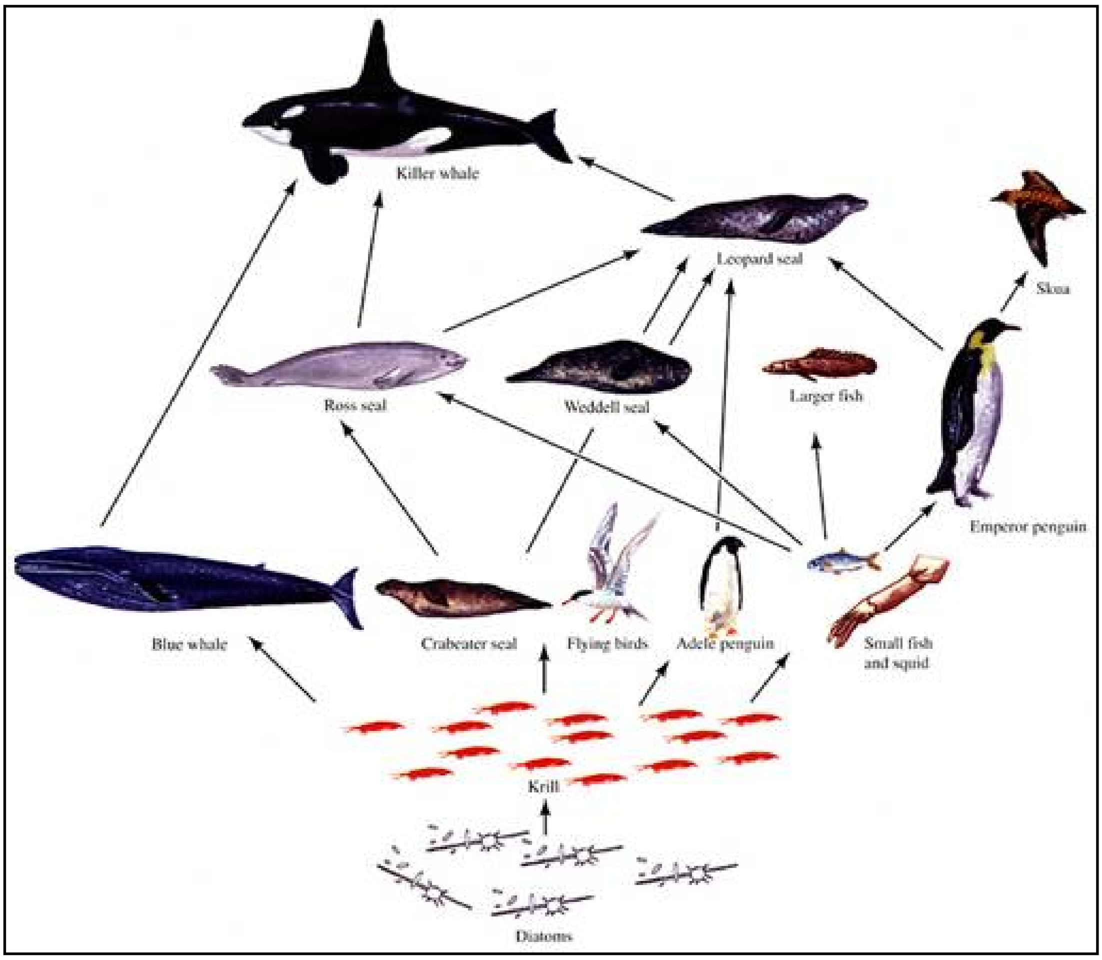
Figure 2-3).

Figure 2-1: Simple Food Chain



Source: http://moodleshare.org/mod/book/tool/print/index.php?id=1747&chapterid=221

Figure 2-2: Simple Food Web

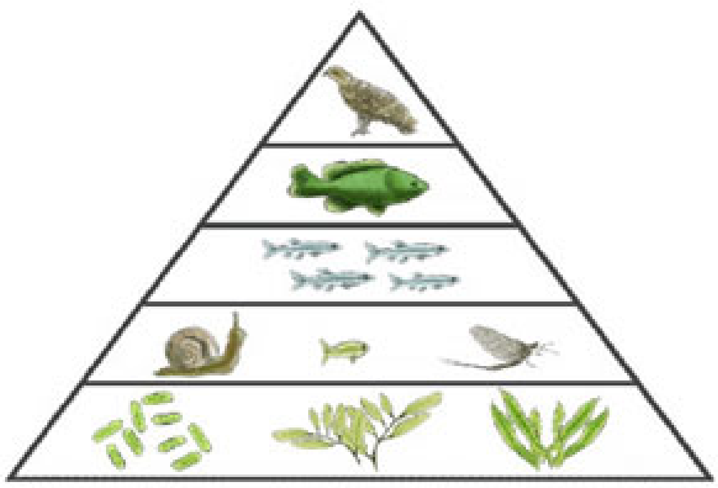


Source: http://sky.scnu.edu.cn/life/class/ecology/chapter/Chapter17.htm

- **Integrity:** "Ecological integrity is the abundance and diversity of organisms at all levels, and the ecological patterns, processes, and structural attributes responsible for that biological diversity and for ecosystem resilience." (Coast Information Team, 2004)[21]. In other words, this concept cover how species-rich, diverse, complex—and therefore resilient—an ecosystem is, when disturbed or stressed. Ecological integrity is also a measure of characteristic an ecosystem is in its region: how complete, how representative, how free of alien species and degraded habitats.

[21] Cited on http://www.sfu.ca/haida-ebm/ecological_integrity/

Figure 2-3: Ecological Pyramid



Source: http://www.learner.org/courses/essential/life/session7/closer5.html

- **Resilience:** resilience is the ability of an ecosystem to respond to disturbance and recover rapidly. In general, more complex and diverse systems are more resilient.
- **Connectivity and size:** in general, the larger the size and the better connected an ecosystem, the greater its resilience - unless the removal of barriers between systems allows the spread of alien, invasive species. **Fragmentation** of ecosystems affects gene flow and many other processes. The main impacts of changes in the size and connectivity of land (particularly forest) ecosystems include[22]:
    - changes in patch size (impacts through species/area relationships);
    - edge effects (biophysical impacts, sometimes increasing access for other uses);
    - isolation effects (distance from core area increases vulnerability to predation and disease impacts and decreases ability of species to recolonise).

  In freshwater habitats (particularly rivers) the main impacts of fragmentation (e.g. from dam-building) are:
    - changes in sedimentation patterns;
    - changes in water flow/oxygenation rates/temperature regimes;
    - effects of physical barriers obstructing migratory movements of species.

Within any particular ecosystem there may be **keystone species,** which are central to normal functioning of the entire system. Examples on land are: elephants in Africa, which both maintain the balance between forest and grassland and are necessary for the dispersal of

[22] Sourced from:

http://www.bipindicators.net/indicators/ecosystemintegrityservices/connectivityfragmentationofecosystems/2010 many plants; and the wolf in North America, without which herbivore numbers may increase uncontrolled to numbers, which damage habitats. Along North America's Pacific coastline, the starfish *Pisaster ochracues* is a keystone predator[23].

Freshwater ecosystems include ponds, lakes, streams, rivers and wetlands, with a basic division between still water and flowing water. The functioning of freshwater ecosystems is often highly dependent on annual hydrological processes, especially flooding: the life cycles of many aquatic organisms require seasonal floods to create breeding and feeding grounds. Threats to freshwater ecosystem include changes to water quality as well as water quantity and timing, especially from **eutrophication** (excess nutrients such as P and N) and **contamination** by toxic substances, especially heavy metals and pesticides.

2.1.3 Ecosystem Services

Ecosystem services are all the many benefits that humans receive from ecosystems. These can be resources or processes, and direct or indirect, but all are derived from the existence and functioning of ecosystems.

The 2005 Millennium Ecosystem Assessment (MA), a four-year study involving more than 1,300 scientists worldwide[24], classified ecosystem services into four categories (**Table 2-1**): **provisioning**, **regulating**, **cultural** and **supporting**.

Table 2-1: Ecosystem Services

Provisioning	**Regulating**	**Cultural**
Goods produced or provided by ecosystems Food, freshwater, fuel wood, timber, fibre, genetic resources,	*Benefits obtained from regulation of ecosystem processes* Regulation of climate, disease regulation, flood regulation, water purification, pollination.	*Non-material benefits obtained from ecosystems* Spiritual, inspiration, aesthetic, education, recreation and ecotourism.
Supporting		
Services necessary for production of other services Soil formation, nutrient recycling, primary production, supporting biodiversity Note: this category is under revision, and may be replaced by different terminology such as "Habitat Services".		

[23] See http://www.washington.edu/research/pathbreakers/1969g.html

[24] See http://www.unep.org/maweb/en/index.aspx for details of the MA.

A typical list of wetland ecosystem services is given in **Table 2-2**.

Table 2-2: Wetland Ecosystem Services and Related Structures and Functions

Ecosystem services	Ecosystem structure and function
Coastal protection	Attenuates and/or dissipates waves, buffers winds
Erosion control	Provides sediment stabilisation and soil retention
Flood protection	Water flow regulation and control
Water supply	Groundwater recharge/discharge
Water purification	Provides nutrient and pollution uptake, as well as retention, particle deposition
Carbon sequestration	Generates biological productivity and diversity
Maintains fishing, hunting and foraging activities	Provides suitable reproductive habitat and nursery grounds, sheltered living space
Tourism, recreation, education and research	Provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora
Culture, spiritual and religious benefits, besquest values	Provides unique and aesthetic landscape of cultural, historic or spiritual meaning

Source: ten Brink *et al.* (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands: Executive Summary. TEEB.

As stated in the latest TEEB report[25], ecosystems provide a range of services that benefit people, society and economy at large, which are known as ecosystem services (MA, 2005). Many of these ecosystem services are related to water and wetlands via water provision, regulation, purification, and groundwater replenishment, and are crucial in addressing objectives of water security and water for food security. Other ecosystem services provided by wetlands play important roles in relation to nutrient cycling, climate change (climate mitigation and adaptation), food security (provision of crops and nurseries for fisheries), job security (maintenance of fisheries, soil quality for agriculture) and a range of cultural benefits, including knowledge (scientific and traditional), recreation and tourism, and formation of cultural values, including identity and spiritual values.

Two major studies have produced or are producing data on ecosystem services and their value to society:

- The Millennium Ecosystem Assessment (2005) - the first global study on the state of the natural environment and the benefits it gives to society in terms of ecosystem services.
- The Economics of Ecosystems and Biodiversity (TEEB) - an international project on valuing the natural environment.

[25] ten Brink *et al.* (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands.

The value of ecosystem services can be very high (**Box 2-2**). Economists assign several types of values to ecosystems and ecosystem services[26]:

- **Direct use value** attributed to direct utilisation of ecosystem services;
- **Indirect use value** attributed to indirect utilisation of ecosystem services, through the positive externalities that ecosystems provide;
- **Option value** attributed to preserving the option to utilise ecosystem services in the future;
- **Existence value** attributed to the pure existence of an ecosystem;
- **Altruistic value** based on the welfare the ecosystem may give other people;
- **Bequest value** based on the welfare the ecosystem may give future generations.

Box 2-2: The Value of the World's Ecosystem Services

The value of the world's ecosystem services and natural capital

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion (1012) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

Source: Costanza *et al.* (1997). *The value of the world's ecosystem services and natural capital.* Nature, Vol. 387, 253-260

Monetising ecosystem services can be useful for decision-making, but wetlands have many intrinsic and unquantifiable values. There is an argument that the assignment of theoretical monetary value to ecosystem services is a way to avoid making decisions based on science or moral values.

[26] Wikipedia http://en.wikipedia.org/wiki/Ecosystem_valuation

TRAINING AIDS	
Discussion topics	1) Why are water-related ecosystem services so important? 2) Do decision-makers in your country recognise the full value of ecosystem services provided by rivers and lakes? Are these values explicitly included in decision making about dams? 3) Can - and should - moral issues, such as the continued existence of megafish in river systems, outweigh short-term economic benefits?
Exercises	4) Group exercise: select a river basin or a wetland that you are familiar with, and list examples of each of the four types of ecosystem services it provides. 5) Group exercise: draw a diagram showing how building flood embankments along a river could affect ecosystem services provided by the floodplain.
Additional reading and resources	1) *River ecosystems*: http://en.wikipedia.org/wiki/River_ecosystem 2) Tony Juniper. 2013. *What has nature ever done for us?* Profile Books, London. 336p 3) Mekong river flows http://mekongriver.info/home 4) Nilsson, C. & Svedmark, M. (2002). *Basic principles and ecological consequences of changing water regimes: riparian plant communities*. Environmental Management 30, 468-80. 5) TEEB. 2013. *The Economics of Ecosystems and Biodiversity for Water and Wetlands*. http://www.teebweb.org/wp-content/uploads/2013/02/TEEB_WaterWetlands_Report_2013.pdf 6) De Groot *et al.*, 2006. *Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services*. Ramsar Technical Report No. 3. www.**ramsar**.org/pdf/lib/lib_rtr03.pdf

Case Studies

The following information on four aspects of the Mekong's biodiversity and ecosystems is taken from the Mekong Flows website http://www.mekongriver.info/biodiversity

1. Biodiversity of the Mekong River

The Mekong River, with its monsoon based annual flood pulse, supports a biological diversity second only to the Amazon in numbers of fish, mammals and birds. A number of the most sensitive and charismatic species, however, are critically endangered. In addition, the Mekong's flood pulse underpins the *most productive* and arguably *most complex* ecosystem services regime in the world, producing fish that sustains the majority of the protein and fatty oil needs of 55 million natural resource-dependent floodplain inhabitants in the Lower Mekong Basin of Laos, Thailand, Cambodia and Vietnam.

Recent estimates of the biota of the greater Mekong region put the species count numbers at 20,000 plant, 430 mammal, 1200 bird, 800 reptile and amphibian, and 850 fish species (see new species here). The inland fisheries yield was estimated at 2.6 million tonnes per year in the LMB, which is the world's largest freshwater yield.

Three major bio-regions define the Lower Mekong Basin. Each region has different habitats and unique ecological associations that provide interdependent connectedness of critical habitat for different life stages of numerous fish. These fish are consumed by other river and wetland dependent species, such as birds and mammals - including humans.

2. River of Giants

The Mekong's assemblage of tributaries and dry and wet season habitats has fostered a high level of fish species diversity and endemism. As many as 1,300 species of fish may be found, making it 1st in species per unit area and 3rd in total number after the Amazon and perhaps the Congo (Rainboth, 1996). One quarter of all giant fish species - the most species of giant freshwater fish in the world (WWF, 2010) - are found in the central river bioregion and the Tonle Sap bioregion. The giant freshwater stingray (*Himantura chaophraya*), possibly the largest freshwater fish on Earth, grows to 5 m in length. The Mekong giant catfish (*Pangasianodon gigas*) is the world's heaviest recorded freshwater fish - up to 300 kg - and the Giant Silver Barb is only slightly smaller. Additionally, the infamous "dog-eating" catfish (*Pangasius sanitwongsei*) is found in these bioregions. The freshwater Irrawaddy dolphin (*Orcaella brevirostris*) is also found in the river's main channel (Mattson *et al*., 2002). At the other end of the size spectrum, as many as 223 species of planktonic rotifers are estimated to live in the central river bioregion (Malay *et al*., 2011).

4.2 m stingray in Mekong (photo source: http://news.nationalgeographic.com/news/2003/11/photogalleries/giantcatfish/photo6.html)

3. The Great Lake, Tonle Sap

The most conspicuous elements of the Tonle Sap are the birds and the fish, as well as the flood pulse, the driving force of the ecosystem processes supporting the system's huge natural productivity. Knowledge of the full biodiversity, and the specific flood pulsed ecosystem processes that support it, is considered poor by most scientists (Santa Barbara, 2011). Yet, by value of its biological richness, it is a Biosphere Reserve as part of UNESCO's Man and the Biosphere Network (1997) and on the IUCN Ramsar list of Wetlands of International Importance (1999). In 2001 the Cambodian Ministry of Environment reported a count of 885 species of historical floodplain plants and animals (Mok *et al*., 2001), while in 2005 only 471 species - including 200 plants, 46 mammals and 225 birds - were recorded in the Lake region (ADB, 2005).

A major Tonle Sap site for large colonial water birds is Prek Toal, on the lake's northwestern tip. Breeding species here include the globally threatened greater adjutant (*Leptoptilos dubius*), lesser adjutant (*Leptoptilos javanicus*), Bengal florican ibis (*Houbaropsis bengalensis*), milky stork (*Mycteria cinerea*), and the globally near-threatened grey-headed fish eagle (*Ichthyophaga ichthyaetus*), darter (*Anhinga melanogaster*), painted stork (*Mycteria leucocephala*), black-necked stork (*Eppypiorhynchus asiaticus*) and black-headed ibis (*Threskiornis melanocephalus*) (Goes & Hong 2002; IUCN, 2004).

Fish are the largest vertebrate group in the Tonle Sap ecosystem, both in number of species and in biomass. Some species remain permanently in the Tonle Sap, while others use the lake and floodplain only temporarily and migrate back and forth to the Mekong. The biogeography of most migrating fish species is based on scant quantitative research.

Four species of water snake from the Lake provide a significant harvest tonnage, mainly is used to feed farmed Siamese crocodile, of which there may still be a remnant presence in the wild.

4. Mekong Delta

The delta once provided a rich habitat for Mekong anadromous fish species, those species that require or endure the estuary's salinity transitions. Today, however, this abundant delta is one of the top three most threatened deltas in the world from the impacts of climate change, reduction of Mekong sediment flows, and human land use modification. Only 1.3% of the once biodiversity-rich Mekong Delta now remains in a semi-natural condition, and the few remaining wetland species are wholly reliant on these remnant patches. The region is intensively cultivated for rice and for cage-cultured *Pangasius* catfish.

Source: Mekongriver.info: http://mekongriver.info/biodiversity

2.2 Hydropower Impacts

Key aspects	• A large knowledge base on hydropower impacts exists. • Hydropower impacts arise at all stages of the project cycle. • The benefits and impacts of hydropower projects are seldom spread evenly amongst the population. • Most of the world's rivers and a significant proportion of the world's population have been affected by large dams. • Hydropower impacts may be direct and indirect, and may affect the catchment upstream, the river downstream, the entire river basin, and the coastal zone. • The most significant ecological impacts result from blocking fish passage and changing downstream flow conditions.

TRAINING AIDS	
Purpose of session	To review typical hydropower impacts on river basins and ecosystems.
Learning objectives	At the end of this session, the trainee will: • Have a general understanding of the range of impacts of hydropower projects, with a focus on aquatic ecosystems.
Key readings	1) Chapter 3, Ecosystems and Large Dams, in: WCD (2000). Dams and Development: a New Framework for Decision-Making. Earthscan, London.

2.2.1 Impacts of Hydropower Projects

2.2.1.1 Overview

The largest in-depth review of the technical, financial, economic, environmental and social performance of large dams was the analysis carried out by the WCD[27]. In addition to their many economic benefits, the Commission found that:

- Large dams display a high degree of variability in delivering predicted water and electricity services – and related social benefits – with a considerable portion falling short of physical and economic targets, while others continue generating benefits after 30 to 40 years.
- Large dams have demonstrated a marked tendency towards schedule delays and significant cost overruns.

[27] WCD. 2000. Dams and Development: A New Framework for Decision-Making. Earthscan, London.

- Large dams designed to deliver irrigation services have typically fallen short of physical targets, did not recover their costs and have been less profitable in economic terms than expected.
  - Large hydropower dams tend to perform closer to, but still below, targets for power generation; generally meet their financial targets but demonstrate variable economic performance relative to targets, with a number of notable under- and over-performers.
  - Large dams generally have a range of extensive impacts on rivers, watersheds and aquatic ecosystems. These impacts are more negative than positive and, in many cases, have led to irreversible loss of species and ecosystems.
  - Efforts to date to counter the ecosystem impacts of large dams have met with limited success, owing to the lack of attention to anticipating and avoiding impacts, the poor quality and uncertainty of predictions, the difficulty of coping with all impacts, and the only partial implementation and success of mitigation measures.
  - Pervasive and systematic failure to assess the range of potential negative impacts and implement adequate mitigation, resettlement and development programmes for the displaced, and the failure to account for the consequences of large dams for downstream livelihoods have led to the impoverishment and suffering of millions, giving rise to growing opposition to dams by affected communities worldwide.
  - Since the environmental and social costs of large dams have been poorly accounted for in economic terms, the true profitability of these schemes remains elusive.

The Commission also found that " … Perhaps of most significance is the fact that social groups bearing the social and environmental costs and risks of large dams, especially the poor, vulnerable and future generations, are often not the same groups that receive the water and electricity services, nor the social and economic benefits from these."

As evidence of the scale of impacts of water infrastructure, consider that dams, inter-basin transfers and water withdrawals for irrigation have already fragmented some 60% of the world's rivers[28], directly displaced 40-80 million people (WCD, 2000), and affected at least some 472 million river-dependent people downstream (see 1.2.4).

As stated by Goodwin *et al.* (2006),[29] research during the past three decades is just beginning to reveal the true complexities and linkages of watershed ecosystems and how dams and impoundments affect rivers. Fluvial ecology and geomorphology came of age in the 1970s, and many consider that the discipline of regulated river ecology started at the First International Symposium on Regulated Streams (Ward & Stanford 1979). Before that, the few papers dealing with dam impacts were mostly concerned with specific issues such as anadromous salmonid migration or water quality. Ackermann *et al.* (1973) and Baxter (1977) provide a compilation of papers and a review of the earlier literature on environmental effects of dams, more focused on the changes caused within the reservoir itself, while Petts (1984)

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[28] Revenga C., Murray S., Abromavitz J., and Hammond A. 1998. Watersheds of the World: Ecological Value and Vulnerability. World Resources Institute and Worldwatch Institute, Washington DC.

[29] Goodwin, P., K. Jorde, C. Meier & O. Parra. 2006. Minimizing environmental impacts of hydropower development: transferring lessons from past projects to a proposed strategy for Chile. *J. Hydroinformatics* 8:4, 253-270.

can be considered the first comprehensive textbook on environmental management of impounded rivers.

The environmental impacts of hydropower result from construction activities, the existence of the dam and transmission lines (**Figure 2-5**) and their operation.

As stated by the WCD, the impacts of large dams on ecosystems can be classified according to whether they are:

- **First-order impacts** that involve the physical, chemical, and geomorphological consequences of blocking a river and altering the natural distribution and timing of streamflow;
- **Second-order impacts** that involve changes in primary biological productivity of ecosystems, including effects on riverine and riparian plant-life and on downstream habitat, such as wetlands; or
- **Third-order impacts** that involve alterations to fauna (such as fish), caused by a first-order effect (such as blocking migration) or a second-order effect (such as decrease in the availability of plankton).

Box 2-3: Impacts of Hydropower due to Existence and Operation of Dams and Reservoirs

Impacts due to the existence of dam and reservoir:

- Imposition of a reservoir in place of a river valley (loss of habitat).
- Changes in downstream morphology of riverbed, delta, and coastline, due to altered sediment load and increased erosion.
- Changes in downstream water quality: effects on river temperature, nutrient load, turbidity, dissolved gases, concentration of heavy of heavy metals and minerals.
- Reduction of biodiversity, due to blocking of movements of organisms (e.g. salmon).

Impacts due to patterns of dam operation:

- Changes in downstream hydrology:
  - Change in total flows; volume;
  - Change in seasonal flows (e.g. spring flood becomes winter flood)
  - Short-term fluctuations in flows (sometimes hourly);
  - Change in extreme flows (both high and low)
- Changes in downstream morphology caused by altered flow pattern.
- Changes in downstream water quality caused by altered flow pattern.[16]
- Reduction in riverine/riparian/floodplain habitat diversity, especially because of elimination of floods.

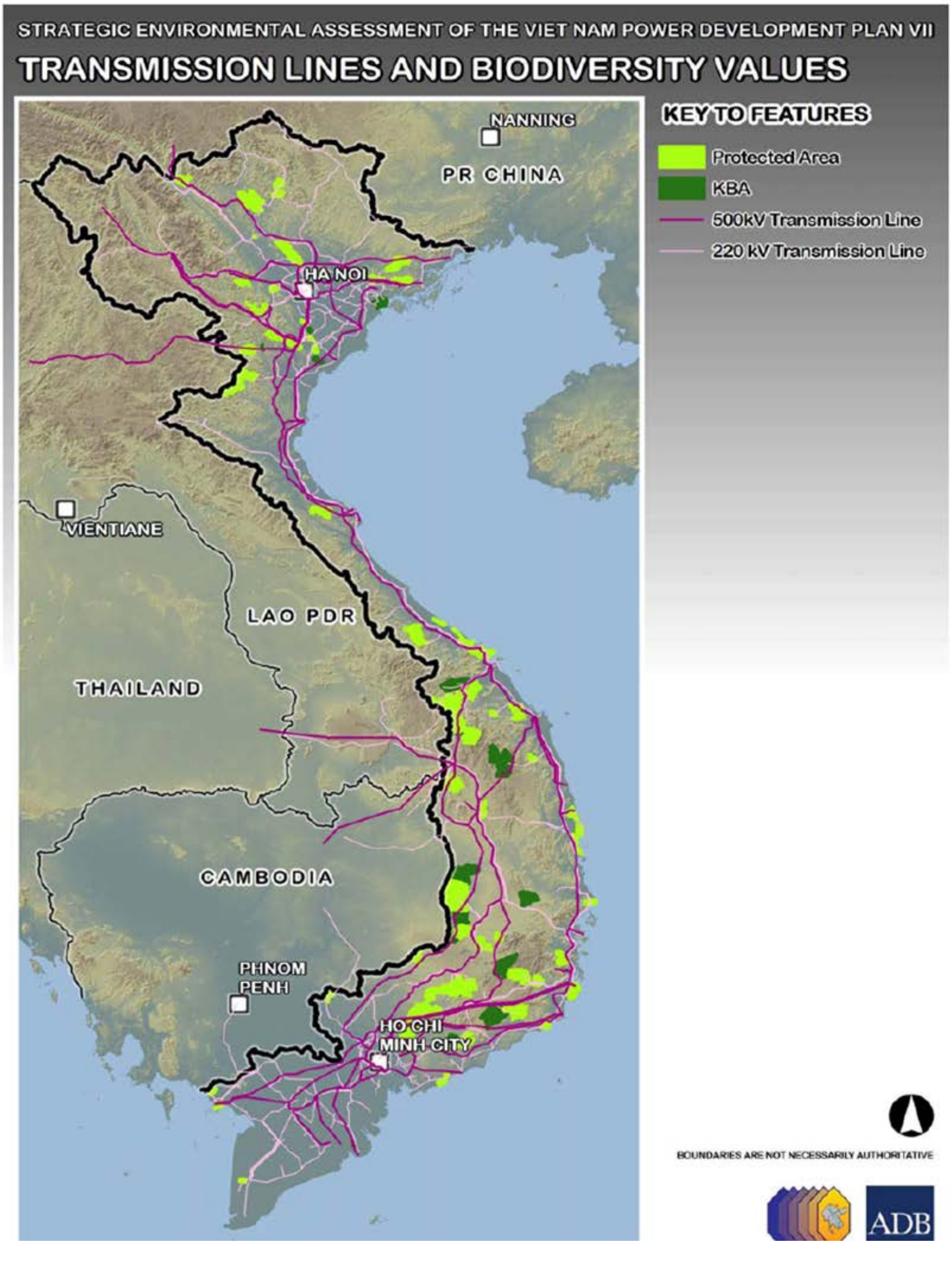
Source: McCully (1996). *Silenced Rivers: The Ecology and Politics of Large Dams*. Zed Books, London.

The impacts of each hydropower facility differ and require case-by-case assessment. Where a cascade of dams is built on the same river, there are **cumulative impacts** from all the dams.

The impacts of hydropower projects can also be categorised spatially into **upstream**, **down-stream**, **basinwide**, and **coastal zone** impacts; the views of one researcher are given in Box 2-4.

Typically, the construction of a dam and creation of a reservoir directly destroys terrestrial habitat, and since many species prefer valley bottoms, this can have a disproportionate effect on wildlife habitats and endangered species. In addition to the barrier effect of the dam on movement of fish, the reservoir may also act as a barrier to movement and seasonal migration of some terrestrial species (e.g. elephants).

Figure 2-4: Transmission Lines and Biodiversity - an Example of Mapping



Source: ADB SEA of Vietnam Power Development Plan

Box 2-4: Impacts of dams arranged spatially

Impacts of dams arranged spatially

Upstream Effects

Sedimentation issues are not confined solely to the reservoir and downstream reaches. The backwater reach can extend many miles upstream of the reservoir. The depositional environment immediately following implementation is confined to the delta region at the head of the reservoir. As this delta builds up, additional sediment is deposited in the upstream reach of the river, due to the backwater effect. The aggradation in the reach in turn raises the local water surface elevations, creating additional backwater and deposition even further upstream. This feedback mechanism allows the depositional environment to propagate much further upstream than the initial hydraulic backwater curve might suggest.

Upstream effects include effects on the benthic communities, due to deposition as well as the obvious barriers to fish migration corridors. Conversely, one of the effects of the backwater from dams is the potential drowning of natural migratory barriers within a basin, promoting the spread of some fish species beyond their pre-project domains. For example, the Itaipu reservoir inundated Guayara Falls (Brazil/Paraguay) and eliminated a natural barrier, which had prevented fish from the Upper Parana ´ spreading through the lower watershed. Conversely, in other parts of the world, dams are being used to protect native headwater species from harmful exotics. In Colorado, dams are used to isolate native greenback cutthroat trout from mixing with the larger, more aggressive, introduced brook trout (Pringle 1997). However, reservoirs can pose risks to headwater streams if facultative river species move up through a watershed, displacing local populations. Such an example occurred above the 200 m deep Dworshak Reservoir (Idaho, USA), where redside shiners (*Richardsonius balteatus*), although native to the system, developed very large populations of robust individuals in nearshore waters of the reservoir that were far more abundant than the original river populations. Adults would subsequently travel far upstream for spawning, competing with the native cutthroat trout populations (Falter *et al.* 1979).

Another key issue related to large dams is rooted in conservation biology theory. If the fluvial system is stressed too far by the implementation of large dams, the ecosystem may not be able to recover from major natural perturbations such as droughts, fire, tributary ‘blow-outs’, or episodic flood events. If there are insufficient stronghold watersheds with robust populations remaining in the system, then these types of natural disturbance could extirpate some species (Rieman *et al*. 2000).

Impacts of dams arranged spatially

Downstream Impacts

The effects of dams on the flow regime and sediment transport, with the concomitant downstream geomorphic changes, have been recognized and anticipated for several decades (see, for example, Simons & Senturk 1977). Typical possible responses include reduction in channel bed slope downstream of the dam, encroachment of riparian vegetation, decreases in the channel's conveyance capacity, changes in channel pattern or style (for example, from braided to meandering), and degradation of the river bed.

A less obvious effect is that the decrease in large flood events can result in a loss of biodiversity. The landforms in a river corridor, and the vegetation able to colonize them, if any, which together provide habitats for aquatic and riparian species, are not fixed in space and time, but change continuously due to their interaction with the river. This shifting habitat mosaic, created by flooding disturbances, is a fundamental component of a healthy river ecosystem (Stanford *et al.* 2005). If the rate of physical change within the river corridor is decreased, the river system becomes more homogeneous, as the existing vegetation stands mature and fewer species dominate. The replacement of the original, changing, heterogeneous habitat mosaic by a uniform corridor results in a loss of ecosystem diversity and resilience, because different aquatic and riparian species require a diversity of habitats, with different species and uneven stages of growth. The ecological impacts of dams show some striking generalities worldwide (Petts 1984; Stanford *et al*. 1996; Wirth 1997; Schmidt *et al.* 1998):

- Habitat diversity is substantially reduced. Flow and sediment regimes are drastically affected, so that the fluvial dynamics that create heterogeneous channel and floodplain habitat patches are altered. The longitudinal connectivity is interrupted by the dam barrier. Seasonal flow variability is reduced, but daily discharges can be highly variable. The natural temperature regime is lost because of hypolimnetic releases. Dewatering severs the longitudinal dimension and can cause high mortality of aquatic organisms through stranding. The lack of flooding allows vegetation to encroach upon the channel and the riparian zone then becomes less diverse.
- Native diversity decreases while exotic species proliferate. The altered hydrologic, sediment, and temperature regimes do not provide adequate environmental conditions for most native species. Conversely, the homogenization of habitats allows exotics to compete better. For example, some desert fish species are adapted to extreme flow and temperature regimes. They fare well where no exotic species could survive, but if a dam regulates flow conditions, then the non-natives can invade and out-compete the native species, driving them to extinction.3. Water quality is altered downstream of the dam.
- Alterations to the temperature regime and increases in the fine organic material are often anticipated during project design but the severity of the problem was frequently underestimated (d'Anglejan 1994). It must be noted that in some cases, productivity can be enhanced by the changes; for example, when a highly variable flow regime is regulated into a constant discharge year-round. In this case, a handful of species can reach large population numbers, but this is always matched by a decrease in diversity, due to the extirpation of many other, rarer species, which depended on the temporal variability of the flows, and the associated spatial variability of the habitat, for their survival.

Impacts of dams arranged spatially

Basin-Wide Effects

Alteration to the nutrient balance is not solely restricted to downstream reaches. Recent research (Bilby *et al.* 1996; Cederholm et al. 1999; Soto *et al.* 2006) has demonstrated the role of Pacific salmon and other anadromous salmonids in transporting marine nutrients across ecosystem boundaries, from oceans to headwaters. Fish behaviour is also influenced by changes in the hydrologic regime; for example, by creating shifts in physical cues that affect the timing of the migration.

Coastal Zone Effects

Most regulated rivers diminish or alter the timing of freshwater outflow to bays, estuaries and coastal wetlands with resulting negative impacts (Rozengurt & Haydock 1993). One well-documented example of additional stresses created by dams and water diversions pushing an ecosystem toward collapse has been documented in San Francisco Bay (Nichols et al. 1986; Williams 1989). In the extreme drought of 1977, release of water flows controlled by upstream reservoirs dropped to $100m^3/s$ from the customary dry season discharges of $400m^3/s$. This reduction in freshwater inflow contributed to a drop in phytoplankton biomass to less than 20% of normal, with zooplankton also significantly reduced. These conditions resulted in striped bass, one of the key indicator species of the health of the ecosystem, being reduced to the lowest recorded levels.

Source: Peter Goodwin, Klaus Jorde, Claudio Meier and Oscar Parra. 2006. Minimizing environmental impacts of hydropower development: transferring lessons from past projects to a proposed strategy for Chile. WA Publishing. *Journal of Hydroinformatics* 08.4.

Impacts of dams arranged spatially

Other citations:

Bilby, R. E., Fransen, B. R. & Bisson, P. A. 1996 Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. *Can. J. Fish. Aquat*. Sci. 53, 164–173.

Cederholm, C. J., Kunze, M. D., Murota, T. & Sibatani, A. 1999 Pacific Salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. *Fisheries* 24 (10), 6–15.

d'Anglejan, B. 1994 Potential sedimentological impacts of hydroelectric developments in James Bay and Hudson Bay. In: *Hydro-Electric Development: Environmental Impacts*. Paper no 5. James Bay Publication Series.

Falter, C. M., Leonard, J. M. & Skille, J. M. 1979 *Early Limnology of Dworshak Reservoir*. Final Report submitted to the US Army Corps of Engineers, Walla Walla, WA, Contract No. DACW68-72-C-0142.

Nichols, F. H., Cloern, J. E., Luoma, S. N. & Peterson, D. H. 1986 The modification of an estuary. *Science* 231, 567–573.

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Pringle, C. M. 1997 Exploring how disturbance is transmitted upstream: going against the flow. *J. N. Am. Benthol. Soc*. 16 (2), 425–438.

Rieman, B. E., Hessburg, P. F., Lee, D. C., Therow, R. F. & Sedell, J. R. 2000 *Toward An Integrated Classification of Ecosystems: Defining Opportunities For Managing Fish And Forest Health*. USDA Forest Service. Rocky Mountain Research Station, Boise, ID.

Rozengurt, M. & Haydock, I. 1993 *Freshwater flow diversion and its implications for coastal zone ecosystems*. In Trans. 58th North American Wildlife and Natural Resources Conference, pp. 287–293. Wildlife Management Institute. Washington DC.

Schmidt, J. C., Webb, R. H., Valdez, R. A., Marzolf, G. R. & Stevens, L. E. 1998 Science and values in river restoration in the Grand Canyon. *Bioscience* 48 (9), 735–747.

Simons, D. B. & Senturk, F. 1977 *Sediment Transport Technology*. Water Resources Publications LLC. Highland Ranch, CO.

Soto, D., Arismendy, I., Gonzalez, J., Sanzana, J., Jara, F., Jara, C., Guzman, E. & Lara, A. 2006 Southern Chile, trout and Salmon country: invasion patterns and threads for native species. *Revista Chilena de Historia Natural* 79 97–117.

Stanford, J. A.,Ward, J. V., Liss, W. J., Frissell, C. A., Williams, R. N., Lichatowich, J. A. & Coutant, C. C. 1996 A general protocol for restoration of regulated rivers. *Regul. Rivers Res. Mngmnt*. 12,391–413.

Williams, P. B. 1989 Managing freshwater inflow to the San Francisco Bay estuary. *Regul. Rivers Res. Mngmnt*. 4, 285–298.

Wirth, B. D. 1997 Reviewing the success of intentional flooding of the Grand Canyon. *Hydro Rev*. Apr., 10–16.

Construction may open up the catchment upstream of the dam to logging and clearance, with associated habitat degradation and destruction and also an increase in erosion and therefore sediment yield to the reservoir.

Downstream, ecological conditions in the dewatered stretch of the river will change significantly, with further changes downstream dependent on the new flow regime and water chemistry. A change from annual flooding to daily peaking flows can be particularly disruptive to aquatic ecosystems. Changes to flooding can also be highly disruptive to fish life cycles, which have evolved to be dependent on flood events and seasonal habitat changes.

The trapping of sediments and nutrients behind dams can have major consequences on habitats and geomorphological processes downstream. One of the most well-known examples is the impact of the High Aswan Dam on the Nile Delta and coastal fisheries: construction of the dam terminated the annual flood and the transport of nutrients and sediment to the delta; inshore fisheries collapsed, and the delta, already affected by irrigation barrages, is now receding at up to 240 m/yr (WCD, 2000).

Overall, the WCD study found that impeding the passage of migratory fish was the most significant ecosystem impact. In North America, dam construction is one of the major causes for freshwater species extinctions.

2.2.1.2 Greenhouse Gas Emissions

Recent research has found that, under some circumstances, hydropower reservoirs can be major emitters of greenhouse gases (GHGs), reducing or even over-riding their climate-related benefits, compared with thermal power generation. The principle gas of concern is methane (CH_4), derived from anaerobic decomposition of organic matter in reservoirs. This process is so powerful that researchers are now considering ways to capture the methane and use it as a power source (see, e.g. Lima *et al.* (2007)[30]. This research estimated that, globally, large dams might annually release about 104 ± 7.2 million tonnes of CH_4 to the atmosphere through reservoir surfaces, turbines and spillways.

As explained by Fernside (2007)[31] :

> "*Methane accumulates in the water near the bottom of the reservoir because the water column is thermally stratified (generally at a point less than 10 m below the surface), such that the colder deep water does not mix with the warmer surface water. Since the deep water (hypolimnion) has virtually no oxygen, decomposition ends in CH_4 rather than CO_2. Organic matter undergoing decomposition comes both from what was originally present in the vegetation and soil before the reservoir was formed and from carbon that enters the reservoir each year, one example being from the soft vegetation that grows on the mudflats that are exposed annually when the water level is drawn down, only to be flooded again when the reservoir is refilled*."

The following diagram (**Figure 2-5**) illustrates some of the major impacts of damming rivers and their effects on GHG emissions.

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[30] Lima, I.B.T, F.M. Ramos, L.A.W. Bambace & R.R. Rosa (2007). Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective. *Mitig Adapt Strat Glob Change* (2008) 13:193–206

[31] Phillip Fernside. *Why hydropower is not clean*. http://www.scitizen.com/future-energies/why-hydropower-is-not-clean-energy_a-14-298.html

Figure 2-5: Dams and GHG Emissions

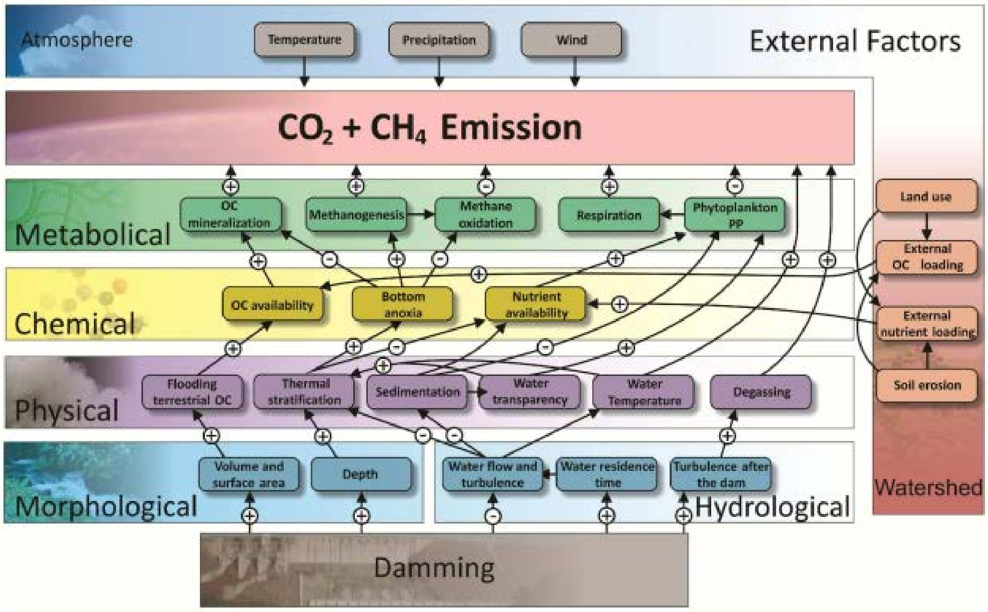


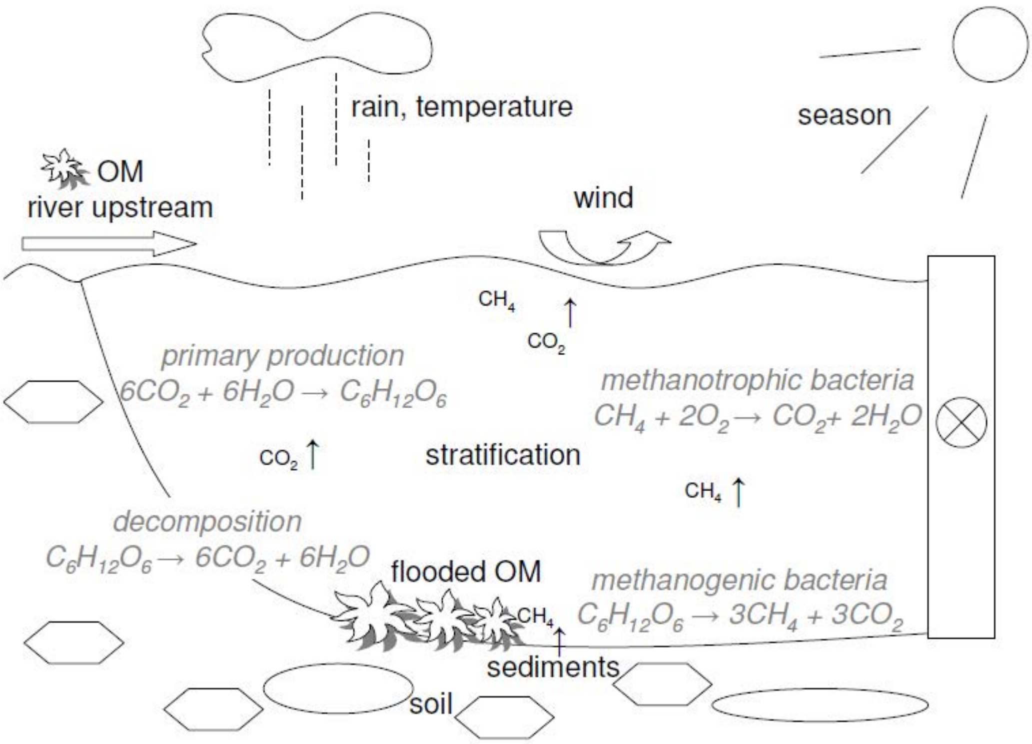
Fig. 3. Diagram illustrating some of the major impacts of damming rivers and their effects on GHG emissions. Direct hydrological impacts of damming rivers trigger a cascade of shifts in the physical and chemical environment, leading to indirect (through changes in metabolism) and direct changes in GHG fluxes. External factors affecting GHG emissions are mainly related to atmospheric conditions and drainage basin characteristics. OC = organic carbon; PP = primary production. Arrows with the (+) symbol represent positive effect; arrows with the (-) symbol represent negative effect.

Source: Mendonca *et al.* (2012)[32]

Hydroelectric reservoirs are sources of anthropogenic greenhouse gas (GHG) emissions. GHG (CO2 and CH4) can be produced via three main paths of the reservoir. On the bottom layer is the decomposition of organic matter originating from the flooded area. Primary production is in the reservoir, and from the river upstream. Greenhouse gases from different pathways reach the atmosphere by diffusing and bubbling in the reservoir itself, as well as in the river downstream. A large amount of gases are also released when the water passes through the turbine and spillway.

Figure 2-6 Dams and GHG Emissions 2

[32] Mendonça, R., N. Barros, L.O. Vidal, F. Pacheco, S. Kosten & F. Roland (2012). Greenhouse Gas Emissions from Hydroelectric Reservoirs: What Knowledge Do We Have and What is Lacking? In: Greenhouse Gases - Emission, Measurement and Management, Dr Guoxiang Liu (Ed.), InTech. Available from: http://www.intechopen.com/books/greenhouse-gases-emission-measurement-and-management/greenhouse-gas-emissions-from hydroelectric-reservoirs-what-do-we-have-and-what-is-lacking



Souce: Claudia Farrèr Hydroelectric Reservoirs – the Carbon Dioxide and Methane Emissions of a "Carbon Free" Energy Source , Master of Environmental Sciences- Term Paper in Biogeochemistry And Pollutant Dynamics, 21st December 2007

By 2030 the LMB could experience significant changes, including:

- Significant climate and hydrological changes, with far reaching effects on natural systems, including the Mekong mainstream.
- Major adjustments in local livelihoods and key development sectors would be required to work with these changed systems.
- Auditing, and possibly retrofitting, existing hydropower projects.
- Review and possible design modifications to Yunnan dams.
- Increased hydropower capacity in catchments experiencing high rainfall and runoff.

Box 2-5 Emissions from Hydro Dams in Cambodia

Recent studies on hydro dams have found that large amounts of methane are emitted from dams in tropical landscapes. These emissions occur from the anaerobic fermentation of biomass in the dam reservoir. The extent of the emissions varies by dam from between a few hundred grams to two kilo CO2 equivalents per kWh generated; and is dependent on the size of the reservoir, the climate and amount of biomass in the reservoir (Kummu, Varis, and Timo 2010).

Emissions depend on the ecologic zone, size of reservoir, and amount of electricity generated. Smaller, deeper reservoirs, between steep mountains, produce fewer emissions as they do not flood as much organic matter, have a higher head and produce a lot of electricity with minimal water flow. Gross emissions show the difference in emissions and the average of 482 Gg CO2 eq. per GWh. Expected emissions are the highest from the Battambang 1, Lower Se San 3, and Pursat 2 dams. Only four of the planned hydro dams in Cambodia are expected to have higher emissions, over 766 Gg CO2 eq. per GWh, compared to low emission coal fired power plants.

Table below: Summary gross emissions of CO2 from proposed dams in Cambodia

No	Name	Area (Km^2)		Power (GWh)	Gross emissions, CO_2eq (100 yr)	
		Total	Average		t/yr	t/yr/GWh
1	Kirirom I	1	1	40	1750	44
2	Kirirom II	4	4	79	8138	103
3	Kamchay	20	17	498	38608	78
4	Stung Atay	10	14	572	30280	53
5	Stung Tatay	35	30	858	66238	77
6	Lower Sesan 2+	84	71	1953	122487	63
7	Stung Chey Areng	76	65	618	143832	233
8	Sambor (MD)	880	748	14870	1283194	86
9	Lower Sesan 3	980	833	1310	1854675	1416
10	Pursat 1	113	96	448	164774	368
11	Pursat 2	40	34	42	58327	1389
12	Battambang 1	143	122	120	208519	1738
13	Lower Sre Pok 3	985	837	1754	1436302	819

Sources:

1. Kummu, Matti, Olli Varis and Timo Rasanen (2010) Greenhouse gas emissions from reser-voirs-Case Cambodia (In press). Water and Development Research Group, Aalto University, Finland.

2. Ministry of Environment (2010) Greenhouse Gas Mitigation Analysis for the Energy and Transport Sector. A thematic report prepared for the Second National Communication Re-port for UNFFCCC.

Potential mitigation options include: (i) Not to construct dams that are expected to have large emissions; (ii) Reducing the organic matter in the reservoir; (This is a relative new area requiring more research. In Cambodia trees are typically removed from the reservoir; however removal of the roots increases the risk of erosion) and, (iii) Recovering methane from the water released from the power house. The methane gas could be used for additional power generation. Again studies are required to determine the feasibility of this mitigation option as suggested by the study above.

TRAINING AIDS	
Discussion topics	1) Can the "environmental" impacts of hydropower be considered separately from "social" impacts? 2) Is there a physical or moral limit to how much we should alter the natural environment?

Exercises	Divide into small groups; select a hydropower project known to all partici-pants; list the impacts *not* predicted during project planning; how important are these impacts ecologically, socially and economically?

Additional reading and resources	1) MRC. 2010. *SEA of Hydropower on the Mekong Mainstream*. http://www.mrcmekong.org/about-the-mrc/programmes/initiative-on-sustainable-hydropower/strategic-environmental-assessment-of-mainstream-dams/ 2) McCully, P. 2001. *Silenced Rivers: The Ecology and Politics of Large Dams* (updated edition). Zed Books, London. 3) Goodwin, P., K. Jorde, C. Meier & O. Parra. 2006. Minimizing environmental impacts of hydropower development: transferring lessons from past projects to a proposed strategy for Chile. *J. Hydroinformatics* 8:4, 253-270. 4) Peter Goodwin, Klaus Jorde, Claudio Meier and Oscar Parra. 2006. *Minimizing environmental impacts of hydropower development: transferring lessons from past projects to a proposed strategy for Chile*. Journal of Hydroinformatics, 08.4 http://www.iwaponline.com/jh/008/0253/0080253.pdf 5) FAO: *Impacts of Dams on Rivers*. At: http://www.fao.org/docrep/005/y3994e/y3994e0i.htm#TopOfPage 6) The website pages on *Environmental Impacts of Dams* at http://www.internationalrivers.org/environmental-impacts-of-dams 7) Thayer Scudder. 2005. *The Future of Large Dams: Dealing with Social, Environmental, Institutional and Political Costs*. Earthscan. 8) Carew-Reid, J., J. Kempinski & A. Clausen. 2010. *Biodiversity and Development of the Hydropower Sector: Lessons from the Vietnamese Experience –Volume I: Review of the Effects of Hydropower Development on Biodiversity in Vietnam*. Prep. for the Critical Ecosystem Partnership Fund by ICEM –International Centre for Environmental Management, Hanoi, Vietnam. http://www.icem.com.au/02_contents/06_materials/06-reports.htm 9) IEA Implementing Agreement for Hydropower Technologies and Programmes. 2000. Annex III *Hydropower and the environment: Present context and guidelines for future action*. Subtask 5 Report, Volume I, Main report http://www.ieahydro.org/reports/hya3s5v2.pdf 10) UNESCO/IHA GHG Research Project: see resources at: http://hydropower.org/iha/development/ghg/ 11) *GHG Measurement Guidelines for Freshwater Reservoirs*. Available from: http://hydropower.org/iha/development/ghg/guidelines.html 12) *The GHG Risk Assessment Tool.* Beta version available from: http://hydropower.org/iha/development/ghg/risk-assessment-tool.html 13) Lima, I.B.T, F.M. Ramos, L.A.W. Bambace & R.R. Rosa (2007). *Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective*. Mitig Adapt Strat Glob Change (2008) 13:193–206 DOI 10.1007/s11027-007-9086-5. Available at: http://ecologia.icb.ufmg.br/~rpcoelho/Congressos/DGL2008/Reservoirs

	%20GHG%20emiissions/Global%20change%202008%20ok.pdf 14) Mäkinen, K. & Shahbaz Khan. 2010. Policy considerations for greenhouse gas emissions from freshwater reservoirs. *Water Alternatives* 3(2): 91-105. www.water-alternatives.org 15) Ward, J. V. & Stanford, J. A.1979. *The Ecology of Regulated Rivers*. Plenum Press. New York. 16) Ackermann, W. C., White, G. F. & Worthington, E. B. (Eds). 1973. Man-made Lakes: Their Problems and Environmental Effects. *Geophysical Monograph* 17. American Geophysical Union, Washington, DC. 17) Petts, G.1984. *Impounded Rivers. Perspectives For Ecological Management*. John Wiley & Sons, Chichester. 18) Baxter, R. M.1977. Environmental effects of dams and impoundments. *Ann. Rev. Ecol. Systematics* 8, 255–283.

Case Studies

Case Study 1: Fish Extinctions and Dams

This case study is list of examples of fish extinctions to illustrate the impacts of some dams, from an international conservation NGO.

Fish Extinctions and Dams

Dams affect the aquatic communities of rivers by reducing current flow and separating the upper and lower parts of rivers with impenetrable barriers. Fish migration is affected, since many neotropical fish migrate long distances, often in complex patterns involving flood plains. Consequently certain species have become locally extinct upstream of dams, such as the dorada, picuda, bagre and patalo above the Betania Dam in Colombia. Similar effects have been seen in fish and shrimp populations on Caribbean islands. Migratory fish have become extinct in the upper Parana River (a tributary of the Plata River) in Brazil/Paraguay, where numerous dams have been built over the past half century. In the Lower Plata basin, catfish are almost extinct, and other fish are declining in population. The population of Chinese paddlefish, endemic to the Chang Jiang River in China, has declined greatly since the Gezhouba Dam was built, as the dam impedes the fishes' access to breeding sites upstream. This species will doubtless become extinct since it can no longer reproduce. Chinese sturgeon were similarly affected by this dam; they can no longer migrate, and the species is extinct below the dam. Asian river dolphins are endangered by the alteration of rivers. The Indus dolphin population consists of fewer than one thousand animals, the Yangtze dolphin of China, fewer than 200. These are not sustainable population numbers. The Irrawaddy dolphin, an estuary dweller, which enters rivers, is gone in many parts of its former habitat, such as the Chao Phya River in Thailand. This dolphin will suffer even more when additional large-scale dams planned for Southeast Asian rivers prevent migration and block access to upstream habitats.

Source: extracted from Rainforest Conservation Fund website http://www.rainforestconservation.org/rainforest-primer/3-rainforests-in-peril-deforestation/d-causes-of-tropical-rainforest-destruction/14-dam-constructionuse-of-rainforests-as-hydropower-sources

Case Study 2: Impacts of Mekong Mainstream Hydropower

As a case study of the potential impacts of hydropower, trainees are encouraged to read the summary of the findings of the MRC's Strategic Environmental Assessment (SEA) of mainstream hydropower projects, available online at:

http://www.mrcmekong.org/about-the-mrc/programmes/initiative-on-sustainable-hydropower/strategic-environmental-assessment-of-mainstream-dams/

Box 2-6 Mekong livelihoods and the regional natural resources

The livelihoods of the Mekong Basin population are inextricably linked to the region's natural resources. Any agent of environmental change that compromises these resources will therefore have a profound impact on local livelihoods. A reduction in the productivity of fishing and agriculture will have major consequences for the food and economic security of the local people. Hydropower development will deny much of the basin's population the ability to sustainably support themselves. Many will be forced to find alternative livelihoods, which will often lead to further environmental destruction, highlighting the unsustainability of continued hydropower development.

It is important to take an interdisciplinary approach while assessing the impact of natural resource development projects. While environmental impact assessments have often been conducted for Mekong hydropower projects, the social impacts have generally received significantly less attention. Assessing only the environmental impacts fails to recognize the value of these natural resources, in their current state, to the basin's inhabitants.

As summarized by Witoon Permpongsacharoen: "This is the lifeblood, the life source, for millions of people. You simply cannot afford to make any big mistakes with the Mekong" (Blake, 2001, p. 5). If the basin's inhabitants are to maintain the livelihoods they have enjoyed for centuries, policy-makers must strike a delicate balance between the pursuit of economic growth and the conservation of natural resources (Rix, 2003). This undoubtedly involves looking at more sustainable alternatives to the proposed hydropower projects.

Case Study 3: Mercury in Canadian Hydro Reservoirs

This case study recounts some of the Canadian experience with the formation of biologically available mercury in hydropower reservoirs, and its effects on fish and humans.

Methyl Mercury in Canadian Reservoirs

Canadian experience with the impoundment of rivers to create reservoirs for hydroelectric dams has revealed that methyl mercury, a central nervous system toxin, is formed through bacterial synthesis in flooded soils and vegetation. Fish accumulate the methyl mercury produced in this way, which then becomes a potential health hazard for consumers of fish.

The process of methyl mercury production occurs naturally in lakes and rivers, but certain new reservoirs in northern Manitoba and north-western Quebec in Canada have resulted in a four to six-fold increase in methyl mercury concentrations in fish. In particular, methyl mercury contamination has become a significant issue at the La Grande hydroelectric complex (Phase I of the James Bay Project) which was built by Hydro-Québec in northwestern Quebec between 1970 and 1984, and will continue to play a role in the Quebec government's plans to proceed with additional hydroelectric development in the same region.

Prior to hydroelectric development in these regions of Canada, methyl mercury contamination was a concern because of regionally elevated levels of mercury found in fish. In the 1970s, methyl mercury concentrations as high as 100 milligrams per kilogram (mg/kg) were found in the hair of some Cree Indian fishermen. The World Health Organization sets the tolerance limit for human exposure to methyl mercury at 6 mg/kg; therefore, the high levels found in the Crees have prompted questions about long-term toxicity and the possible effects of foetal exposure.

Since the construction of Phase I of the James Bay Project, limits have been placed on fish consumption in order to control exposure to methyl mercury. Recent surveys of adult Crees over 40 years old reveal that approximately 5% of this adult population have in excess of 25 mg/kg in their hair.

Source: extracted from: Penn, A. *Potential Methyl Mercury Contamination in the Three Gorges Reservoir*, at http://journal.probeinternational.org/2009/03/19/chapter-5-potential-methyl-mercury-contamination-three-gorges-reservoir/

2.3 International Framework

Key aspects	• An extensive body of international law exists that is directly relevant to sustaining river ecosystems. • These environmental laws and agreements - mostly UN Conventions – are set within a wider framework of international social and human rights laws, relevant to hydropower decision-making. • The dominant approach to water resources management is Integrated Water Resources Management (IWRM. This is supported by extensive literature and guidelines.

TRAINING AIDS	
Purpose of session	To introduce the international framework of environmental agreements and IWRM guidelines relevant to river ecosystems and hydropower.
Learning objectives	At the end of this session, the trainee will: • Be aware of the principal international environmental agreements relevant to rivers and hydropower. • Be aware of Integrated Water Resources Management, its fundamental principles, and that there is an extensive literature to provide further information.
Key readings	1) Hassing *et al.* 2009. *Integrated Water Resources Management in Action*. UN World Water Assessment Programme, Dialogue Paper. Available from http://www.un.org/waterforlifedecade/iwrm.shtml

2.3.1 The UN Conventions

There are four UN Conventions directly relevant to sustaining freshwater ecosystems. In chronological order, these are:

- Convention on Wetlands of International Importance, especially as Waterfowl Habitat, Ramsar, 1971 (“Ramsar Convention”).
- Convention Concerning the Protection of the World Cultural and Natural Heritage, Paris, 1972 (“World Heritage Convention”).
- Convention on the Conservation of Migratory Species of Wild Animals (CMS), Bonn, 1979.
- Convention on Biological Diversity (CBD), Nairobi, 1992 (“Biodiversity Convention”).

The Ramsar Convention on wetlands allows states to propose specific wetlands (including rivers and lakes, as well as other freshwater habitats) to be designated as “Ramsar sites” on account of their international ecological importance. At preset, 167 contracting parties (states) and more than 2,100 Ramsar sites exist worldwide. The Convention works closely with five International Organization Partners (IOPs): Birdlife International, the International Union for Conservation of Nature (IUCN), the International Water Management Institute (IWMI), Wetlands International and WWF International.

The World Heritage Convention has resulted in the establishment of the world's most important natural heritage sites, which states are required to protect. These sites include many wetlands. The CMS relates, in particular, to migratory birds but also covers terrestrial wildlife and fish, which migrate internationally. (States may opt to manage and conserve these transboundary species). The CBD provides a framework for state parties to develop action plans for biodiversity conservation at the national level.

Hydropower development may result in increased access to or exploitive pressure on endangered species. In these cases the relevant UN Convention is CITES, which establishes a binding list of species whose international trade is controlled:

- Convention on the International Trade in Endangered Species of Wild Flora and Fauna, (CITES), Washington DC, 1973.

Hydropower development may also increase access to tropical forests, in which case some of the provisions of the International Tropical Timber Agreement, (ITTA), Geneva, 1994 may be relevant.

Trainers and trainees should also be aware of the large body of international law based on the various UN Conventions on social issues and human rights. These all flow from the 1948 UN General Assembly declaration, the **Universal Declaration of Human Rights**.

2.3.2 Other International Laws and Agreements

There are many regional environmental agreements. For example, in Europe:

- Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Helsinki, 1992 ("ECE Water Convention").
- Convention on Environmental Impact Assessment in a Transboundary Context, Espoo, 1991 ("Espoo Convention").
- Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, Aarhus, 1998 ("Aarhus Convention").

Regional environmental agreements are a subset of international treaties governed by international treaty law, specifically, the Vienna Convention on the Law of Treaties (1969). This Convention provides general guidelines and rules for the development, negotiation, adoption and entry into force of international treaties.

2.3.3 Major Tools for Water Resources Development Planning

Over the last two decades **Integrated Water Resources Management** (IWRM) has emerged as the principal tool for water resources development planning. As its name suggests, IWRM responds to the need for comprehensive planning of water as a fundamental resource for ecosystems and society. IWRM can be defined as "*a coordinated, goal-directed process for controlling the development and use of river, lake, ocean, wetland, and other water assets*."[33] Another definition is from the Global Water Partnership "*IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*."

IWRM is focused on sustainability. As stated in Wikipedia, it is a "comprehensive, participatory planning and implementation tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations". An IWRM approach is an open, flexible process, bringing together decision-makers across the various sectors that affect water resources, and bringing all stakeholders to the table to set policy and make sound, balanced decisions in response to specific water challenges faced.

IWRM is not a new concept. An early example of its application that is frequently mentioned is the establishment of the Tennessee Valley Authority in 1933, which integrated the functions of navigation, flood control and power production while addressing the issues of erosion control, recreation, public health and welfare.[34]

Over the last twenty years attempts at water sector reform have largely been based on four principles developed at a meeting in Dublin:

- **Principle 1.** Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- **Principle 2.** Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.
- **Principle 3**. Women play a central part in the provision, management and safeguarding of water.
- **Principle 4.** Water has an economic value in all its competing uses and should be recognised as an economic good as well as a social good.

In putting the IWRM principle into practice, many countries have adopted an approach where regulatory decisions, such as water allocation and pollution licensing, are implemented at the scale of the river basin or catchment. This has been accompanied by the emergence of institutional arrangements for water resources management, based on hydrological boundaries. While most of these institutions can be grouped into **River Basin Organisations** (RBOs) some are specifically mandated with managing groundwater water aquifers and lakes basins.

Extensive literature on IWRM exists. An excellent state-of-the-art review was carried out during the Sixth Phase of the International Hydrological Programme of UNESCO (IHP-VI), from 2002 to 2007, and updated at the start of the Seventh Phase of IHP (IHP-VII). Case

[33] Cardwell *et al.* 2006. *Integrated Water Resources Management: Definitions and Conceptual Musings*. J. Contemporary Water Research & Education 135: 8-18. Universities Council on Water Resources.

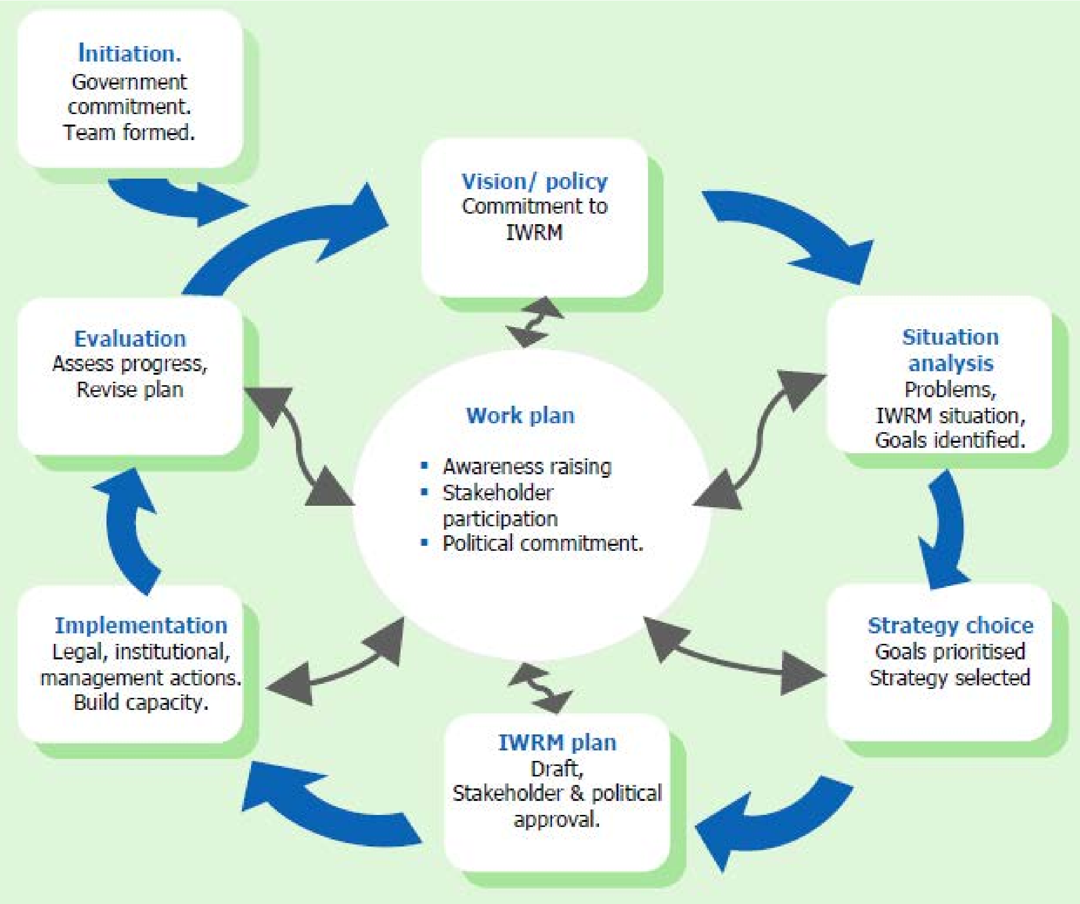
[34] Snellen & Schrevel. 2004. *IWRM for sustainable use of water: 50 years of international experience with the concept of integrated water management.* Ministry of Agriculture, Nature and Food Quality, The Netherlands.

history literature related to integrated river basin management (IRBM) and IWRM was reviewed. A typical set of lessons learned from a case study is reproduced below (**Box 2-7**).

Useful training manuals and operational guides on IWRM have been developed by Cap-Net, a UNDP capacity development programme for sustainable water management.

Stages in IWRM planning are illustrated in **FFigure 2-7**.

Figure 2-7: Stages in IWRM Planning and Implementation



Source: IWRM Training Manual and Operational Guide. 2005. Cap-Net/Global Water Partnership/UNDP

Box 2-7: Lessons Learned from Case Study of IWRM, Nan River Basin, Thailand

3. Nan River Basin, Thailand	1. Using existing mechanisms, processes and values is of crucial importance (rather than imposed state agency conditions incompatible with local culturally embedded practices). 2. Villagers' interest in participation derives from their interest in the outcomes (not from a standardized institutional form of participation). 3. Specific river basin organizations may not be the most strategic point of intervention. Other key groups and networks may play an important role, given the modest resources that are available to become involved in water and river basin issues. 4. Research is significant as much for the process of involvement as for the nature of the results and findings. 5. The inclusive process carried out by a civil society organization attracted interest at community and local government level. 6. Research reports give legitimacy that advocacy and critique does not necessarily afford at the policy level. a) Understanding the various ways in which water and river basin management are actively negotiated at a local level gives (i) more thorough insight into key river basin management issues and (ii) a basis to challenge bureaucratic approaches to infrastructure planning and river basin administration currently in place as 'mainstream' practice.

Source: Kennedy *et al.* 2009. The United Nations World Water Assessment Programme: Insights: *IWRM Implementation in Basins, Sub-basins and Aquifers: State of the Art Review.* International Hydrological Programme of UNESCO.

Transboundary cooperation in hydropower development and management can increase project benefits to all riparian countries, whilst simultaneously decreasing the possibility of negative transboundary impacts. A variety of approaches are available to mitigate environmental and social impacts, and to share costs and benefits. A comparative analysis of mechanisms and tools applied in five case studies, the Manantali Dam (Senegal, Mali, and Mauritania), the Itaipu Dam (Paraguay/Brazil), the Columbia River Project (USA/Canada), the Kariba Dam (Zambia/Zimbabwe), and the Kosi Dam (Nepal/India); provides various points which could be considered by the MRC in relation to the hydropower developments in the LMB[35]:

- Basin-wide institutions can provide an essential framework for coordinated hydropower development and management.
- Designating or creating a specified agency for dam operational management can facilitate day-to-day cooperation.
- Cost-benefit sharing mechanisms need to be fair and flexible.
- Social and environmental mitigation measures as well as their financing need to be considered from the planning stage.
- Cooperation on a regional and local level is necessary to effectively design and implement social and environmental mitigation measures.

[35] Kramer, A., O. Hensengerth, A. Mertens & A. Carius. 2012. Assessment of RBO-Level mechanisms for Sustainable Hydropower Development and Management. GIZ.

TRAINING AIDS	
Discussion topics	1) Is there a need for better water management in your country? Are water sector responsibilities fragmented or integrated? What are the consequences? 2) How are men and women affected differently by water resource management policies in your country?
Exercises	• Consider the water management structures in your country: what institutional and legal reforms are needed to implement IWRM? List these and make a priority list or flow chart for reform.
Additional reading and resources	1) Environmental agreements: http://en.wikipedia.org/wiki/List_of_international_environmental_agreements#Freshwater_resources 2) IWRM: http://www.un.org/waterforlifedecade/iwrm.shtml 3) *IWRM Reader*. UN-Water Decade Programme on Advocacy and Communication (UNW-DPAC). United Nations Office to Support the International Decade for Action 'Water for Life' 2005-2015. 4) *IWRM Training Manual and Operational Guide*: http://www.cap-net.org/TMUploadedFiles/FileFor67/IWRM_Plan.doc or www.gwpforum.org or request on CD with all supporting references from info@cap-net.org 5) Global Water Partnership Toolbox on IWRM: homepage: http://www.gwptoolbox.org/index.php?option=com_content&view=article&id=20&Itemid=22 6) Global Water Partnership Toolbox on IWRM: management instruments: http://www.gwptoolbox.org/index.php?option=com_tool&cat_id=3

2.3.4 Case Studies

The following case studies from southeast Asia illustrate multiple aspects of IWRM. Source: Global Water Partnership Toolbox:

http://www.gwptoolbox.org/index.php?option=com_case&region=Asia%20South%20East&Itemid=46

Case Study 1

The following case study is a report of a major survey of IWRM in 30 countries. Source: Cap-Net/Global Water Partnership/UNDP, 2005, *IWRM Plans: Training Manual and Operational Guide.*

Impacts of IWRM

Progress has been made over the last 20 years to improve water policies, plans and laws and remains an ongoing process. The benefits are not always easy to quantify; however, based on the sample of 30 countries, there has been significant impact as illustrated in the sample below, reported in the Level 2 interviews:

Impact on water resources management

- China reported 90% efficiency gains in terms of water use/ unit of GDP, as well as integrated system for urban flood control, wastewater discharge, water source protection and water environment;
- Mexico reported many accomplishments, including a comprehensive legal system, a national water authority, a functioning water rights system, and incipient water markets;
- New governance processes and improved coordination have been implemented across government agencies in Brazil with a strong role for stakeholders;
- Samoa reported improved coordination across government agencies;
- Rwanda has established decentralized environmental clubs that enforce adherence to environmental laws;
- In Australia, water markets have been effective to improve efficiency and flexibility while maintaining environmental flow objectives. Also, a rules-based approach has been established to ensure water development and environmental objectives are met.
- In Mozambique and Estonia stakeholder participation has resulted in greater commitment to improved water resources management;
- Private sector involvement has brought increased financial flows in Armenia and Mozambique; and
- New state water databases have been established in Armenia and Estonia.

Impact on water users

- Many countries reported improved access to water supply, including Albania, Armenia, Benin, Cap Verde, Ghana, Guatemala, Jamaica, Namibia, Samoa, Tunisia, and Uganda;
- Wastewater management reforms in Spain have reduced costs;
- Water use efficiency has improved with system losses reducing from 30 to 17% in Estonia;
- Uganda and Costa Rica reported improved protection from pollution and overexploitation with associated health gains;
- All municipalities and 90% of rural settlements in Estonia have wastewater treatment facilities;
- 110 wastewater treatment plants have been built in Tunisia;
- Ghana has rehabilitated 40% of irrigation schemes for more effective water use and productivity;
- In Uzbekistan, cropping patterns have been changed and irrigation infrastructure upgraded

with significant water efficiency gains; and

- Irrigated area and hydropower has increased in Guatemala and Uganda bringing many people out of poverty.

Case Study 2

An Assessment of Lao PDR's National Biodiversity Strategy to 2020 and Action Plan to 2010

In 1996, the Government of Lao PDR acceded to United Nation International Convention on Biological Diversity (CBD). In meeting the requirements of the convention, in 2004, the government of Lao PDR formulated and approved its first National Biodiversity Strategy and Action Plan (NBSAP). This NBSAP laid out an action plan until 2010 and a strategy until 2020. Currently, the Lao PDR is in the process of updating and publishing a 2nd NBSAP, which seeks to respond to lessons learned from the implementation of the 1st document.

Beginning in June 2011, IUCN and the Department of Forest Resource Conservation undertook this assessment through soliciting information on CBD relevant progress from a wide range of government and non-government stakeholders. This report is a compilation of the responses received.

The assessment revealed key progress in the following areas under the first NBSAP:

- Biodiversity research
- Recording of local knowledge
- Expansion of NPAs
- Implementation of management plans in a few key NPAs
- Drafting of a Biosafety Law
- Expansion of ecotourism
- Land Use Planning and land allocation
- Ramsar accession
- Stricter EIA/ESIA laws

Areas with limited progress included:

- Lack of resources, including management plans, in the majority of NPAs
- Lack of access and benefit sharing
- Lack of enforcement of EIA/ESIA laws as many concessions move forward despite negative impacts on surrounding environment
- No Biosafety Law
- Limited concerns about environmental sustainability in land use planning and allocation
- Restricted use of the "polluter pays principle" and limited visible progress in creating Green Cities.

Assessment of the 1st NBSAP document revealed several shortcomings. For example, it did not provide any indicators or assign specific government departments and institutions to be responsible for implementing each action and monitoring progress. Nor did it outline a monitoring plan. The document would likely have been more successful (and directed donor funds towards implementation) if it had identified priority targets, instead of a long list of targets, and provided estimate budgets for work towards those targets.

As such, the 2nd NBSAP should identify and clearly lay out priority actions, potential funding sources, budget estimates, indicators of success, and the institution(s) responsible for each target. All targets should be measurable. Given the recent change in ministerial structure, the 2nd NBSAP should first and foremost focus on revising and improving the CBD institutional structure. A new structure should focus on cross sector planning and strategies and call for additional government funds to support this work.

With regards to biodiversity conservation priority areas, under the 2nd Program of Work on Protected Areas (PoWPA) and NPA management plans NBSAP, there is a proposed focus on the following areas:

- Strategic plans for species conservation
- Wetlands conservation
- Access and benefit sharing
- Land use planning that incorporates sustainability criteria ,with a particular focus on agro-biodiversity.

Source: IUCN (2011). NBSAP Assessment: An assessment of Lao PDR's National Biodiversity Strategy to 2020 and Action Plan to 2010. Gland, Switzerland: IUCN.46pp.

Case Study 3

Thailand's biodiversity is protected by various laws, the most important of which are as follows:

- National Park Act (1961),
- National Conserved Forest (1964),
- Wildlife Conservation and Protection Act (1992),
- Plant Storage Act (1964)
- Second Plant Storage Act (2008)
- Fishery Act, 1947
- Animal Species Maintenance Act (1966)
- Export and Import to the Kingdom Act (1979),
- National Environment Enhancement and Conservation Act (1992):
  Part 3: Conservation and Environmentally Protected Areas
- Plant Species Protection Act (1999)
- Traditional Thai Medical Knowledge Enhancement and Protection Act (1999)

International/ Regional Ecosystem Framework

The international framework related to biodiversity and ecosystems, appled to a regional ecosystem framework.

1. The World Bank

"*The World Bank advocates the application of environmental assessments to provide information about the ways on new economic activities (including projects that involve dam construction) may directly or indirectly affect ecosystems. The Bank requires that the environmental assessments carried out for the supporting projects to reflect the persons who are affected by the project, including the poor, indigenous people, and disadvantaged groups. The Bank will not support projects which involve the significant conversion or degradation of critical natural habitats unless there are no other feasible alternatives to the project and its siting and the overall benefits from the project substantially outweigh its environmental costs. The current Bank policies and guidelines that are of most relevance specifically to ecosystem impacts of large dams are published in the Bank's Operational Handbook (World Bank, 1999) and include:*

World Bank Operational Policy 4.04 : Natural Resources

World Bank Operational Policy 4.01 : Environmental Assessment):

World Bank Procedure 4.01 : Environmental Procedures);

World Bank Operational Policy 4.07 : Water Resources Management"

2. Requirements of International Conventions

"The Convention on Biological Diversity (CBD) to date ratified by 178 countries (199x) explicitly recognizes the links between biodiversity conservation and sustainable development. It acknowledges that biological diversity is more than just the sum of species numbers; it encompasses the variety, variability and uniqueness of genes and species and of the ecosystems in which they occur. The Convention's overall objectives include the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from the utilization of genetic resources. As of February 2000, 122 countries have also ratified the Convention on Wetlands (Ramsar 1971) which provides broad guidelines on reducing the impact of development projects (e.g. dams) on wetlands."

Source : Dams, Ecosystem Functions and Environmental Restoration, Final Version: November 2000 Prepared for the World Commission on Dams (WCD) by: Ger Bergkamp, Matthew McCartney, Pat Dugan, Jeff McNeely and Mike Acreman

Case Study 4

Legal framework for ecosystem protection in Vietnam

- Law on Environmental Protection, 2005
- Law on Water Resources 2012
- Law on Biodiversity, 2008
- Land Law, 2003
- Law on Forest Protection and Development, 2004
- Law on Fisheries, 2003
- Decree on River Basin Management, 2008
- Decree on Payment for Forest Ecosystem Services (PFES), 2010

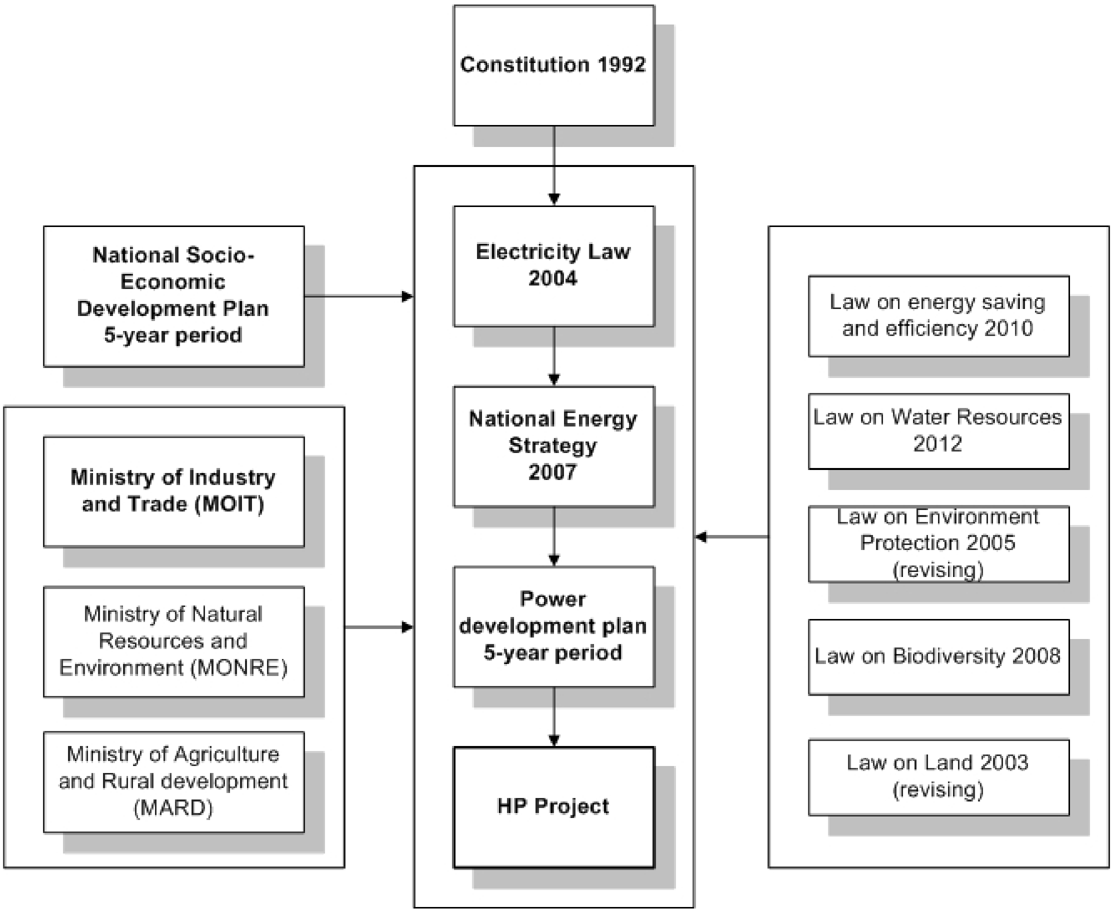


Figure: Legal framework for hydropower development in Vietnam

Source: Dao Trong Tu et al, 2011, reproduced with permission in Ha Thanh Lan et al, Case study on Ba Ha Hydropower Plant, 2013

Cases - Region: Asia South East

Indonesia: A watershed approach to coastal zone management in Balikpapan Bay (#85)

Indonesia: Indonesia's water resources policy reform process (#175)

Lao PDR: Water Planning and Economic Development (#408)

Malaysia: Community and non-governmental organisation partnership in highland catchment management (#174)

Malaysia: Managing the Kinabatangan floodplains in Sabah (#256)

Myanmar: Water licensing & strengthening of water user groups (#310)

Philippines: Establishing an Industrial Wastewater Effluent Fee Program, Laguna de Bay (#82)

Philippines: Watershed rehabilitation and management strategies in Davao City Water District (#293)

Thailand: Community based management to conserve local ecosystem (#331)

Thailand: Fish conservation project to address poverty and ecological recovery (#330)

Thailand: Flood management and mitigation of flood damage in Nong Pai (#323)

Thailand: Partnership policy in Songkhla Lake (#269)

Thailand: Sustainable fishery in Si-nad Swamp area (#324)

Transboundary: Adaptation to climate change in the countries of the Lower Mekong Basin (#385)

Transboundary: Transboundary water management on the Mekong River (#137)

Vietnam: IWRM principles strengthen sustainability of rural water supply and sanitation (#122)

Vietnam: Scaling up rural sanitation – political economy constraints and opportunities (#423)

Vietnam: Water Law and related legislation for implementation of IWRM (#112)

3 BIODIVERSITY CONSERVATION

MODULE 3: BIODIVERSITY CONSERVATION		
Scope	**Session/ Sub-Topic**	**Scope**
Biodiversity conservation (fauna, flora, river basin ecosystems, wetlands)	**Session 3.1: Rivers**	
	Rivers	Review of typical biodiversity along a river system from headwaters to the sea, with interdependencies horizontally (floodplains) and longitudinally (up/downstream); approaches to defining and maintaining river health.
	Freshwater biodiversity	Introduction to freshwater biodiversity, services and threats; biodiversity of the Mekong River.
	Session 3.2: Wetlands	
	Wetlands	Definitions; global role in biodiversity conservation; ecosystem services provided by wetlands; fragility; threats and loss of wetlands.
	Flora	Review of typical wetland vegetation: types, diversity; services provided by vegetation (inc. flood protection).
	Fauna	Review of typical wetland fauna: fish, mammals, herptiles, insects etc.; issues of habitat loss from various causes; predation (hunting by humans).
	Session 3.3: Birds	
	Bird diversity and ecological functions	Review of special position of birds: diversity & ecological functions; as indicator species for ecosystem health (habitat; pesticides etc).
	Bird migration	Overview; flyways; international agreements; important bird areas (IBAs).
	Session 3.4: Tools	
	Tools for Conservation	The ecosystem approach; conservation planning tools.

3.1 Rivers

Key aspects	• Rivers are ancient hydrological systems, which form the landscape through different landforms and processes from their headwaters to the sea. • Flooding is a key driver of ecological processes. • River health can be measured with various indicators. • The main threats to a river's health are: o barriers like dams; o degradation of floodplain habitats; o pollution; o invasive species.

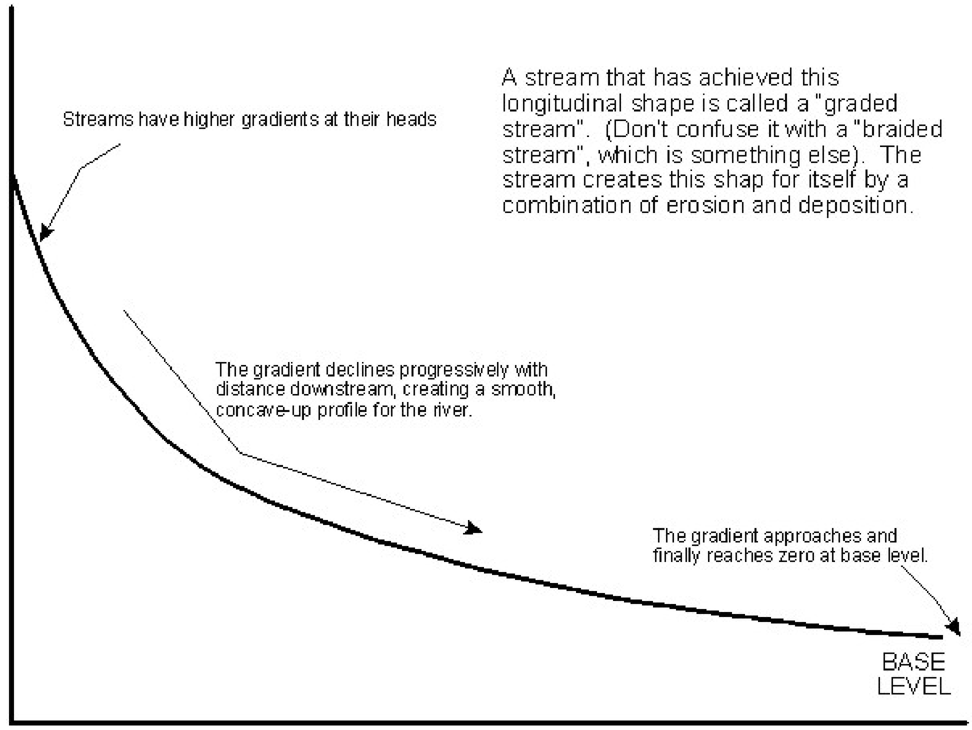
TRAINING AIDS	
Purpose of session	The purpose of this session is to provide trainees with an overall understanding of fluvial processes and ecology.
Learning Objectives	By the end of this session, the trainee will: • Be able to identify key linkages and processes vital to a river's health. • Be aware of how water infrastructure development policies might affect river health.
Key readings	1) River. Wikipedia. http://en.wikipedia.org/wiki/River 2) Baran, E. 2010. Mekong fisheries and mainstream dams. In: ICEM (2010). MRC SEA of hydropower on the Mekong mainstream. Available at: http://www.worldfishcenter.org/resource_centre/WF_2736.pdf 3) Higler, L.W.G. Biology and Biodiversity of River Systems. Fresh Surface Water - Vol II - Biology and Biodiversity of River Systems. Encyclopaedia of Life Support Systems. http://www.eolss.net/Sample-Chapters/C07/E2-07-04-03.pdf

3.1.1 River Ecology

3.1.1.1 Overview

From its source, a typical river has a steep upper section, the headwaters, a less steep middle section and a meandering lower section (**Figure 3-1**). A particular length or section of river is termed a "reach". Since a river has many contributing streams - tributaries - that look like the branches of a tree, the main river is often termed the main stem. The point where two rivers or streams meet is a confluence. Water enters the main stem from the river's drainage basin—the area of land through which the river and its tributaries flow, and from which it receives surface runoff. The drainage basin is also termed a catchment (English) or watershed (US English) (**Table 3-1**). Drainage basins are separated by a watershed or divide. Under some circumstances, areas outside the surface drainage basin may contribute water to the river through groundwater flow.

Figure 3-1: Typical River Profile



Source: http://itc.gsw.edu/faculty/bcarter/physgeol/river/profile1.jpg

Table 3-1: Catchments vs. Watersheds: English Terminology

British English	US English
Catchment Watershed	Watershed Divide

In its headwaters a river is marked by erosive processes, and in its lower course by sedimentary processes. In between, the transition may be gradual or sudden - as in the Terai in Nepal, where the Himalayan rivers emerge from the front range, the Siwaliks. Downstream, rivers meander through their floodplain, a landform created by thousands of years of annual flooding and sediment deposition. In their lower courses some rivers have been affected by sea level changes during glacial and inter-glacial periods; for example, the Nile, which has carved a valley several hundred meters deeper than its present form.

Where rivers enter the sea, or an inland depression, they may form deltas. River branches in the delta are termed distributaries rather than tributaries. The channel of mixing salt and freshwater is termed the estuary.

Ecological conditions along rivers vary enormously. The River Continuum Concept (Vannote *et al.*, 1980)[36] considers the river as an open ecosystem in dynamic equilibrium, constantly changing and interacting physically and ecologically with the banks along its course from source to mouth. By definition, the major factor in river ecology is **flowing water** - except in lakes and in other wetland habitats, such as swamps and seasonally-flooded grasslands. In addition to flow, **light**, **temperature** and **chemistry** are key factors. The basis for most riverine ecosystems are **algae** (phytoplankton and periphyton), the primary producers, which capture sunlight—together with some types of aquatic plants. Invertebrates (mostly insects, and some molluscs) feed on the primary producers and are, in turn, eaten by other consumers further up the food chain, principally fish. Fish (like insects) may be categorised into **feeding guilds**: planktivores eat plankton; herbivore-detritivores are bottom-feeding species that eat plankton and detritus; some fish are surface feeders, or water column feeders (below the surface); omnivores eat a wide range of foods; top predators focus eat other fish or large invertebrates; and parasites prey on their host organisms.

In tropical freshwater systems there is usually a high proportion of detritivores, due to high inputs of nutrients from outside the aquatic system (plant and soil material washed in during floods).

Along the river the proportions of major groups of organisms (the herbivore-detritivores: shredders, collectors, and scrapers, and the predators) change. In the upper reaches of the river, trees may shade the watercourse, providing favourable conditions for leaf-shredders. Scrapers - grazing animals that scrape algae from rock surfaces - increase in numbers downstream, where more sunlight reaches the water. Further downstream collectors increase, feeding on fine fragments of material from upstream. Predator types and numbers reflect prey availability. Where there is disturbance, proportions and frequency of these groups of animals may change.

The interface between land and the river is the **riparian zone**. This is usually a nutrient-rich and dynamic zone, where the riparian plant community is dominated by hydrophilic (water-loving) plants providing a varied habitat with many niches. In the lower reaches of the river the riparian zones extend into the floodplains. Floodplain vegetation typically consists of emergent aquatic plants, trees, and shrubs. Riparian zones and floodplains provide breeding areas for fish and important habitats for water birds.

In a river system with adjacent floodplains, the main driving force that structures the biota, including fish communities that use the floodplain for shelter, spawning, and feeding; is the **flood pulse**. Organisms in a river system usually adapt morphologically, anatomically, physiologically, and ethologically to the patterns of the flood pulse, which facilitates physical and chemical changes in the environment. They also usually depend on the flood pulse signals that trigger their life cycle activities, such as gonad development and migration.

[36] Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Seddell & C.E. Cushing. 1980. The River continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-137 http://zimmer.csufresno.edu/~sblumens/AquatEcol/vannote_1980.pdf

3.1.1.2 River Health

River health is a term indicating the ecological condition of a river. River health is more than just the water quality or the presence of certain plants and animals. What are most important in maintaining the health of a river are effective linkages among the diversity of habitats to enable the maintenance of ecological processes, and the diversity of plants and animals that depend on the processes. One description of criteria for a river's ecological health is shown in **Box 3-1**.

Box 3-1: Criteria for River Health

An ecologically healthy river will have flow regimes, water quality, and channel characteristics, such that:

- In the river and riparian zone, the majority of plant and animal species are native and the presence of exotic species is not a significant threat to the ecological integrity of the system.
- Natural ecosystem processes are maintained.
- Major natural habitat features are presented and maintained over time.
- Native riparian vegetation communities exist sustainably for the majority of the river's length.
- Native fish and other fauna can move and migrate up and down the river.
- Linkages between river and floodplain and associated wetlands are able to maintain ecological processes.
- Natural linkages with the sea or terminal lakes are maintained.
- Associated estuaries and terminal lake systems are productive ecosystems.

Source: Victorian River Health Strategy, 2002. http://www.water.vic.gov.au/environment/rivers/river-health/healthy-rivers#one

3.1.1.3 Threats to River Health

The main threats to a river's health are:

- Pollution that degrades water quality (industrial, domestic, agricultural).
- Introduction of alien invasive species (fish, weeds, plants, snails, other animals).
- Degradation of catchment and floodplain habitats (deforestation, fire, agriculture, road and dyke construction).
- Dams, weirs, and other structures (inter-basin diversion, irrigation, hydropower).

Dams are the biggest threat to the ecology of a river. Dams create large scale and far-reaching quantitative and qualitative changes in aquatic habitats, through modifying flood depth, duration, and timing and reducing the amount of sediment and associated nutrients arriving in downstream areas. Dams also alter hydrological signals that fish and other aquatic animals depend on to trigger their life cycle activities, such as migrating and spawning. In permanently inundated areas newly created by dams, the total species richness will decrease as many of the plant species adapted to seasonally inundated conditions will die under anaerobic conditions. Riparian vegetation is replaced by algae and submerged communities.

The barrier effects of dams affect both the fauna and flora of the river. Dams obstruct the migration routes of fish and other aquatic animals, and may also interfere with plant dispersal (Jansson *et al*., 2000)[37].

River regulation may affect coastal environments by reducing sediment inputs, nutrient supplies and freshwater flow volumes. These may affect delta and coastal fluvial dynamics, coastal vegetation such as mangroves, inshore fisheries, and saline intrusions. A classic case is the loss of coastal wetlands around the Mississippi Delta and a reduction on protection from the effects of hurricanes such as Katrina[38].

Bunn and Arthington (undated)[39] provide the following four principles concerning the influence of flow regimes on aquatic biodiversity:

- **Principle 1:** Flow is a major determinant of physical habitat in streams, which, in turn, is a major determinant of biotic composition.
- **Principle 2:** Aquatic species have evolved life history strategies primarily in direct response to their natural flow regimes.
- **Principle 3:** Maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species.
- **Principle 4:** The invasion and success of exotic and introduced species in rivers is facilitated by the alteration of flow regimes.

3.1.2 Freshwater Biodiversity

Fresh water makes up only 0.01% of the world's water, yet this tiny fraction of global water supports at least 100,000 species out of approximately 1.8 million - almost 6% of all described species (Dudgeon *et al.*, 2005)[40].

Species richness in relation to area of habitat is extremely high in many freshwater groups with an estimated 10,000 fish, 5,000 amphibians and 6,000 mollusc species dependent on freshwater habitats. Other major groups with high dependence on freshwater include bacteria, fungi, plants, additional invertebrate taxa, reptiles, birds and mammals[41].

To meet the different requirements of different life history stages, most aquatic organisms require access to a variety of habitats in the course of their life cycle. This requirement has two implications: (1) a variety of habitats must exist; and (2) organisms must be able to migrate between them (actively or passively). Migration requires some degree of connectivity between aquatic habitats[42].

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[37] Jansson, R., C. Nilsson, B. Renofalt. 2000. Fragmentation of riparian floras in rivers with multiple dams. Ecology, April 2000.

[38] See, e.g., https://www.sciencemag.org/content/315/5819/1679.short

[39] Stuart E. Bunn and Angela H. Arthinton. Flow regimes and aquatic biodiversity. Environmental Management 30, 492-507

[40] Dudgeon, D., A.H. Arthington, M.O. Gessner, Z-I. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A-H. Prieur-Richard, D. Soto, M.L. J. Stiassny & C.A. Sullivan (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews, 81, pp 163-182. http://journals.cambridge.org/abstract_S1464793105006950

[41] A.H. Arthington K. Lorenzen B.J. Pusey R. Abell A.S. Halls K.O. Winemiller D.A. Arrington E. Baran. Session 3 review river fisheries: ecological basis for management and conservation. Online link: http://aquaticecology.tamu.edu/files/2012/07/Arthington-et-al-05.pdf

[42] Same as 8

The Mekong River, with its monsoon based annual flood pulse, supports a biological diversity second only to the Amazon in numbers of fish, mammals and birds. A number of the most sensitive and charismatic species, however, are critically endangered.

The following ten key points summarise the importance, threats, status and conservation challenges of freshwater biodiversity (**Box 3-2**; **emphasis** added for this manual).

Box 3-2: Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges

1) Fresh water makes up only 0.01% of the World's water and covers only 0.8% of the Earth's surface, yet this tiny fraction of global water supports at least 100,000 species out of approximately 1.75 million – almost 6%. Not surprisingly, considering their landscape position and value as a natural resource, **fresh waters are experiencing declines in biodiversity far greater than those in the most aff ected terrestrial ecosystems**. These declines seem to be especially serious in some tropical latitudes, and particularly aff ect large fishes and other vertebrates.

2) Freshwater biodiversity is the **over-riding conservation priority** during the International 'Water for Life' Decade for Action (2005 to 2015) and beyond. Assuming rends in human demands for water remain unaltered and species losses continue at current rates, the opportunity to conserve significant proportions of the remaining biodiversity in fresh water will vanish before the 'Water for Life' decade ends.

3) **Threats** to global freshwater biodiversity fall into five categories: **overexploitation**; **water pollution**; **flow modification**; **destruction or degradation of habitat**; and **invasion by exotic species**. Their combined and interacting influences on biodiversity are now worldwide—exacerbated further by global-scale environmental changes, such as nitrogen deposition and climate change. Knowledge of these threats is increasing among scientists but is insufficiently incorporated within water-resource development, and thus requires wider dissemination and emphasis.

4) **Inventories** of freshwater biodiversity are **incomplete** in many parts of the world, especially the tropics, and rates of species loss may be higher than currently estimated. An immediate, coordinated effort to assess global freshwater biodiversity, including major hotspots, should be launched in partnership with major non-government organizations, the United Nations, research institutions and scientific societies. This exercise should take place in parallel with the ongoing development of strategies for the conservation and management of freshwater biodiversity.

5) Fresh water is subject to **severe competition among multiple human stakeholders**, in many regions, and serious conflicts can arise when water supplies are limiting or traverse political boundaries. Conservation of biodiversity is complicated further by the landscape position of rivers and wetlands as 'receivers' of land use effluents, and the problems posed by endemism, limited geographic ranges and non-substitutability.

6) **Protection of freshwater biodiversity** is perhaps the **ultimate conservation challenge** because, to be fully effective, it requires control over the upstream drainage network, the surrounding land, the riparian zone, and – in the case of migrating aquatic fauna – downstream reaches. Such prerequisites are hardly ever met, and will necessitate development of inclusive management partnerships at appropriate (drainage-basin) scales. The complicated issues associated with protected-areas design and management or fresh waters require energetic and imaginative attention from researchers.

7) Water regimes influence aquatic biodiversity via several, inter-related mechanisms operating over a range of spatial and temporal scales. The **maintenance of natural variability in flows and water levels is therefore essential** to underpin conservation strategies for freshwater biodiversity and habitats. This requires establishing a hydrological regime that mimics natural variability in flows and water levels

rather than focusing on minimum levels only. For most freshwater systems and taxa, scientists can – at present – neither estimate the quantities of water that can be extracted nor the temporal changes in flow that can be tolerated. Research on this matter of environmental water allocations is needed urgently. Furthermore, it is essential that provision of flows needed to preserve biodiversity be treated with the same importance as engineering concerns and other goals when water-resource developments are planned.

8) Freshwater biodiversity provides a broad variety of valuable **goods and services for human societies**. Some are **irreplaceable**. Notwithstanding, there is a paucity of empirical data showing how the value of goods and services derived by retaining habitats in relatively natural conditions compares with that obtained when they are converted for human use. The uses of fresh water, including non-consumptive use, underscore the importance of considering the perspectives of a wide range of stakeholders in environ mental valuation and in the development of effective conservation policies.

9) **Maintenance of biodiversity is a critical test** of whether water use and ecosystem modifications are sustainable. Conservation strategies protecting all elements of freshwater biodiversity would guarantee that water use for humans is sustainable while, in contrast, the magnitude of the threat to and loss of biodiversity is an indicator of the extent to which current practices are unsustainable.

10) A **mixture of strategies will be essential** to preserve freshwater biodiversity in the long term. It must include reserves that protect key, biodiversity-rich water-bodies (especially those with important species radiations) and their catchments, as well as species- or habitat-centred plans that reconcile the protection of biodiversity and societal use of water resources in the context human-modified ecosystems. In parallel, scientists must more effectively communicate the importance and value of freshwater biodiversity to stakeholders and policy makers, so as to make certain that all available information on freshwater biodiversity is applied effectively to ensure its conservation.

Source: Dudgeon *et al.* (2005). http://journals.cambridge.org/abstract_S1464793105006950

In terms of biodiversity, the Mekong River is the second river in the world for its fish diversity, after the Amazon (Baran, 2010)[43]. It was ranked third in 2000 (Dudgeon, 2000) but its species list has been substantially updated since then. The Mekong region is thus a biodiversity hotspot, whose magnitude is only now being recognised: more than one thousand new species of plants and animals have been discovered in the basin within a decade, of which 279 are new species of fish (WWF, 2009). Lao PDR, Thailand and Vietnam are among the top 5% of countries for their number of freshwater fish species and number of threatened fish species.

In sub-basins, species richness is roughly proportional to the watershed surface area. In the LMB, the highest fish diversity is found in the Tonle Sap and in the Mun/Chi River Basins, followed by the Srepok, Sesan and Songkhram River Basins (Baran, 2010). The Tonle Sap has the highest fish biodiversity of any lake after the East African Great Lakes.

The following excerpt from the website of the Mekong Biodiversity Conservation Programme (2002-2006) provides an overview of the biodiversity of the Mekong River (**Box 3-3**).

Box 3-3: Mekong River Basin: Overview of Biodiversity

[43] Baran, E. 2010. Mekong fisheries and mainstream dams. Fisheries sections in: ICEM (2010). SEA of Hydropower on the Mekong Mainstream. Prepared by ICEM for MRC. 145 p

Biodiversity of the Mekong River Basin

The biodiversity of the Mekong River Basin is immense, and of truly exceptional significance to international biodiversity conservation—even in comparison with other parts of tropical Asia. The river and its numerous tributaries, backwaters, lakes, and swamps support many unique ecosystems and a wide array of globally threatened species, such as the Irrawaddy Dolphin, Siamese Crocodile, Giant Catfish, and birds such as the Giant Ibis and Sarus Crane. The diversity of the river fauna itself is surpassed only by that of the Amazon and the Congo, with over 1,300 species of fish inhabiting the main channels, tributaries, and associated wetlands.

This biodiversity is fundamental to the viability of natural resource-based rural livelihoods of a population of 55 million people living in the Lower Mekong Basin equivalent to more than 90% of the population of the entire Mekong Basin, and about one third of the total population of Cambodia, Lao, Thailand, and Vietnam combined. Rural livelihoods are founded on the integrated use of a wide range of natural resources, adapting to the seasonal changes of flooding and recession. The significance of this diversity of economic activity, and therefore the importance of wetland ecosystems, has often been overlooked in natural development strategies. Increasingly, evidence indicates that wetland resources are of particular importance to poorer groups, with significant implications for poverty reduction strategies, food security planning, and rural urban migration and employment. These will become even more significant if wetland resources are reduced.

Source: MWBP website http://www.mekongwetlands.org/Programme/mekong.htm

Note that the majority of fish species of the Mekong depend on seasonally-flooded areas for food and reproduction. According to Baran (2010), 87% of the known species are migratory and 50% of the fish catch comprises long-distant migrants.

TRAINING AIDS	
Discussion topics	1) Should hydraulic engineers have training in ecology? Should economists? Should politicians? 2) With so many people now living in cities, should the educational curriculum for children include fieldwork in natural environments?
Exercises	Working in a team, select a river basin that you are familiar with: • Identify the key linkages and processes that are essential for the river's ecological health. • Identify the key threats to the processes. • Develop (practically, economically, politically) feasible measures to maintain the key linkages and processes to maintain the ecological health of the river.
Additional reading and resources	1) Humphries, P., A.J. King, and J.D. Koehn, 1999. Fish, flows and floodplains: links between freshwater fishes and their environment in the Murray-Darling River system, Australia. *Environmental Biology of Fishes* 56: 129-151. 2) Resources on healthy rivers: http://www.healthywaterways.org/HealthyWaterways/Resources/Posters.aspx 3) Articles on river health in China: http://www.watercentre.org/projects/rhef/project-resources/river-health-articles 4) Development of a regional freshwater ecosystem health monitoring programme: Bunn, S.E., Abal, E.G., Smith, M.J., Choy, S.C., Fellows, C.S., Harch, B.D., Kennard, M.J. and Sheldon, F. (2010). Integration of science and monitoring of river ecosystem health to guide investments in catchment protection and rehabilitation. *Freshwater Biology* 55, 223-240. 5) Stuart E. Bunn and Angela H. Arthington. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* 30, 492-507. Available online at: http://www98.griffith.edu.au/dspace/bitstream/handle/10072/6758/Basic_Principles.pdf;jsessionid=1A2D2C90874FE3302304375915B09416?sequence=1 6) Brierley, G.J. & K.A. Fryirs (2005) *Geomorphology and River Management: Applications of the River Styles Framework*. Blackwell Publishing, Oxford, UK, 398pp. Available from http://www.blackwellpublishing.com/book.asp?ref=1405115165&site=1 7) Lazarus, K., P. Dubeau, C. Bambaradeniya, R. Friend, L. Sylavong, 2006. *An Uncertain Future: Biodiversity and Livelihoods along the Mekong River in Northern Lao PDR*. IUCN, Bangkok, Thailand and Gland, Switzerland. 49pp. Available online at:

	http://cmsdata.iucn.org/downloads/an_uncertain_future___lazarus_et_al.pdf 8) Lu, X. X. and R. Y. Siew, 2005. Water discharge and sediment flux changes in the lower Mekong River. *Hydrology and Earth System Sciences* 2; 1-39. 9) Meynell, P.J., (ed.), 2003. *Scoping Study for Biodiversity Assessment of the Mekong River in Northern Laos and Thailand*. IUCN Mekong Water and Nature Initiative and Mekong Wetlands Biodiversity and Sustainable Use Programme, Bangkok, Thailand. 10) Poulsen A. F. and others, 2000. *Fish migrations and spawning habits in the Mekong mainstream - A survey using local knowledge*. Assessment of Mekong Fisheries: Fish Migrations and Spawning and the Impact of Water Management Project (AMFC) Vientiane, Lao PDR, February 2000; 132 p. 11) Baran, E., 2004. *Cambodian inland fisheries: an overview*. Presentation at the Seventh Asian Fisheries Forum, 30 November-4 December 2004, Penang, Malaysia.

Case Studies

The following case study from Australia illustrates an inclusive approach to managing the health of a fast-developing region's waterways. Source: Bunn *et al.* 2007. *Making the connection between healthy waterways and healthy catchments: South East Queensland, Australia*. Water Science and Technology: Water Supply 7, 93–100.

Making the connection between healthy waterways and healthy catchments: South East Queensland, Australia

The waterways of South East Queensland, Australia, represent unique and complex ecosystems that have a high conservation value and support major recreational and commercial fisheries. The agricultural districts of the region also contribute significantly to the regional economy and, together with the growing urban areas, are heavily reliant on good quality water supplies. However, the human footprint of these activities has led to significant changes in catchment hydrology and sediment delivery, declining water quality and loss of aquatic biodiversity. Predicted population increases in the region are likely to further impact on the ecological and economic health of its waterways and catchments, and there are growing community expectations to reverse the decline in water quality and ecosystem health. In response to these concerns, government, industry and community stakeholders have worked in close cooperation to develop a whole-of-government, whole-of-community approach to understanding and managing the region's waterways.

Key factors contributing to its success

(i) The development and public presentation of 'Report cards' on the health of waterways in the region. These are based on the robust EHMP data and presented to senior policy makers each year in a public (televised) ceremony.

(ii) The continual refinement and testing of conceptual models. These are not only used to improve our scientific understanding and identify key knowledge gaps but also to communicate important processes to stakeholders.

(iii) A strong link between science and policy makers. The Partnership model has facilitated an open dialogue between the Scientific Expert Panel and key local and state government policy makers and managers.

(iv) Targeted management actions, including STP upgrades, riparian restoration, stormwater quality improvement devices.

(v) Monitoring of effectiveness of management actions. Developing targeted monitoring programs to assess effectiveness of management interventions.

Conclusions

There are several key lessons from the SEQ Healthy Waterways Program that are likely to be transferable to other regional catchment management programs aimed at improving water quality and aquatic ecosystem health. These include: the importance of a shared common vision, the involvement of committed individuals (scientists, politicians, managers, community), a cooperative approach, the need for defensible science, and effective communication. These factors have been important in the development and success of the Healthy Waterways Partnership in South East Queensland. Furthermore, without this approach, it would not have been possible to stimulate the growing recognition in the region of the important connections between healthy waterways and their catchments.

3.2 Wetlands

Key aspects	• There are many types of wetlands. These types include rivers and lakes, as well as marshes and seasonally flooded areas, and also coastal wetlands. • Wetlands have a very high biodiversity and ecological value in relation to their size. • Wetlands provide a very wide range of ecosystem services. • Wetlands have very high economic value in terms of their ecosystem services. • Wetlands are being damaged and destroyed rapidly. • Dams are one of the main threats to wetlands.

TRAINING AIDS	
Purpose of session	To provide trainees with a working knowledge of wetlands, their functioning, values, and threats, as part of a river basin ecosystems.
Learning objectives	By the end of this session, trainees will be able to: • Understand why intact wetlands are important. • Discuss policy and development activities that affect the survival of wetlands ecosystems.
Key readings	1) Ramsar. Wetland ecosystem services - an introduction. http://www.ramsar.org/pdf/info/services_00_e.pdf 2) Ecosystems and human wellbeing: wetlands and water. Millennium Ecosystem Assessment. http://www.unwater.org/downloads/MA_wetlandsandWater_English.pdf 3) Robert Mather (2009). Wetlands in the Mekong Basin. AsianWater Nov. 2009. http://cmsdata.iucn.org/downloads/aw_nov_specialfeature_wetlands_rm.pdf

3.2.1 Wetlands

3.2.1.1 Definition

What is a wetland, and what distinguishes wetlands from other types of environments? Many definitions exist. Surely wetlands should be wet; however, many dry out from time to time, and some may be dry for longer than they are wet. This makes it difficult to define wetlands in a simple way. The Mekong Wetland Biodiversity Program[44] put it as: *"wetlands are simply ecosystems where the presence of water (either temporarily or permanently) has a significant influence on its ecological character".*

Wetlands are present in all climatic regions and in all topographic conditions around the world, in the Arctic, on mountains, even in the middle of deserts. They are especially common in tropical and temperate lowlands, and are one of the most biologically productive ecosystems on earth.

A definition from the US Fish and Wildlife Service (1979) is:

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water….Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year".*

One of the best known definitions of wetlands is provided by the Ramsar Convention (The Convention on Wetlands of International Importance, especially as Waterfowl Habitat). Wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (article 1.1).

The Ramsar Classification System for Wetland Type includes 42 types of wetlands, which belong to one of three broad categories (Ramsar Convention Secretariat, 2011):

- Inland wetlands
- Marine/coastal wetlands
- Human-made wetlands

These categories are further subdivided by the type of water: fresh / saline / brackish / alkaline, and may be further classified by the substrate type or other characteristics.

Box 3-4: Wetland livelihoods characteristics in brief (adopted from Allen et all, 2008)

Diverse: Wetland livelihoods employ a wide range of resources and encompass a broad range of strategies at different times of the year. These include a range of farm and non-farm activities such as; cultivating crops, fishing, hunting, collecting non-timber forest products (NTFPs), as well as selling labour nationally and internationally. These diverse strategies are not simply driven by available assets. Rather, people do what they do as a result of a range of seasonal, environmental, cultural, political, financial and social conditions. Different households tend to follow different livelihood strategies depending on their cultural background, skills and assets.

Dynamic: Wetland livelihoods reflect the dynamism seen in nature with special connection to the seasonal patterns of flooding and recession.

[44] http://www.mekongwetlands.org/Common/download/MWBP-what-are-wetlands.pdf

Adaptive: Utilising local knowledge as the foundation of livelihood thinking and thus livelihood strategies, wetland livelihoods exhibit a remarkable degree of adaptability to annual and seasonal changes as well as considerable innovations in adapting these conditions to suit their needs.

Inclusive: All sections in society are involved in employing assets in various ways through a range of livelihood strategies. Gender and generational contributions to household and community well-being permeate the rich and diverse range of livelihood strategies employed by wetland residents.

3.2.1.2 Ecosystem Services provided by Wetlands

Wetlands maintain and support vital ecological functions and provide important habitats for plants, fish, water birds, endangered species, and other wildlife. Wetlands also provide an abundance of products, such as edible plants, honey, fish, fodder and fuelwood—so much so, that for local residents they are effectively “natural supermarkets”.

The many important ecosystem services provided by wetlands are summarised in

Box 3-5.

Box 3-5: Ecosystem Services Provided by Wetlands

A source of life for people and wildlife

Wetlands contribute in no small way to our quality of life - indeed, to our very survival.
Wetland ecosystems are often undervalued. Few people realise the range of products derived from freshwater habitats like wetlands: food such as fish, rice and cranberries; medicinal plants; peat for fuel and gardens; poles for building materials; and grasses and reeds for making mats and baskets and thatching houses.

These complex habitats act as giant sponges, soaking up rainfall and slowly releasing it over time. Wetlands are like highly efficient sewage treatment works, absorbing chemicals, filtering pollutants and sediments, breaking down suspended solids and neutralising harmful bacteria.
They are also the most biologically diverse ecosystems on Earth.

Flood control

The most significant social and economic benefit that wetlands provide is flood control. Peatlands and wet grasslands alongside river basins can act like sponges, absorbing rainfall and controlling its flow into streams and rivers. When peat becomes completely saturated and unable to absorb any more water, surface pools and peatland vegetation – including sedge meadows and some types of forest – help to slow and reduce runoff. Similarly, floodplains alongside the lower reaches of major rivers, such as the Nile, Yangtze and Danube allow heavy rainfall or spring snowmelt to spread out slowly. When the peat bogs are drained or the floodplains reduced, the risk of flash floods is increased.

Clean water

Wetlands act as the Earth's filters, cleaning up water in a number of ways. For example, nitrogen in water is transformed to harmless nitrogen gas, nutrients are taken up by wetland plants in the water. Wetlands remove pollutants such as phosphorous, heavy metals and toxins, which are trapped in the sediments of the wetlands. In addition, nitrogen and heavy metals are incorporated into peat during its formation.
New York City found that it could avoid spending USD$3-8 billion on new wastewater treatment plants by investing USD$1.5 billion in the purchase of land around the reservoirs upstate. This land purifies the water supply for free.

Food supply

Rice is the staple diet of nearly 3 billion people - half the world's population. It is grown in wetlands across Asia and west Africa, and in the United States. Almost as important is sago palm, which provides starch from which sago flour is made. Palms from the wetlands of Africa yield valuable oils for cooking and soap making.

Shoreline and storm protection

The devastating effects of natural phenomena such as hurricanes, cyclones and tsunamis cannot be denied. Worldwide, an estimated 200 million people who live in low-lying coastal regions are at potential risk from catastrophic flooding.

Coastal wetlands – such as reefs, mangroves and saltmarshes – act as frontline defences against potential devastation. The roots of wetland plants bind the shoreline together, resisting erosion by wind and waves and providing a physical barrier that slows down storm surges and tidal waves, thereby reducing their height and destructive power.

Cultural value

Throughout history humans have gathered around wetlands; these areas have played an important part in human development and hold religious, historical or archaeological value to many cultures around the world. For example, on the Coburg Peninsula (the world's first Ramsar site), traditional Aboriginal owners still conduct an active ceremonial life and undertake semi-traditional hunting and gathering in this coastal wetland.

Materials and Medicines

Wetlands yield fuelwood for cooking, thatch for roofing, fibres for textiles and paper making, and timber for building. Medicines are extracted from their bark, leaves, and fruits, and they also provide tannins and dyes, used extensively in the treatment of leather.

Recreation areas

Wetlands everywhere provide important leisure facilities - canoeing and fishing, shell collecting and bird watching, swimming and snorkelling, hunting and sailing.

Vital habitat

It has been estimated that freshwater wetlands hold more than 40% of all the world's species and 12% of all animal species. Individual wetlands can be extremely important in supporting high numbers of endemic species. For example, Lake Tanganyika in Central Africa supports 632 endemic animal species.

Wetlands provide a nursery habitat for many commercially important fish species that are harvested outside the wetland. The Varzea Flooded Forest in Brazil is a breeding ground for more than 200 species of fish.

A refuge for migrating birds

When winter sets in across the northern hemisphere, it triggers the most extraordinary mass movement of any living creature on Earth - the annual migration of countless birds over vast distances. The world's wetlands offer a welcome pitstop, offering protection and food before the birds continue on to their final destination.

Source: WWF website at http://wwf.panda.org/about_our_earth/about_freshwater/intro/value/

Key messages on wetlands from the recent TEEB report (an international initiative to draw attention to the benefits of biodiversity) are given in **Box 3-6**.

Box 3-6: Key Message on Wetlands from 2013 TEEB Report

1) The "nexus" between water, food and energy is one of the most fundamental relationships - and increasing challenges - for society.

2) Water security is a major and increasing concern in many parts of the world, including both the availability (including extreme events) and quality of water.

3) Global and local water cycle are both strongly dependent on wetlands.

4) Without wetlands, the water cycle, carbon cycle and nutrient cycle would be significantly altered, mostly detrimentally. Yet policies and decisions do not sufficiently take into account these interconnections and interdependencies.

5) Wetlands are solutions to water security – they provide multiple ecosystem services supporting water security as well as offering many other benefits and values to society and the economy.

6) Values of both coastal and inland wetland ecosystem services are typically higher than for other ecosystem types.

7) Wetlands provide natural infrastructure that can help meet a range of policy objectives. Beyond water availability and quality, they are invaluable in supporting climate change mitigation and adaptation, support health as well as livelihoods, local development and poverty eradication.

8) Maintaining and restoring wetlands in many cases also lead to cost savings when compared to man-made infrastructure solutions.

9) Despite their values and despite the potential policy synergies, wetlands have been, and continue to be, lost or degraded. This leads to biodiversity loss - as wetlands are some of the most bio-diverse areas in the world, providing essential habitats for many species - and a loss of ecosystem services.

10) Wetland loss can lead to significant losses of human wellbeing, and have negative economic impacts on communities, countries and business, for example through exacerbating water security problems.

11) Wetlands and water-related ecosystem services need to become an integral part of water management in order to make the transition to a resource efficient, sustainable economy.

12) Action at all levels and by all stakeholders is needed if the opportunities and benefits of working with water and wetlands are to be fully realised and the consequences of continuing wetland loss appreciated and acted upon.

Source: Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. and Davidson N. (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels; Ramsar Secretariat, Gland

3.2.1.3 Value of Wetlands

The Ramsar Convention on Wetlands[45] states that *"Wetland ecosystems are part of our natural wealth. At a worldwide scale they provide us with services worth trillions of US dollars every year – entirely free of charge – making a vital contribution to human health and well-being. With the global population set to increase to nine billion by 2050, increasing pressure on water resources and the threats posed by climate change, the need to maximise these benefits has never been greater or more urgent".*

The value of wetlands in monetary terms is estimated in

[45] http://www.ramsar.org/cda/en/ramsar-pubs-info-ecosystem-services/main/ramsar/1-30-103%5E24258_4000_0__

Box 3-7.

Box 3-7: Economic Value of Wetlands

- The Millennium Ecosystem Assessment gave wetlands a value of USD 15 trillion in 1997.
- A study of the role of coastal wetlands in reducing the severity of impacts from hurricanes in the United States found that they provided storm protection services with an estimated value of USD 23.2 billion per year.
- The annual economic value of the remaining Danube River floodplains, including their flood mitigation function, was assessed in 1995 at EUR 650 million.
- New York City found that it could avoid spending USD 3-8 billion on new wastewater treatment plants by investing USD 1.5 billion in the purchase of land around the reservoirs upstate. This land purifies the water supply for free.
- In the Caribbean, the shoreline protection services provided by coral reefs are valued at up to USD 2.2 billion annually.

Source: The value of wetlands. WWF website http://wwf.panda.org/about_our_earth/about_freshwater/intro/value/)

3.2.1.4 Wetlands in the Mekong River Basin

Wetlands in the Mekong River Basin also support a wide range of globally threatened species such as the Giant catfish, Siamese crocodile, Eastern Sarus crane, Giant ibis, and Irrawaddy dolphin.

According to Mather (2009), *"significant wetlands in the Lower Mekong Basin include lakes and marshes such as Nong Bong Khai in Northern Thailand and Goot Ting in North-eastern Thailand; seasonally inundated forests in tributaries of the middle Mekong such as the Songkhram River in Thailand and the Xe Bang Hieng River in Laos; stretches of the mainstream itself (such as from Siphandone in Laos to Kratie in Cambodia); the Tonle Sap Great Lake of Cambodia and the Mekong Delta of Cambodia and Vietnam".*

Mather (2009) also indicated that *"the Mekong supports the world's most productive inland fisheries – 3 million t of fish valued at US$ 3 billion are caught each year, providing up to 80% of the animal protein intake for 60 million people. Productivity is driven by the flood pulse hydrology (wet season flows are 30 times greater than dry season). Crucially, 70% of fish catch in Tonle Sap is of species that migrate long-distances between rainy season inundated floodplains and dry season refuge habitats. The integrity of key wetland habitats of the Mekong mainstream and tributaries including rocky rapids, deep pools (some up to 70 m deep), sand banks, braided channels, seasonally inundated forests and vast grassland floodplains - and the connectivity between them, are essential for the continued provision of food security for millions of people".*

Box 3-8 How much value do wetlands truly have? A case study from Cambodian Mekong Ramsar Site in Stung Treng Province
Targeted household surveys were conducted to provide quantitative information about wetland values (particularly the value of the fisheries resource) to local communities. The assessment confirmed that fisheries are more valuable to poorer households as an income

source.

Table A: Values of fish in *Riel* per household per year ($1=4,100 Riel)

Value	Average	Poor	Less poor
Fish consumed	500,000	600,000	500,000
Income from fish	1,200,000	2,000,000 *(77% total)*	600,000 *(56% total)*
Total	**1,700,000**	**2,600,000**	**1,100,000**

The average value of the fisheries resource is 1.7 million *Riel* (USD425) per household per year. For a poorer household, however, fisheries are worth about 2.6 million *Riel* (USD650) per year. Much of this value is derived from income earned from selling fish, which is used mainly to purchase rice, the food staple. The value of other wetland uses was then estimated using relative ratings.

Table b: Wetland values: Riel per household per year

Rating	Value	Wetland uses
●●●●●	1,700,000	Fishing, washing, cooking/drinking
●●●●	1,360,000	Transportation
●●●	1,020,000	Construction material, firewood
●●	680,000	Aquatic animals, waterbirds, reptiles, irrigation, traditional medicines
●	340,000	Floodplain rice, recreation, dolphins
Total	**12,900,000**	USD 3,225

Using this method, the average value of the wetland to a household in Veun Sean village was calculated as approximately USD 3,225 per year.

The study by Try and Marcus (2006) shows that 21 villages with 2375 families or households exist within the Ramsar Site. If we multiply this amount of USD 3,000 with 2375 families show that the total wetland incomes are US$7,125,000 per year. The total area of the Ramsar site is 14,600 ha if aggregate with US$ 7,125,000 this means that the total value per hectares is US$488.1/ha/year. This use is considered sustainable with appropriate conservation.

References:

1. Chong, Joanne (2005) Valuing the Role of Aquatic Resources in Livelihoods: Economic Aspect of Community Wetland Management in Stung Treng Ramsar Site, Cambodia. IUCN Water, Nature and Economics Technical Paper No. 2. IUCN-The World Conservation Union, Ecosystems and Livelihood Group Asia, Colombo.
2. Sunleang, Srey and Thuon Try (2006) Cambodia National Report: An Overview of Wetland Valuation in the Lower Mekong Basin. Mekong River Commissions, Vientiane.
3. Try, Thuon and Chambers Marcus (2006) Situation Analysis: Stung Treng Province, Cam-

bodia. Mekong Wetland Biodiversity Conservation and Sustainable Use Program, Vientiane, Lao PDR.

3.2.1.5 Threats and Causes of Loss of Wetlands

The latest report produced by TEEB[46] in January 2013 provides a summary of the causes of wetland loss around the world: "Notwithstanding the high value of the ecosystem services that wetlands provide to humankind, wetlands continue to be degraded or lost due to the effects of intensive agricultural production, irrigation, water extraction for domestic and industrial use, urbanisation, infrastructure and industrial development and pollution. In many cases, policies and decisions do not take into account these interconnections and interdependencies sufficiently".

Similarly Mather (2009)[47] wrote "Wetlands are among the most productive ecosystems, comparable with rainforests and coral reefs. Wetlands are being converted to agricultural land and are vulnerable to altered flood patterns and the impact of shrimp-and fish-based aquaculture. Such changes are drastically reshaping large areas of natural wetlands, resulting in the disappearance of indigenous species of plants and animals."

In the Mekong Basin, drivers of wetland loss are similar to the rest of the world. They include, for example, reclamation of wetlands for cultivation; overexploitation of wetlands for cultivation of wetland resources in the small wetlands that remain; deforestation; mining; and road construction.

However, according to Mather (2009), dams are the single largest threat to wetlands in the Mekong Basin: " … of all planned developments, **Mekong mainstream dams represent the single largest threat to the wetlands, fisheries and local livelihoods of the Lower Mekong**. Dams and reservoirs block natural fish migration routes; dams also alter the amount, timing, and speed of flow of rivers; the river's natural patterns of erosion and silt deposition; as well as water temperature and water quality - all of which can have massive impacts on aquatic life. Dams act as a barrier to fish migrating upstream, and fish mi-grating downstream generally have to pass through turbines, resulting in many of them being killed. Dams with large storage reservoirs affect river hydrology, including changes in the onset of floods, the size of area flooded and the duration of the floods. Reduced "flood pulse" transport of sediment into the floodplains reduces the nutrients available for aquatic plant growth - the primary productivity engine driving much of the fisheries productivity. At the same time, smaller floods of shorter duration reduce the available habitat for fish, and reduce the survival rates of eggs and juveniles. Changes in dry season flows, and changes in the timing of the start of the floods, can disrupt the spawning and migration cues that trigger the changes in fish behaviour needed for migration, reproduction and ultimately the survival of the species". (**emphasis** added).

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[46] Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. and Davidson N. (2013) The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels;

Ramsar Secretariat, Gland

[47] Robert Mather. Wetlands in the Mekong Basin. Asian Water November 2009

3.2.2 Wetland Flora and Fauna

3.2.2.1 Flora

Four main groups of water plants ("hydrophytes") are found in wetlands:

- **Submergent plants** such as sea grasses and eelgrass are found completely under water in both saline and freshwater conditions. Submerged plants provide important food for fish and animals and habitat for invertebrates.
- **Floating plants** such as water lily, lotus, water hyacinth have small roots and are usually found in slow moving water with high nutrient levels. Floating aquatic plants may provide a food source for birds.
- **Emergent plants** such cattails, wild rice, eleocharus grass are rooted in the bottom soils but have their parts above the water surface. Many have aerenchyma (internal air channels) to transmit oxygen from the atmosphere to their roots.
- **Tree and shrubs**, such as the melaleuca tree found in freshwater wetlands and mangroves along the coastline. Mangroves are highly adapted to the saline, tidal conditions of coastal wetlands and are critical in the life cycles of many coastal and inshore species.

In addition, wetland flora also includes **algae** varying in size, colour, and shape. They occur in lakes, inter-tidal zones, and moist soils, and are food for animals - both fish, and invertebrates. As primary producers, plankton - microscopic algae - are the basis of the food web. Filamentous algae are long strands of algae cells that form floating mats. Chara and Nitella algae are upright algae that look like submerged plants with roots.

Wetland plants have special adaptations, such as above-ground roots able to absorb oxygen, or specialised cells that can limit the amount of salt entering the plant.

3.2.2.2 Fauna

The main groups of animals living in wetlands are:

- **Insects and other invertebrates** total more than half of the 100,000 known animal species in wetlands. Insects and other invertebrates (e.g. molluscs - snails, clams, crustaceans) can be submerged in the water or soil, on the surface, and in the atmosphere.
- **Fish:** more than 40% of all fish species are found in freshwater environments. This high diversity is due to conditions that encourage speciation (isolated river systems and lakes).
- **Amphibians:** frogs need both terrestrial and aquatic habitats to reproduce and feed. Tadpoles feed on algae while adult frogs feed on insects. Frogs are an indicator of ecosystem health as their skin absorbs both nutrient and toxins from the surrounding environment resulting in an above average rate of extinction in unfavourable and polluted environment.
- **Reptiles**, such as crocodiles, snakes, lizards and turtles.

- **Mammals:** many mammal species depend on wetland habitats. Some are herbivores such as Africa's specialised ungulate, the puku (*Kobus vardonii*), whilst others are carnivores such as otters.
- **Birds:** one of the best known functions of wetlands is to provide habitat for birds. Birds use wetlands for feeding, breeding, nesting, as a source of drinking water, and for social interactions. Water depth, quality, duration and timing of flooding, availability of food and shelter, the absence or presence of predators, and types of vegetation are factors that influence the value of a wetland as habitat for different bird species. Many migratory birds depend on wetlands during migration.

TRAINING AIDS	
Discussion topics	***1)*** Why are wetlands at such risk? Given their importance, why do they not have higher protected status? ***2)*** Is better economic valuation of wetlands the answer? Can all wetland services be valued?
Exercises	Divide into small groups. Invent a freshwater or coastal wetland, and sketch this on a flipchart. Now carry out a stakeholder analysis. Who is interested in the wetlands? What are their concerns, and how much power do they have to influence decisions?
Additional reading and resources	***1)*** Mitsch, W.J. Wetlands. W.J. Mitsch & J.G. Gosselnk - 4th ed. ***2)*** Millennium Ecosystem Assessment: http://www.unep.org/maweb/en/index.aspx ***3)*** Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. & Davidson N. (2013). The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels; Ramsar Secretariat, Gland. Available at http://www.teebweb.org/wetlands/ ***4)*** De Groot *et al.*, 2006. Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services. Ramsar Technical Report No. 3. www.ramsar.org/pdf/lib/lib_rtr03.pdf

Case Studies

The following story by Aly Heare (2012) tells of wetland conservation effort at Tram Chim National Park in the Mekong Delta in Vietnam. Available online at:

http://umvietnamstudy.wordpress.com/2012/01/23/the-balancing-act/

The Balancing Act

January 17, 2012

By Aly Heare

Good Morning Vietnam, and an early morning it is in Tram Chim National Park. But our tired eyes are instantly rewarded as we set off in our motorboat guiding us down the watery road system of the national park's 'backcountry.' As the boat slips through the warm water birds explode upward with sudden swoops of their wings. We see kite hawks, egrets, cranes, king fishers, and hummingbirds with everything in-between, everything except the mascot of Tram Chim: the Sarus crane. The birds glide up and away from our obnoxious motor to the safety and solitude this park provides for all these magnificently winged creatures, and humankind alike.

Tram Chim transformed from a national reserve into a national park on December 29,1998. On that fateful day the park made a promise to both the government and the land to protect and preserve its wildlife while also honouring the history and culture of the Mekong Delta. The first half of the promise presented challenges aplenty, but the second half of the promise added an even greater complexity; the balancing act between conservation efforts and livelihood.

Tram Chim is now the proud home to 231 species of birds, 32 of which are listed in the Red Book (IUCN's threatened species list). Every bird I see is a work of art but the real royalty of the park's bird population is the Sarus crane. This magnificent species of crane is 1.8 meters tall, meaning it is slightly taller than my 5'9'' stature. They are romanticized by their mating habit of having only one partner for a lifetime, a husband or wife if you will. If their partner were to pass away the Sarus crane would never remarry and some are even said to have died of a broken heart. Call it corny, but I for one love it. The Tram Chim is the cranes' feeding ground from January to June, so we would have been extraordinarily lucky to have glimpsed one in the first place. Tram Chim is on the right path for fulfilling the first half of their promise, but what of the second part?

No national park is without the dilemma of people vs. nature. The case of Tram Chim is no exception in the debate over which should have a greater precedence when managing the needs of a park. But Tram Chim has taken a new perspective and developed a system that implements the people into the internal workings of the park. For example, the local people are allowed to fish in the park, but to a limit. They are also encouraged to come into the park during a designated season to harvest last season's dead grass. This practice then makes room for next season's new growth, decreases fire danger, and the people gain a valuable asset in their mushroom cultivation practices. In this way the people of the surrounding community have gained a stake in the park and are more willing to help not hinders it betterment. Furthermore, a quick response team made up of the locals has been trained in fire management practices, due to the very serious threat of wild fire in the dry season. Tram Chim National Park, in my view, is an expert tight ropewalker in the balancing act between conservation and the peoples' livelihoods.

So far in Tram Chim's short life as a national park, this two-part promise has been kept. I can see each half with my naked eye as I glide along the water lily and lotus flower filled waterways. I see the people in gilt of the little boy with the water buffalo on a leash washing itself in the water, and I see conservation in the swoop and glide of the enormous wingspan of a heron. But most of all, I see hope for the protected places of Vietnam and the escape they provide for the wild kingdom, human and animal alike.

3.3 Wetland Birds

Key aspects	Birds are a highly diverse life form inhabiting ecosystems around the world. Birds have many ecological functions. Many bird species are wetland-dependent. Many bird species are migratory and protected under international law.

TRAINING AIDS	
Purpose of session	The purpose of this session is to provide the trainee with general knowledge about the ecological importance of birds, with a focus on water birds, their dependency on riverine and wetland environments.
Learning objectives	By the end of the session, the trainees will be able to: Understand the need to conserve habitats for birds Identify threats to the survival of bird populations Discuss implications of policy, development activities and practices that affect bird populations.
Key readings	Robert E. Stewart, Jr. National Biological Service. *Wetlands as bird habitat.* National Water Summary on Wetland Resources. United States Geological Survey, Water Supply Paper 2425. http://water.usgs.gov/nwsum/WSP2425/birdhabitat.html *Bird migration*. Wikipedia. http://en.wikipedia.org/wiki/Bird_migration

3.3.1 Bird Diversity and Ecological Functions

3.3.1.1 Ecological Role of Birds

Birds are one of the most diversified types of living creature on earth. With around 10,000 species, birds inhabit ecosystems around the globe.

Ecosystems - and people - benefit a great deal from the services that birds provide. Examples of their important ecological roles are:

- **Dispersers:** seed dispersal is one of the most important aspects of birds' roles in ecosystems. Birds also pollinate flowers by transporting pollen on their beaks and feathers from one flower to another. Occasionally, birds help the spread of other organisms; for example, fish eggs.

- **Biological controllers:** many birds are insectivores, and therefore help keep insect populations in check. Swallows, swifts, and night hawks, for example, consume hundreds of insects, many of which are pests. Without birds, agricultural crops might be devastated by exploding pest populations. Some birds play a "keystone" role; for example, woodpeckers, which create cavities in trees used by many other species; their disappearance would directly affect ecosystem functioning.
- **Birds and humans:** birds and their eggs have probably been important food sources for humans throughout our evolution as a species. Bird products, such as feathers, have been used for adornment and for making mattresses, hats, etc. Pet birds are traded throughout the world. The beauty of birds and their songs inspire artists to create poetry, music and paintings. Bird watching is a fast growing recreational industry. Birds have inspired the invention of aeroplanes. And birds are spiritually important in many cultures: for example, the Sarus Crane is worshipped in Vietnam and other Asian countries as it is believed that the crane carries the souls of good people to heaven upon death.
- **Birds as environmental indicators:** as highly visible apex species, birds are very good indicators of environmental quality. Roger Tory Peterson[48], a well-known bird conservationist, has said "*Birds are indicators of the environment. If they are in trouble, we know we'll soon be in trouble*". The Vietnamese have a traditional saying "*only on prosperous lands do birds land*".

Birds are very responsive to environmental changes. Changes in bird populations can provide useful indication of broader environmental change as they relate to a set of ecological factors. A healthy and diverse ecosystem supports a high number and a diversity of species. If the number of species drops to lower than expected, this indicates that something is wrong with the ecosystem. For example, birds are at the top of the food chain and thus very vulnerable to chemicals in the environment, through the process of **biomagnification** (an increase in concentration of a pollutant from one link in a food chain to another). The UK government uses the status of birds as one of 14 baseline sustainability indicators. This is known as The Population of Wild Birds Quality of Life Indicator. Changes in bird populations are also an indicator of climate change: there are many examples of birds around the world changing their ranges due to global warming, as well as examples of bird migration becoming out of synch with the timing of food supplies (insect emergence).

Reductions in bird populations, and their extinction, may disrupt ecosystem processes and services if they cannot be replaced. Risks include the extinction of plant species that depend exclusively on certain bird species for dispersal and/or pollination, and increased pest damage to crops.

Dam projects can have many impacts on bird populations. An often neglected impact is bird collisions with transmission lines: these may intersect bird flight paths to a wetland resource, such as a river or reservoir, or may affect an international flyway (for example, if strung across a deep Himalayan valley).

[48] Roger Tory Peterson (August 28, 1908 - July 28, 1996) was an American naturalist, ornithologist, artist, and educator, and is held to be one of the founding inspirations for the 20th century environmental movement.

3.3.1.2 Waterbirds

Birds using river and wetland ecosystems for all or most of their lifecycles are waterbirds. Waterbirds have many special adaptations to the water environment, ranging from webbed feet to bills and legs adapted to feed in water to special diving and swimming abilities.

Some of the main groups of waterbirds are:

- Seabirds (marine birds)
- Shorebirds (waders)
- *Anseriformes* (ducks, geese, swans, magpie geese, screamers)
- Grebes (order *Podicipediformes*)
- Loons (order *Gaviiformes*)
- *Ciconiiformes* (storks, herons, egrets, ibises, spoonbills and others)
- *Pelecaniformes* (pelicans and others)
- Flamingos (order *Phoenicopteriformes*)
- Some members of the order *Gruiformes* (including cranes and rails, crakes, coots and moorhens)
- Kingfishers
- Gulls

Waterbirds depend on wetlands for feeding, breeding, nesting, and social interaction. A wetland with a more diverse plant community usually has higher bird species richness. Wetlands, as one of the most biologically productive ecosystems on earth, are also important as feeding and roosting grounds for a range of resident and migratory water birds.

Different bird species exploit different niches within a wetland. For example, cormorants and ducks prefer open water while herons and egrets prefer foraging in grassland areas.

3.3.2 Bird Migration

3.3.2.1 Overview

Many bird populations migrate seasonally. Of the 10,000 known bird species in the world, some 1,855 species are long distant migrants[49]. The most common pattern (in the northern hemisphere) is to fly north in the spring to breed in the temperate or Arctic summer, and to return south in the autumn to warmer wintering grounds. Migration has an ancient evolutionary history, and the main drivers appear to be the availability of food and habitat, and as response to the weather.

Each migratory species tends to have its own route between nesting and winter ranges. Waterbirds are constrained by their need for an unbroken chain of wetlands as stopover habi-

[49] BirdLife International: http://www.birdlife.org/flyways/index.html

tats. There are three major waterbird flyways around the globe, each of which has several internal flyways:

- African-Eurasian Flyway
- Americas Flyway
- East Asian-Australasian Flyway

The East Asian-Australian Flyway, extending from the Arctic Circle through East and South-East Asia to Australia and New Zealand, encompasses 22 countries.

Different groups of birds tend to fly at different altitudes during migration. Long distance migratory birds tend to fly high to take advantage of thermals to save their energy in flight. During migration, birds can fall victim to predators (animal and human), and to degraded habitats. Staging and wintering areas may be altered by humans (e.g. forest loss due to conversion to agriculture or commercial plantations, or wetlands dyked or converted to agriculture or used heavily by tourists). The loss of key stopover areas and associated food supplies can be highly damaging to bird populations. Wetland habitat loss and degradation is a significant threat to migratory waterbirds, and the conservation of important sites across the flyways is essential to their survival. As of 2008, some 11% of all long distance migratory bird species were threatened or near-threatened[50].

3.3.2.2 International Cooperation

Migratory waterbirds can only be effectively conserved through international cooperation across entire flyways. Key international agreements are:

- The Convention on Biological Diversity (CBD).
- The Ramsar Convention.
- The Convention on Migratory Species (the CMS or Bonn Convention).

A number of bilateral agreements also exist, such as those between Australia and Japan, China, Korea, and the East Asian-Australian Flyway Partnership. Each of these agreements provides for the protection of migratory birds from take or trade except under limited circumstances; as well as the the protection and conservation of habitats, exchange of information, and building cooperative relationships.

The CMS is the only global convention specifically for the Conservation of Migratory Species, their habitats, and routes. Currently the CMS has about 100 Contracting Parties (nation states). These cooperate to conserve migratory species and their habitats by providing strict protection for the endangered migratory species listed on Appendix I to the Convention, by concluding multilateral agreements for the conservation and management of other migratory species (listed in Appendix II), and by undertaking cooperative research activities.

Bird conservation has a high profile around the world. One of the main bird conservation NGOs is BirdLife International, which has developed an Important Bird Areas (IBA) programme with the goal of identifying, monitoring, and protecting a global network of protected areas for the conser-

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[50] Same as previous.

vation of the world's birds and other biodiversity. An IBA is an area recognised as being globally important habitat for the conservation of bird populations. Currently there are about 10,000 IBA in some 200 countries around the world. Often IBAs form part of a country's existing protected area network and so are protected under national legislation, and some countries have a National IBA Conservation Strategy.

To be listed as an IBA, a site must satisfy a strict criteria such as (i) hold significant numbers of one or more globally threatened species; (ii) is one of a set of sites that together hold a suite of restricted-range species or biome-restricted species, and (iii) hosts a specific number or proportion of that species regional or global population. The identification of IBAs has been an effective way of identifying conservation priorities.

TRAINING AIDS	
Discussion topics	Is your country party to the Ramsar Convention or CMS? If not, why not? Have birds been a factor in decision-making in a project you are familiar with? Is there any evidence of bird collisions with transmission lines in your country? Are birds used as an indicator in your country's environmental or sustainability measurements?
Exercises	Select a wetland or a river basin you are familiar with: list high profile bird species using the area; identify threats to their survival; develop recommendations for their conservation.
Additional reading and resources	BirdLife International. 2008. Critically endangered birds: a global audit. Cambridge, UK. http://www.birdlife.org/news/news/2008/09/Complete_Critical%20Birds_superlowres.pdf BirdLife International. 2003. Saving Asia's Threatened Birds: A Guide for Governments and Civil Society. Cambridge, UK. BirdLife International: web pages on Important Bird Areas: http://www.birdlife.org/action/science/sites/index.html

Case Studies

The following case study from BirdLife International tells a success story of the designation of a new National Park as a result of its recognition as an IBA. Available online at:

http://www.birdlife.org/datazone/sowb/casestudy/248

The identification of Lo Go Xa Mat as an IBA in Vietnam resulted in the site being declared a national park

Following representations by provincial leaders, Lo Go Xa Mat, an area of lowland forest and wetland in southern Vietnam, was designated a National Park in 2002. Surveys had revealed the site qualified as an Important Bird Area, while subsequent meetings with stakeholders generated considerable local interest in its value for biodiversity, resulting in the request for its formal protection.

Lo Go Xa Mat is an area of lowland forest and wetland in Tây Ninh province of southern Vietnam, located in the Southern Vietnamese Lowlands Endemic Bird Area. The site was declared a protected area by the government of Vietnam in 1986, but this was to commemorate its historical importance as a revolutionary base during the Second Indochina (Vietnam-America) War. In January 2001, following reports that the site had been designated for village resettlement, the BirdLife International Vietnam Programme undertook a reconnaissance trip. Lo Go Xa Mat was found to support a mosaic of lowland habitat types almost lost elsewhere in Vietnam; unfortunately, these were under severe, immediate threat from conversion to agricultural land. Indeed, drainage canals and roads were already under construction.

In response to these threats, BirdLife and the International Crane Foundation convened a meeting with provincial leaders to explain the importance of the site for conservation, and to raise awareness of the threats posed by the resettlement project. The response from the provincial leaders was positive: they agreed to halt the project temporarily, pending a more detailed biodiversity assessment.

Consequently, in October 2001, BirdLife led a joint survey of Lo Go Xa Mat. The site was found to qualify as an Important Bird Area (IBA), due to the presence of a number of globally threatened birds and restricted-range species, including Germain's Peacock-pheasant *Polyplectron germaini* (Vulnerable). The designation of the site as an IBA was announced at a provincial workshop, generating much interest among local leaders, who were formerly unaware of the site's biodiversity value. Immediately following the workshop, the provincial leaders made an official request that the site be designated a National Park. Based on this, Lo Go Xa Mat was declared a National Park by the prime minister in July 2002. Subsequently, central government approved US$ 2 million of funding for the site over a five-year period.

3.4 Tools for Conservation

Key Aspects	• Conservation planning is increasingly implemented through an ecosystem-based approach (EBM). • The principles of EBM are recognised by the Convention on Biological Diversity (CBD) as the framework for actions to implement biodiversity conservation under the convention. • Many planning tools are available available to bring objectivity to conservation planning decisions. • Many of these tools assist in integrating between sectors.

TRAINING AIDS	
Purpose of session	To introduce trainees to the wide range of tools available for planning conservation.
Learning objectives	• To be familiar with the principles of the ecosystem approach to conservation. • To understand that a wide range of tools exists for different aspects of conservation planning.
Key readings	***1)*** Sarkar, S. *et al.* 2006. Biodiversity Conservation Planning Tools: Present Status and Challenges for the Future. *Annual Review of Environment and Resources* Vol. 31: 123-159 2) Allen, David, William Darwall, Mark Dubois, Kong Kim Sreng, Alvin Lopez, Anna McIvor, Oliver Springate-Baginski, and Thu-on Try (2008) Integrating people in conservation planning:An integrated assessment of the biodiversity, livelihood and economic implications of the proposed special management zones in the Stung Treng Ramsar Site, Cambodia

3.4.1 Ecosystem Approach

Until recently the conservation of biodiversity and ecosystem services has depended on the designation of specific locations as "**protected areas**", where exploitation is limited or banned and nature has priority. This approach has had many successes. However, the selection of areas to be protected has tended to be based on political and populist decision-making rather than on conservation science. As a result, key habitat for many species is not protected or is not adequate. It is now widely recognised that there is a need for conservation in the broader landscape or seascape outside protected areas through **ecosystem based management** (EBM:

Box 3-9).

Box 3-9: Ecosystem-based Management

"Ecosystem-based management is an integrated approach to management that considers entire ecosystems, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors."

Karen McLeod *et al*. (2005) http://compassonline.org/?q=EBM

Wikipedia's clear description of the ecosystem approach (http://en.wikipedia.org/wiki/Ecosystem-based_management) includes this statement on its implementation: "… ecosystem-based management is applied to large, diverse areas encompassing an array of interactions between species, ecosystem components, and humans, it is often perceived as a complex process that is difficult to implement. In addition uncertainty is common, and predictions are difficult. However in the light of significant ecosystem degradation, there is a need for a holistic approach that combines environmental knowledge and co-ordination with governing agencies to initiate, sustain and enforce habitat and species protection, and includes public education and involvement. As a result, ecosystem-based management is likely to be increasingly used in the future as a form of environmental management."

In 1995 the ecosystem approach - with its intellectual roots going back to the 1930s - was approved by the state parties to the Convention on Biological Diversity (CBD) as a the primary framework for action under the convention, operating on the basis of 12 principles.

Box 3-10: Principles of the Ecosystem Approach

Principles

The following 12 principles are complementary and interlinked.

Principle 1: The objectives of land management, water and living resources are a matter of societal choices.

Different sectors of society view ecosystems in terms of their own economic, cultural and societal needs. Indigenous peoples and other communities living on the land are important stakeholders, and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2: Management should be decentralized to the lowest appropriate level.

Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their

activities on adjacent and other ecosystems.

Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

- ***A)*** Reduce market distortions that adversely affect biological diversity;
- ***b)*** Align incentives to promote biodiversity conservation and sustainable use;
- ***c)*** Internalize costs and benefits in the given ecosystem to the extent feasible.

The greatest threat to biological diversity lies in changing systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems.

Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Ecosystem functioning and resilience depends on a dynamic relationship within species, among species, and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: Ecosystems must be managed within the limits of their functioning.

In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable of artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

Principle 8: Recognizing varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9: Management must recognize that change is inevitable.

Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential "surprises" in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impacts of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, taking into account, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

Source: Convention on Biological Diversity: http://www.cbd.int/ecosystem/principles.shtml

National Biodiversity Strategies and Action Plans (NBSAPs) are the principal instruments for implementing the CBD at the national level (Article 6). The Convention requires countries to prepare a national biodiversity strategy (or equivalent instrument) and to ensure that this strategy is mainstreamed into the planning and activities of all those sectors whose activities can have an impact (positive and negative) on biodiversity. To date [2012-02-01], 173 Parties have developed NBSAPs in line with Article 6.

EBM goals: defining clear and concise goals for ecosystem-based management is one of the most important steps in effective ecosystem-based management implementation. Overall the goals should be integrative, to include the structure, organization and processes of the management of an area. Correct ecosystem-based management should be based on goals that are both "substantive", to explain the aims and importance of protecting an area, and "procedural", to explain how substantive goals will be met (Slocombe, 1998)[51].

3.4.2 Conservation Planning Tools

Achieving more effective conservation requires the use of science-based approaches, such as **systematic conservation planning** (SCP: **Box 3-11**).

Box 3-11: Systematic Conservation Planning

- Structured step-wise approach
- Developing goals, objectives, targets
- Identifying existing gaps
- Identifying (possible) conservation sites
- Mapping (possible) conservation networks
- Incorporating feedback, revision, reiteration.

Source: Ardron, 2010: http://pacmara.org/tikiwiki/tiki-index.php?page=Conservation+Planning+Resources+and+Tools

Biodiversity conservation tools implement algorithms designed to identify conservation area networks for the representation and persistence of biodiversity features. Budgetary, ethical, and other socio-political constraints dictate that prioritised sites represent biodiversity with minimum impact on human interests (Sarkar *et al.* 2006)[52]. Systematic conservation planning is just one of many conservation tools. More than 200 conservation tools are listed on the website of the Ecosystem-Based Management Tools Network (EBM: www.ebmtools.org) in eleven topic groups (**Figure 3-2** and **Table 3-2**).

Figure 3-2: EBM Tools Network

Source: Ardron (2010)

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[51] Slocombe, D.S. 1998. Defining goals and criteria for ecosystem-based management. *Environmental Management*. 22:483-493.

[52] Biodiversity Conservation Planning Tools: Present Status and Challenges for the Future. Annual Review of Environment and Resources. Vol. 31: 123-159

Table 3-2: Types of Conservation Tools

1. Decision Support Tools
2. Conservation and Restoration Site Selection Tools
3. Land Use Planning, Urban Planning, and Smart Growth
4. Watershed and Marine Ecosystem Models
5. Dispersal and Habitat Models
6. Hazard Assessment and Resiliency Planning Tools
7. Socioeconomic Tools
8. Stakeholder Engagement, Communication, & Visualization
9. Fisheries Management Tools
10. Model Development Tools
11. Date and Project Management Tools

Source: Ardron, J. 2010. *Key Planning Approaches - How They Fit Together; Planning Tools; Marxan/Marxan Zones*. Presentation at: "Decision Support Tools for Conservation Planning in Settled Landscapes" Workshop, Toronto, 15 December 2010.

Why use conservation tools? As presented by Ardron (2010), conservation tools:

- Save time
- Guide the user through the processes
- Stop reinvention of the wheel
- Reduce the need for **some** human expertise
- Explore a wider range of alternatives
- Document decisions
- Help integrate planning across sectors

and **what tools don't do…**

- Provide answers (decision support not decision makers)
- Replace the need for intensive human interaction and collaboration
- Overcome people problems of politics, turf, mistrust, and technophobia
- Come with all the data they need
- Replace the need for project-specific analyses

TRAINING AIDS	
Discussion topics	Have you been involved in any practical conservation action as a result of your country's NBSAP? Do you think it is making a difference? Have you used a software conservation planning tool? Did it make a difference to the final conservation decision or action?
Exercises	Take a large, biodiversity-rich river basin; what decision-support tools would be needed to (i) carry out a conservation gap analysis, and (ii) to create an integrated, prioritised programme for conservation decisions?
Additional reading and resources	Smith, R.D. & E. Maltby. 2003. *Using the Ecosystem Approach to implement the CBD. A global synthesis report drawing lessons from three regional pathfinder workshops.* http://www.cbd.int/doc/case-studies/esys/cs-esys-cbd-en.pdf Ardron, J. 2010. *Key Planning Approaches - How They Fit Together; Planning Tools; Marxan/Marxan Zones*. Presentation at: "Decision Support Tools for Conservation Planning in Settled Landscapes" Workshop, Toronto, 15 December 2010. Plaganyi, E.F. 2007. *Models for an ecosystem approach to fisheries*. FAO Fisheries Technical Paper No. 477. Ecosystem-based fisheries management tools: http://ebmtoolsdatabase.org/resource/ecosystem-based-fisheries-management-tools

Case Studies

Case Study 1

Biodiversity Conservation in Lower Mekong River Basin (LMB)

The Mekong River is ranked as the twelfth longest river in the world. Its basin occupies a drainage area of about 795,000 km^2. The river originates from the Tibetan Plateau and flows downward to the South China Sea; its length is approximately 4,800 kilometers. The Mekong flows through six countries: China, Myanmar, Thailand, Lao P DR, Cambodia and Vietnam. It ranks eighth in the world for annual discharge at approximately 475,000 million cubic meters.

With its unique character, from mountainous area to floodplain, the biodiversity of the Mekong River Basin is enormous—very noteworthy for international conservation. The river and its numerous tributaries, wetlands, lakes and swamps crucially support a variety of distinctive ecosystems and worldwide-threatened species, such as the Irrawaddy Dolphin, Siamese Crocodile, Giant Catfish and birds, such as the Giant Ibis and Sarus Crane. Regarding river fauna diversity, it is reported that over 1,300 species of fish inhabiting in the main channels, tributaries, and connected wetlands.

- o Natural resources and biodiversity is an important base for ecosystem as well as ecosystem services to human wellbeing. However, due to a rapid population growth and massive economic development, natural resources and biodiversity have been critically exploited. Without a wise use of such nature capital, such important base has been to remarkably degrade. Sustainable Use Programme by a J oint UNDP- IUCN-MRC-GEF Funded P rogramme has been developed to address the critical state of the Mekong River Basin.

The purpose of the programme is to strengthen capacity at regional, national and local levels for wetland biodiversity conservation and sustainable use in the Lower Mekong Basin.

Regional level:

- Mekong inter-governmental institutions, such as the MRC, incorporating conservation and sustainable use of wetlands in their day-to-day operations.
- Regional, non-government stakeholders contributing actively in an on-going Regional Wetland Coordination Forum.
- Multilateral organisations operating in the Lower Mekong region, such as Asian Development Bank and World Bank, using the wetland conservation and sustainable use principles, policies, and management tools developed by the programme for use in the Mekong basin.
- Other countries in the Greater Mekong Sub-region considering wetland issues in upstream developments.

National level:

- Wetland institutions in each country, such as National Mekong Committees, National Ramsar Committees, and National Wetland Committees functioning effectively to promote the conservation and sustainable use of wetlands.
- Ministries and departments that have principal responsibility for wetlands and wetland resources incorporating conservation and sustainable use of wetlands in day-to day operations.
- Other line agencies and departments involved with infrastructure developments taking wetlands into account in their policies and planning.
- Civil society organisations in each country contributing actively to wetland policy and planning issues through ongoing national networks

Local level:

- Provincial level planning mechanisms taking wetlands into account used by provinces both inside and outside of the demonstration sites.
- Local community based institutions using wetland resource management skills and tools developed by the programme, both inside and outside the demonstration sites.

Case Study 2

SEA and EIA at Dong Nai River

To date SEA and EIA direct attention to high risk basins proposed for intensive hydropower development, such as those located on the Annamese slope. SEA and EIA also focus on projects proposed in, or near, areas of high intrinsic biodiversity value, such as high altitude rivers, karst systems, and peat swamps. These areas and projects are likely to require the most intensive and detailed planning and the most thorough safeguards and mitigation measures. As an 'early warning' tool, this approach facilitates an 'anticipate and prevent' strategy, in which a full range of alternatives and adjustments can be considered to avoid damage and manage downside risks. Already, the failure to respond to the findings of past SEAs is leading to serious potential or actual biodiversity losses. These losses can be seen in the cascade development on the Dong Nai River in Cat Tien National Park. Many similar examples of hydropower development going beyond the ecological capacity of rivers exist in Vietnam.

The two planned hydropower projects, Dong Nai 6 and 6A (Dong Nai Rive,) raised the issue on environmental impacts as their proposed locations were a great threat to Cat Tien National Park and its Ramsar site, Bau Sau. The total area lost to these two plants was estimated to be only about 137.5 ha; however, ecosystem losses would be far greater.

The project proponent conducted an EIA and submitted it for approval. An Appraisal Committee was established for reviewing and approving this report. However, numerous concerns on environmental impacts were raised, besides those addressed in the report. These were mainly focused on impacts identification and mitigation measures. It was expected that the EIA should be improved before its next submission. The Ministry of Natural Resources and Environment (MONRE) emphasized the harmony of development goals, including "socioeconomic [and[social security, beside biodiversity". A number of petitions by many environment scientists, NGO, including one from Dong Nai People's Committee Province were raised to stop the two plants, even as they stood to lose the projects' investments. Whilst debates carried, the decision to continue Dong Nai 6 and 6A became a political risk.

3.4.2.1.1 http://news.dbv.vn/dong-nai-hydropower-project-6-6a-investor-fiercely-clinging-151347.html

3.4.2.1.2 http://www.dtinews.vn/en/news/021/28838/hydropower-projects-face-construction-halt-for-environment-pollution.html

http://vietnamnews.vn/environment/239544/dong-nai-against-planned-dams.html

Case study 3

SOME EXPERIENCES ON THE APPLICATION OF THE ECOSYSTEM APPROACH: THE CASE OF THE ZAMBEZI BASIN WETLANDS CONSERVATION AND RESOURCE UTILIZATION PROJECT

Problem Statement

The project aimed to conserve the Zambezi Basin wetland ecosystems while facilitating sustainable use.

Description

An integrated, multi-national approach to management was promoted to address the ecological degradation that resulted from the unsustainable use of wetland resources. There were two main types of activities: (1) wetland conservation and (2) community wellbeing. Achievements in (1) were: the Zambezi basin biodiversity assessment, which identified priorities and provided a baseline inventory; introduction of resource-based management regimes, which encouraged more sustainable resource use; and the economic evaluation of wetland resources, which has helped raise local awareness and develop regional policies. Achievements in (2) were: enhanced health, education, food security, income and cultural values. The project found it necessary to first tackle community wellbeing before addressing conservation goals.

Features of Case Study that Highlight Key Aspects of the Ecosystem Approach

- The project found it necessary to focus first on enhancing socio-economic conditions before turning to conservation.
- Economic valuations of goods and services were undertaken at regional and local scales.
- The immediate delivery of benefits to the people responsible for conservation and sustainable use is vital.
- Maintaining ecosystem functioning across the basin (and the value of products locally) was a priority objective.
- A multi-scale approach was followed: the economic valuation of goods, services and biodiversity were undertaken at the local and basin levels, and activities were targeted at the local (village-level institutions established and local bylaws passed) and transboundary scales.
- Improvements to the conservation and ecosystem service status of site studies were not fully evident within the 5-year project period.
- The project aimed to make use of multidisciplinary scientific and traditional knowledge.
- The following Principles were emphasised: 1, 2, 4, 5, 7, 11 & 12.
- CBD Thematic Area: Inland Waters.
- CBD Cross-cutting issues: Incentives, Sustainable Use & NBSAPs.

Lessons Learned

- Conservation and sustainable use objectives cannot be achieved unless education, health, gender equity, transport and incomes and human wellbeing requirements are first improved.
- Local-level economic resource valuation helped build awareness of the need for measures to ensure the sustainable use of the resource base.

- Popular media (radio plays and songs) using local community artists were important for building awareness of the wetland values and sustainable use.
- Regional economic valuation of resources assisted in integrated transboundary planning within the Basin.
- The biodiversity study report needs to be packaged into appropriate formats for the different stakeholders such as planners, policy-makers and local communities for it to be of more practical use.

Source: R. D. Smith and E. Maltby. 2003. *Using the Ecosystem Approach to implement the CBD. A global synthesis report drawing lessons from three regional pathfinder workshops.* http://www.cbd.int/doc/case-studies/esys/cs-esys-cbd-en.pdf

Case study 4

Applying ecosystem based approach for Ramsar Site, Stung Treng (Cambodia)

The project '*Strengthening pro-poor wetland conservation using integrated biodiversity, livelihood and economic assessment*', funded by the UK Darwin Initiative, has sought to improve the information base for wetland sites. This has been done by developing generic tools to gather information on the full livelihoods, environmental and biodiversity values of wetland sites. The integrated assessment of the Stung Treng Ramsar Site was one of two case study assessments undertaken through the project (the second was undertaken in Tanzania; see: Kasthala *et al.* 2008), in order to test the integrated methodology and inform the development of a *Toolkit*, a good practice manual to undertaking integrated assessments of wetlands. In Stung Treng Ramsar Site, the assessment shows that:

The site has been confirmed to be an area of outstanding biodiversity value, with a number of globally and regionally threatened species while local livelihoods at the site are complex and highly dependent upon the utilisation of the wetland's natural resources, particularly for the poor and poorest.

Threats to the Site are mainly external (wildlife trade, dams, external fishers), and major benefits from resource extraction accrue to outsiders. Many species, including some of conservation concern, are highly utilised, sometimes involving destructive harvesting practices, especially by outsider fishers. Biodiversity / conservation management in areas of livelihood use must acknowledge livelihood dependency and seek to work with local people as allies.

Effective resource governance has emerged as a central issue for conservation and livelihood development here. Improving weak governance, reflected in difficulties in regulating outsider's over-exploitation of the resource, is proving the key challenge.

The government currently lacks the effective capacity and resources to enforce current legislation and management objectives, and therefore management should focus on developing co-management opportunities. Whilst some co-management practices have been introduced, the implementation and capacity are still weak.

Leadership is required from top levels of government to prevent corruption and ensure fair and effective implementation of existing legislation, while decision-making over hydroelectric development does not seem to have reflected either the democratic aspirations of the local communities for livelihood security or the full range of values of the resource in its current state to the range of users.

The integrated multidisciplinary approach used in this study has helped reveal a more complete picture of the full value of wetlands, and identify management options that better reconcile the needs of the poorest communities and conservation. This approach has been valuable in refining the spatial zoning of conservation interventions.

The study suggested that:

- The Ramsar boundary should be extended to include the Anlong Chheuteal transboundary Mekong dolphin pool, which, contrary to the World Database of Protected Areas (WDPA) boundary (see Map 2), currently it does not.
- Total exclusion is not a viable option for managing Ramsar Site zonation due to the negative impacts on the livelihoods of those using these areas.
- Transboundary collaboration should be promoted between Cambodia and Lao PDR and other upstream countries.
- Participation of communities in conservation planning for the Site should become institutionalised.
- The government should strengthen support to community-led fisheries conservation initiatives, improve monitoring of fishing activities by external commercial fishers (including companies) and better enforce the existing regulations in relation to their activities.

Source: Adopted from Allen et all (2008)

4 FISHERIES

MODULE 4: FISHERIES		
Scope	**Session/Sub-Topic**	**Scope**
Fisheries management / fisheries migration	**Session 4.1: Freshwater Fisheries**	
	Freshwater fisheries	Introduction to freshwater fisheries (river, lake, estuary, wetland, seasonal, etc.).
	Features of wild capture fisheries	Introduction to types and importance of freshwater fisheries for livelihoods - subsistence and commercial.
	Wild fisheries in the Lower Mekong Basin	Introduction to importance of freshwater fisheries in the LMB.
	Session 4.2: Hydropower Impacts on Fisheries	
	Barrier effects	Barrier effect of dams on upstream and downstream movement of fish; consequences for flagship species (e.g. river dolphin) and fisheries.
	Changed hydrology	Flows, velocities, duration, timing.
	Changed water quality	Oxygen, temperature, pollutants (including mercury); sediment; in reservoirs; in tailwater; downstream.
	Other impacts	Intakes and turbines (pressure differences); social issues - incomers, access to water, markets.
	Session 4.3: Fisheries Mitigation	
	Objectives	Introduction to the establishment of objectives for fisheries mitigation.
	Avoidance	Introduction to strategic water development planning to avoid damage to fisheries; avoidance of main stem dams.
	Environmental flows	Covered by Module 5.

MODULE 4: FISHERIES		
Scope	**Session/Sub-Topic**	**Scope**
	Fish passes	Introduction to issues involved in all types of fish passes and assisted fish movement; ineffectiveness in tropics for many/most species.
	Reservoir fisheries	Introduction to reservoir fishery issues in relation to hydropower development.
	Dam removal	Introduction to global movement for dam decommissioning and river restoration (economic, ecological and other drivers).

4.1 Freshwater Fisheries

Key aspects	Fresh water fisheries depend on healthy ecosystems. The key hydrological event affecting freshwater fisheries in most systems is the annual flood. Small-scale wild capture fisheries tend to be weakly regulated and liable to excessive fishing pressures on fish stocks. Small scale wild capture fisheries are critical to both the livelihoods of many thousands of rural residents and the national protein security.

TRAINING AIDS	
Purpose of session	To provide an overall picture of the types and importance of freshwater fisheries, the flood pulse as the main driver of river fishery productivity, and the scale of fisheries of the Mekong River Basin.
Learning objectives	By the end of the season, trainees will be able to: Understand the main features of wild capture fisheries. Understand the main drivers of fishery productivity. Understand the importance of small-scale fisheries to livelihoods and food security.
Key readings	Arthington *et al.* River fisheries: ecological basis for management and conservation. At: http://www.fao.org/docrep/007/ad525e/ad525e05.htm Dudgeon *et al.* 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev. (2006), 81, pp. 163–182. http://homepages.eawag.ch/~gessner/PDF/Dudgeon.pdf Baran, E. 2010. Working Paper: Fisheries Baseline Assessment. SEA of the Mekong mainstream hydropower. Fisheries and livelihoods. FMSP Policy Brief 4. MRAG. DFID. http://www.mrag.co.uk/Documents/PolicyBrief4_Livelihoods.pdf Hortle, K.G. (2007). Consumption and yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No. 16, Mekong River Commission, Vientiane. 87 pp.

4.1.1 Freshwater Fisheries

Freshwater ecosystems include rivers, their floodplains, lakes and other associated wetlands. Rivers support a significant proportion of the world's fishery biodiversity with large basins, such as the Mekong, supporting some 500 described fish species and several 100 more lacking formal definition[53].

Slightly less than half of all known fish species are freshwater fish (i.e. fish that spend some or all of their lives in freshwater with salinity less than 0.05%). Many fish species reproduce in freshwater but spend most of their adult lives in the sea, such as salmon and trout. Others are born in salt water but live most or part of their adult lives in freshwater. Species that migrate between marine and freshwater have adaptations for both environments.

In many cases species that live in a river basin or a particular river develop morphological and behavioural adaptations to the specific conditions of that location. The conditions are usually linked to the hydrological seasonality of the river. For example, fish may migrate upstream (longitudinal) and or into the floodplain (latitudinal) to find favourable conditions for breeding and feeding. Floods generally provide good conditions for spawning, due to the expansion of habitat and food supplies. The total production of fish in a river system is usually higher in years with higher flooding. The timing and duration of flooding are important factors determining fishery productivity, as are regional conditions: in terms of productivity, seasonal rivers in nutrient-rich landscapes can sustain a greater harvest than seasonal rivers in nutrient-poor landscapes or aseasonal rivers [54].

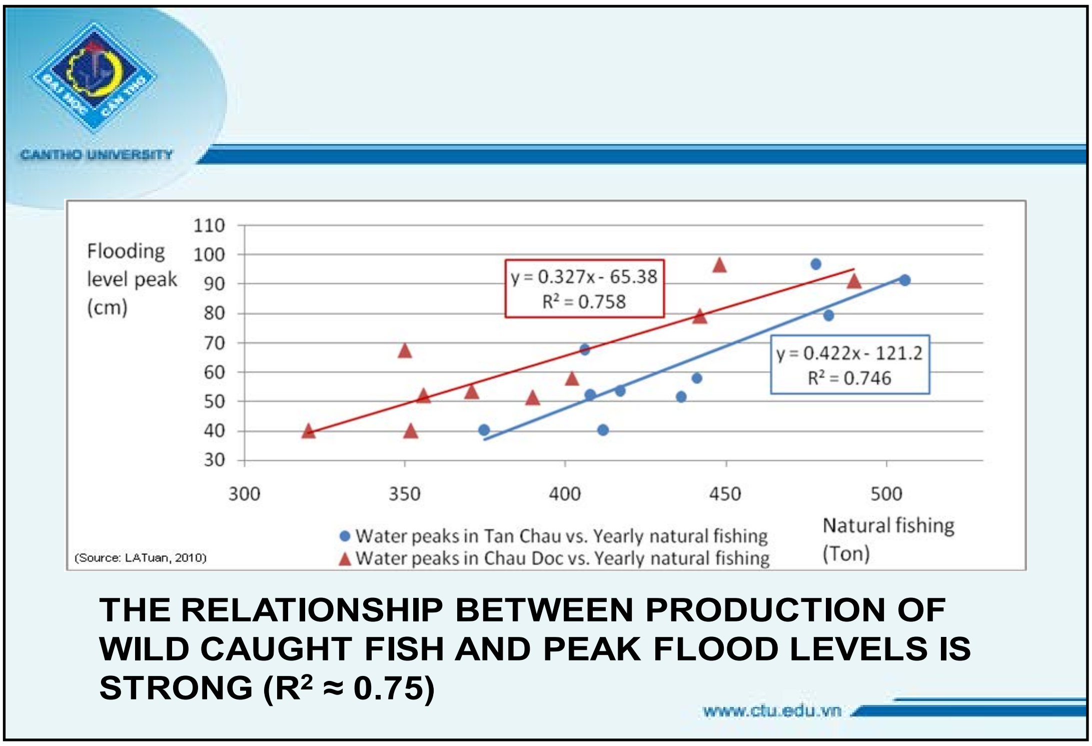
The following figures show the strong relationship between flooding and fish catches in parts of the LMB and in An Gian province, Vietnam (

[53] Dudgeon D. 2000. The ecology of tropical Asian rivers and streams in relation to biodiversity conservation. Annual Review of Ecology and Systematics, 31: 239-263.

[54] Winemiller K.O.Floodplain River Food Webs: Generalizations and Implications for Fisheries Management. Proceedings of the second international symposium on the management of large rivers for fisheries (Volume II). http://www.fao.org/docrep/007/ad526e/ad526e0l.htm

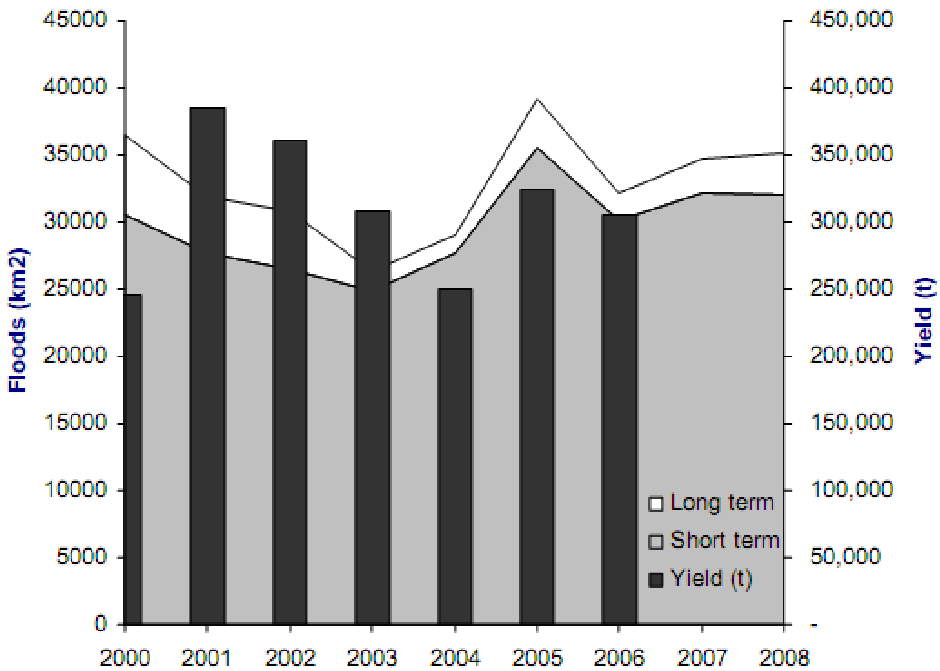
Figure 4-1, **Figure 4-2**, **Figure 4-3**).

Figure 4-1: Flooding and Fish Catches, Mekong Delta



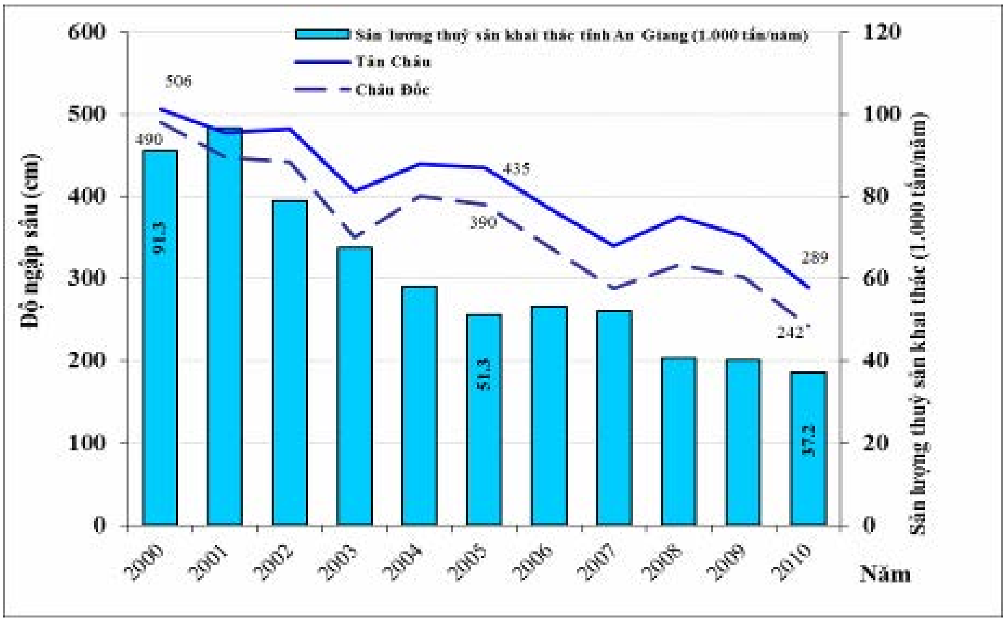
Source: Le Anh Tuan, 2010. Presentation to a roundtable on Mekong Delta wetlands.

Figure 4-2: Flooding and Fish Catches in Cambodia



Source: Martin van Brakel and John Hamprey. Foresight Project on Global Food and Farming Futures. Regional case study: R6 Mekong - Inland fisheries and aquaculture

Figure 4-3: Flooding and Fish Catches in An Gian province, Viet Nam, 2000-2010



Source: An Giang provincial Department of Agriculture and Rural Development, and provincial statistics office

Of all a river's parts, the lateral components of alluvial river systems - floodplains - are the most critical for maintaining river productivity (Junk *et al.*, 1989 as cited in Ickes *et al.* (2005))[55]. Graham & Harris (2005)[56], citing various sources, wrote that "… *floodplains and the river that serve them have been referred to as the most dynamic (Power et al., 1995) and valuable (Ward 1995) of all the habitats on Earth. Unregulated floodplain rivers host a rich and complex variety of ecological communities (Junk et al. 1989; Welcomme 1985), made possible by the spatial heterogeneity and temporal fluctuation that naturally variable flow regimes impose on the system (Cummins 1993; Power et al., 1995; Shiel et al., 1998). Floodplain rivers are also, however, among the most abused resources on the planet (Johnson et al. 1995; Ward 1995)*".

Case Study 1

Flooding and Fish Catches of Thailand

The catchment of Mekong River Basin covers an area of 79,500,000 ha. With a total length of 4,800 km, the Mekong River, passes through six countries; China, Myanmar, the Lao PDR, Thailand, Cambodia and Vietnam. The major Mekong sub-basins in Thailand are the Kok River Basin (789,500 ha); the Chi River Basin (4,913,300 ha); the Mun

[55] Brian S. Ickes, Jon Vallazza, John Kalas, and Brent Knights (2005) *River Floodplain Connectivity and Lateral Fish Passage: A Literature Review*. Contract Completion Report submitted to U.S. Fish and Wildlife Service, Mark Twain Wildlife Refuge Complex 1740 N 24th Street Quincy, Illinois 62301

[56] Graham, R, and Harris, J.H. 2005. *Floodplain inundation and fish dynamics in the Murray-Darling Basin - Current concepts and future research: a scoping study*. Cooperative Research Centre for Freshwater Ecology, Canberra

River Basin (7,057,400 ha); the Ang Sakon Nakhon Basin (5,751,300 ha), and a small portion of the Tonle Sap Basin, located on the eastern fringes of Chanthaburi and Sakaeo provinces. The largest sub-basins in northeast of Thailand include the Mun, Chi, and Ang Sakon Nakon Basins.

The Mekong Basin in Thailand includes a variety of water bodies including floodplains, tributaries, canals, swamps, and reservoirs. According to the Office of Environmental Policy and Planning (formerly OEPP, now the Office of Natural Resources and Environmental Policy and Planning, or ONEP), the water body covers an area of 236,000 ha, consisting of 8,667 rivers, rivulets, and canals; 6,751 swamps and reservoirs; 463 wetlands and lowlands, and 161 other types of water bodies (OEPP, 1999). The major water bodies in the northeast region, as part of Mekong basin, provide a variety of fishing grounds as follows.

- Rivers; Chi, Mun, and Songkhram;
- Swamps; Nong Harn in Sakon Nakhon province,
- Large reservoirs; Ubolratana in Khon Kaen province,
  Lam Pao in Kalasin province,
  Sirindhorn in Ubon Ratchathani province,
  Oon in Sakon Nakhon province,
  Chulabhorn in Chaiyaphum province,
  Lam Phra Pleung and Lam Takong in Nakhon Ratchasima province.
- Seasonally flooded wetlands, especially rice-fields.

A synthesis of 20 consumption studies from across the entire Lower Mekong basin were compiled by the MRC, which estimates the annual production of capture fisheries, including other aquatic animals, exceeds 2.6 million tonnes. The catch from Thai Mekong fisheries, at about 0.9 million tonnes, represents about one-third of the basin's total production. Of this Thai Mekong catch, 0.7 million tonnes are inland fish and 0.2 million tonnes are other aquatic animals.

Fish species prefer certain habitats, which, in the Mekong River Basin, can be classified into three categories:

Large river fishes live and breed in major rivers, even if some species migrate to floodplains to spawn. These are, by and large, members of the Cyprinidae Family, and include the small-scale mud carp (*Cirrhinus auratus*), banded shark (*Hampala macrolepidota*), red-tail tinfoil barb (*Puntius altus*), golden shark (*Leptobarbus hoevenii*), Pla Prom (*Osteochilus melanopleura*), black shark (*Morulius chrysophekadion*), and members of Pangasid, Silurid, and Notopterid families

Carnivorous fishes of the Channidae family (such as the snakehead and giant snakehead), as well as fish species that feed on detritus favor swamps, characterised by low levels of dissolved oxygen and acidic or brackish water. Some fish living in these environments can travel significant distances overland as they possess special respiratory organs for breathing air. These include the walking catfish (*Clarias batrachus*), catfish (*Mystus nemurus*), climbing perch (*Anabas testudineus*), and three-spot gourami (*Trichopterus trichopterus*).

Floodplain dwellers are often small, fast growing species, as well as productive breeders, which complete their life-cycle during the short time when floodplains are inundated. These include members of Cyprinidae Family (e.g. Pla Kled Ti (*Thynnichthys thynnoides*), Pla Za (*Dangila iamensis*), and Jullien's mud carp (*Cirrhinus jullieni*)) (Interim Mekong Committee, 1992).

Source: An Introduction to the Mekong Fisheries of Thailand. Mekong Development Series No.5, Mekong River Commission, May 2007

4.1.2 Features of Wild Capture Fisheries

As of the early 21st century, fish is probably humanity's only significant wild food[57]. Fish consumption varies around the world. In SE Asia it is high: Sverdrup-Jensen (2002)[58] estimated consumption of inland fish and other aquatic organisms by the population of 56.3 million people in the LMB at 2,033 million t/yr, with a consumption average of 36 kg per capita per year.

A fishery can be defined as the exploitation of living aquatic resources held in some form of common or open access property regime (Note: fish account for the bulk of organisms exploited, but invertebrates such as crustacea, molluscs and aquatic insects may also be important in some freshwater, especially estuarine, fisheries)[59].

While generalisation is risky, wild capture fisheries tend to have the following observable features:

- **Open access**

  An important feature of wild capture fisheries is it's general, open access. There are of, course exceptions, including local fishing rights or where licences are purchased by fishing concessionaires, who can then exclude the public. Access is also sometimes access seasonal. For example, in the Mekong Delta in Vietnam, during the dry season, fish trapped in depressions, ponds and canals belong to the owners of the adjacent land plots, but in the flood season access to fisheries is open to all. In Cambodia, Hap Navy, Seng Leang, and Ratana Chuenpagdee (2006)[60] stated that access to, and use of, common property resources is a critical factor in sustaining people's livelihoods, particularly those with few livelihood alternatives.

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[57] Wild Fisheries. Wikipedia. http://en.wikipedia.org/wiki/Wild_fisheries

[58] Sverdrup-Jensen, S. 2002. Fisheries in the Lower Mekong Basin: Status and Perspectives. *MRC Technical Paper No. 6,* Mekong River Commission, Phnom Penh. 103 pp. ISSN: 1683-1489

[59] Laurence E. D. Smitha,S. Nguyen Khoac, and K. Lorenzen. 2005. Livelihood functions of inland fisheries: policy implications in developing countries. *Water Policy* 7: 359-383.

[60] Hap Navy, Seng Leang & Ratana Chuenpagdaee. 2006. *Socioeconomics and Livelihood Values of Tonle Sap Fisheries*. Inland Fisheries and Development Institute, Phnom Penh. 24 p

- **Low investment**

  Although the productivity of wild capture fisheries is lower than that of aquaculture per unit of land, it requires relatively little investment and technologies from fishers, besides the costs of fishing equipment, which is often still small in fishing households. In contrast, aquaculture requires resources, such as land, to build a pond, capital to buy seed fish, and feed.

  The open access and low investment features of wild capture fisheries make these a more feasible livelihood option than aquaculture for the poor and landless with few other resources.

- **Vulnerability and resilience**

  The open access of wild capture fisheries can often lead to a "tragedy of the commons" scenario, where everybody is locked into a course of action that leads to overexploitation.

  The dependence of wild capture fisheries on natural systems makes them vulnerable to climate change and other human impacts such as pollution, competition for water use, and modifications in flow regimes for agriculture, urban uses, industrial uses, and hydropower.

  Although wild capture fisheries are critical to large populations for both subsistence and livelihoods, they are relatively risky and uncertain. Nevertheless, they can be a useful fall-back option in times of economic stress.

- **Role in food security and employment**

  Small scale fisheries tend to contribute mostly to local food security as most of the fish caught are either for home consumption or sale in local markets.

  Rural households can engage in small-scale fishing on a full time or part time basis—as a mixed farming-fishing-livestock livelihood or as a seasonal supplementary income option. Small scale wild capture fisheries also provide employment for ancillary activities, such as net making, boat building, fish paste making, and retailing in local markets.

  Income from small scale wild capture fisheries is seldom large enough to lift households out of poverty, but does provide security at a low, usually predictable level.

- **Low official recognition of role of fisheries**

  Products of small scale capture fisheries are usually for household consumption and/or for sale in local markets. The value of small scale wild capture fisheries is often not reflected in socio-economic reports and GDP figures. Equally, wild capture fisheries are a nature-based asset that may be overlooked when making development decisions. The full social, economic, and ecological values and sustainability of wild fisheries are seldom taken into account in socio-economic, especially water sources, planning and policy.

- **Social, cultural, and lifestyle**

  Households relying on wild capture fisheries may do this for reasons in addition to its being an accessible livelihood option. Fishing is often an inherited lifestyle, a tradition with cultural associations. In this regard, the total benefits derived from wild capture fisheries are greater than the sum of the individual benefits such as food, income, and employment.

With regards to wild fish catch, the Lower Mekong Basin is the most productive freshwater fishery in the world, with an estimated 2.6 million tons harvested each year, equating to an annual value of US$ 1.7 billion. Wild fish catch is about five times more lucrative than the combination of reservoir fisheries and aquaculture production, which totals 240,000 tons and 260,000 tons, respectively. Fish farmers often feed cultured fish with small wild-caught species[61]

In the Thailand-Mekong Basin, the Nam Songkhram river system is recognized for its abundant wild capture fisheries and extensive, seasonally inundated wetlands. Specifically, no dam construction occurs along this river. The flow connectivity between the Mekong mainstream and the lower Nam Songkhram Basin floodplain system significantly contributes toward fish abundance and diversity in the area. Thailand's Department of Fisheries reported that at least 188 fish species, representing 30 families, are found in the Nam Songkhram Basin. A later fisheries study estimated catches in the lower part of the Nam Songkhram Basin could be over 34,000 tons per annum, with a mean yield per unit area of 78.9 kg/ha (Hortle and Suntornratana, 2008 cited in David J.H. Blake, et al 2008)[62]

There is no universally agreed definition of environmental flows. The following definition has been adopted by IUCN:

'An 'environmental flow' is the provision of water within rivers and groundwater systems to maintain downstream ecosystems and their benefits, where the river or groundwater system is subject to competing water uses and flow regulation. Since regulation of flow can occur through direct infrastructure (like on-stream dams) as well as through diversions of water from the system (for example by pumping water away), there are different ways in which environmental flows can be provided.'

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[61] Nicolaas van Zalinge, Peter Degen, Chumnarn Pongsri , Sam Nuov, Jørgen G. Jensen, Nguyen Van Hao and Xaypladeth Choulamany, *The Mekong River System*, Contribution to the Second International Symposium on the Management of Large Rivers for Fisheries, Phnom Penh, 11-14 February 2003.

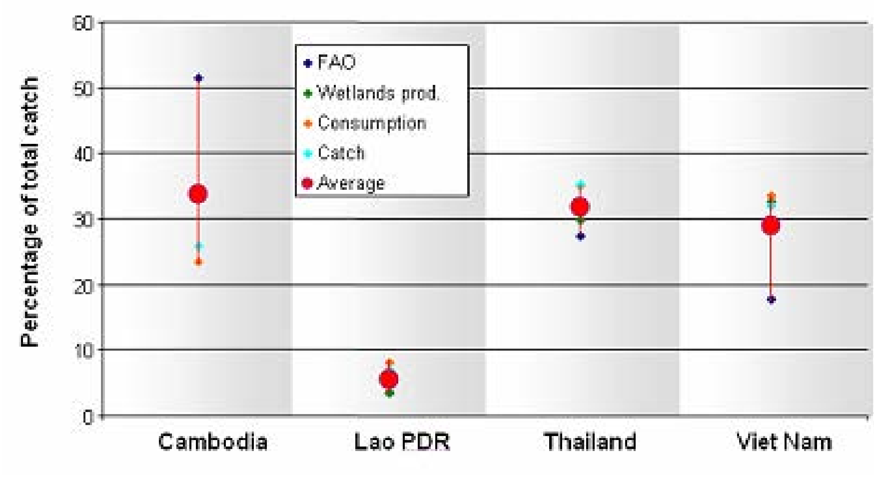
[62] David J.H. Blake et. 2008. *E---Flows in the Nam Songkhram River Basin*. International Union for the Conservation of Nature (IUCN), International Water Management Institute (IWMI), Mekong River Commission (MRC), Water and Development Research Group at Helsinki University of Technology (TKK), Government of Thailand's Department of Water Resources.

4.1.3 Scale and Importance of Wild Fisheries in the Mekong Basin

Fisheries are important livelihood activities in the Lower Mekong basin (LMB). Estimates of fish production in the LMB, based on yield per unit area of aquatic habitat, suggest a possible range of 0.7-2.9 million t/yr (MRC Technical Paper 16). This is consistent with the consumption-based estimate of 2.6 million t/yr (which includes and allowance for waste, exports, and trash fish fed to livestock). It is likely that the actual yield is at the upper end of this range because of the Mekong's high natural productivity and intensive fishing activity. Cambodia is a net exporter to other countries as it has a large area of productive wetlands, intensive fisheries, and a moderate population.

The following figure from Baran (2010)[63] shows each of the LMB country shares of the total catch of the basin, based on varying data sources. Baran concluded that, according to all studies and data, Cambodia, Thailand, and Vietnam each produce about one third of the overall Mekong fish catch, and Laos produces around 5%.

Figure 4-4: Relative Catch by Country in Lower Mekong Basin



Source: Baran (2010)

The following table from Baran (2010) (**Table 4-1**) compares fish catch per inhabitant in the LMB with the world average: within the LMB, in Laos, Thailand and Vietnam, each person produces between 5 and 29 times more freshwater fish than the world average. Cambodia stands out as being the country with the highest fishing intensity in the world; each Cambodian in the LMB harvests 26 to 52 times more freshwater fish than the world average.

[63] Baran, E. 2010. *Mekong Fisheries and Mainstream Dams.* In: ICEM (2010): Mekong River Commission: Strategic Environmental Assessment of hydropower on the Mekong mainstream prepared for the Mekong River Commission. ICEM, Vietnam. 145 pp

Table 4-1: Fish Catch per Inhabitant in LMB compared to World Average

	Freshwater fish catch (FAO, tonnes)	Freshwater fish catch (MRC; catch)	Country population in 2005	% of LMB population in the country	LMB population in 2005	Catch per LMB inhabitant (FAO, kg)	Catch per LMB inhabitant (MRC, kg)
World	7,556,635		65,12,276,000			1.2	
Cambodia	338,969	682,150	13,866,000	80.4	11,148,264	30.4	61.2
Lao PDR	29,213	182,700	5,880,000	93.9	5,521,320	5.3	33.1
Thailand	202,783	932,300	65,946,000	37.5	24,729,750	8.2	37.7
Viet Nam	151,924	844,850	84,074,000	21.8	18,328,132	8.3	46.1

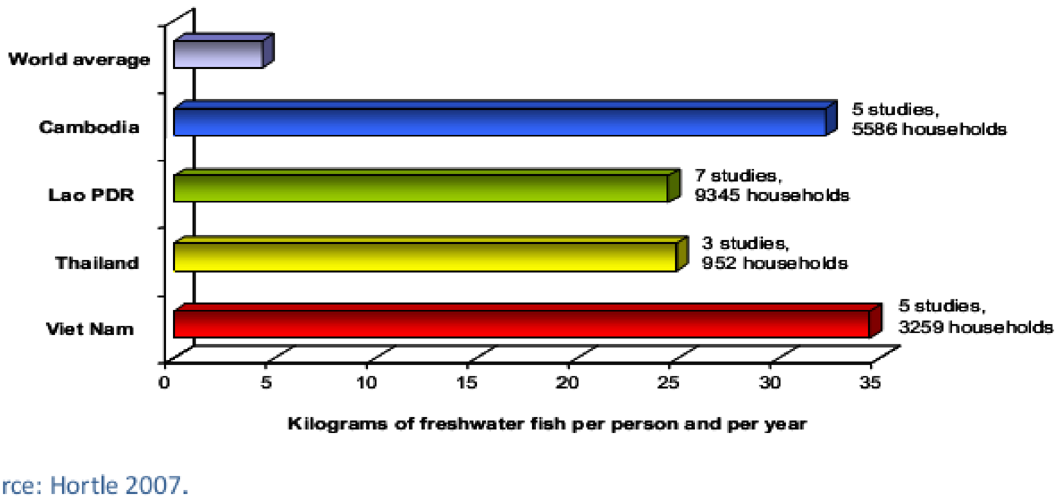
Sources: [1] http://www.fao.org/fishery/statistics/global-capture-production/en
[2] http://esa.un.org/unpp/index.asp
[3] MRC 2003a

Source Baran, 2010

In terms of contribution to food security, the following graph (**Figure 4-5**), also from Baran (2010), shows fish consumption per inhabitant per year in the Lower Mekong Basin, compared to the world average. The figure shows that the four countries in the Lower Mekong Basin feature the highest consumption of freshwater fish in the world.

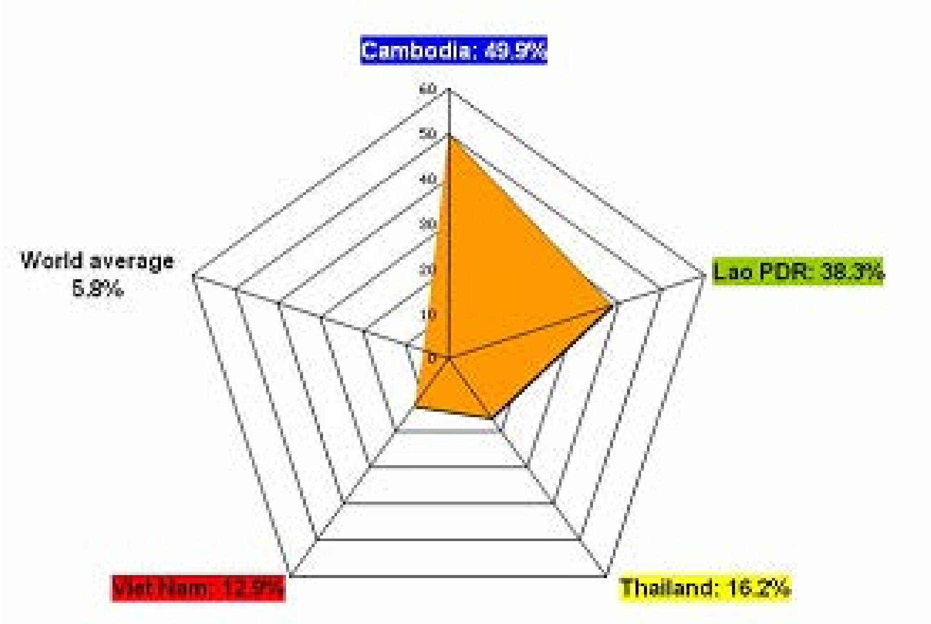
The next diagram (**Figure** 4-6) shows the importance of freshwater fish as source of protein in the diet of people in the Lower Mekong Basin and worldwide: in the LMB fish is a critical part of protein supply; the share of protein in the diet from freshwater fish is between 2.2 and 8.6 times the world average.

Figure 4-5: Freshwater Fish Consumption per Inhabitant per Year in LMB



Source: Hortle, 2007, in Baran, 2010

Figure 4-6: Importance of Freshwater Fish as a Source of Protein in the Diet of People in the LMB



Source: Baran, 2010

Within the Mekong River system, the Tonle Sap is of great importance to Cambodia and the Mekong River ecosystem as a whole. Navy *et al.* (2006)[64] wrote that the importance of the Tonle Sap Lake fisheries is indisputable, given its enormous contribution of about 60% to total inland fisheries production. The Tonle Sap aquatic ecosystem is increasingly being recognised for its importance to the livelihoods of over one million people living in and around the area. These populations rely heavily, if not entirely, on the resources of the lake. Fisheries have long been central to Cambodian lifestyles, particularly to about 1.25 million people living in the five provinces around the lake, who depend on fisheries and other aquatic resources for food, income and livelihoods. According to Hap Navy *et al.* (2006), the gross annual household income from direct consumptive uses for all fisheries-dependent households in the five lake provinces is estimated at USD 233 million.

Based on available literature, a number of factors determine fish production in the Mekong Basin, including water level, flood duration, timing,and regulatory of the flooding, characteristic of the flood zone, and physical/chemical conditions.

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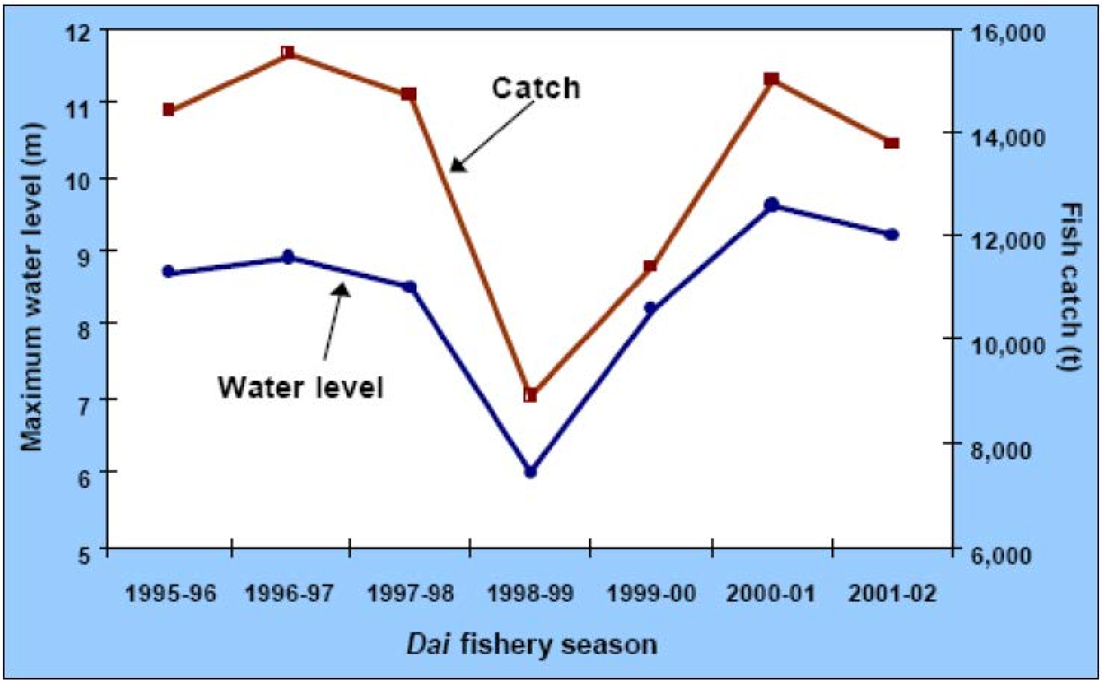
[64] Hap Navy, Seng Leang & Ratana Chuenpagdaee. 2006. *Socioeconomics and Livelihood Values of Tonle Sap Fisheries*. Inland Fisheries and Development Institute, Phnom Penh. 24 p

Figure 4-7: Relationship between the maximum seasonal flood level and fish catch from the Dai or Bag net fishery in Tonle Sap River.



The figure above show high fish yields in years with high floods and can be explained by a number of factors. First, fish spawning success correlates with available spawning grounds: higher floods inundate larger floodplain areas, creating larger spawning areas. Second, a high flood also means that fishing activities dispersed more evenly over larger areas, providing better chances for young fishes to survive. This is not valid for all fish species; for example, snakehead (*Channa micropeltes*) catch was at its highest one year after a high flood (Van Zalinge et al. 2003[65]).

[65] See further on MRC (2010) Assessment of Basin-wide development scenarios (Technical Note 10) on Impacts on the Tonle Sap Ecosystem.

TRAINING AIDS	
Discussion topics	***1)*** How can the importance of small-scale fisheries to rural residents be communicated to decision-makers? ***2)*** Do you think that aquaculture will be able to replace the roles of wild fisheries?
Exercises	Select a river basin or a floodplain you are familiar with: • Construct a problem web or problem tree to identify the causes and threats to its freshwater biodiversity and freshwater fisheries. • Recommend measures for addressing the causes/threats.
Additional reading and resources	***1)*** Laurence *et al.* 2005. Livelihood functions of inland fisheries: policy implications in developing countries. *Water Policy* 7, 359-383. http://www.aquaticresources.org/pubs/Smith_etal_2005(Livelihoods).pdf ***2)*** Welcomme, R. & A. Halls. 2003. *Dependence of tropical river fisheries on flow*. http://www.fao.org/docrep/007/ad526e/ad526e0k.htm ***3)*** Winemiller, K.O. 2003. *Floodplain river food webs: generalizations and implications for fisheries management*. http://www.fao.org/docrep/007/ad526e/ad526e0l.htm ***4)*** *Tonle Sap fisheries: a case study on floodplain gillnet fisheries in Siem Reap, Cambodia*. FAO Regional Office for Asia and the Pacific. http://www.fao.org/docrep/004/ab561e/ab561e07.htm

The Tonle Sap Biosphere Reserve (TSBR), part of the Tonle Sap Lake, covers 14,812 km^2 and consists of three core areas: Prek Toal (213 km^2), Boeung Tonle Chhmar (145 km^2), and Stueng Sen (63km^2). In principle only scientific research and monitoring activities are permitted in these areas, as well as a buffer zone (5,393 Km2), where human activities and settlements are allowed (although must be in accordance with conservation objectives), and a transition zone (8,998 km^2) for integrated economic development. Any development should not harm the other zones (see the map below for the location of different zones).

Acknowledging the importance of fish conservation, the need to reduce tension at different fishing scales, as well as ecosystem stabilization; the government has recently abolished fishing lots (sometimes known as commercial or large-scale fishing lots), which are often cited as the key source of conflicting access and fish degradation. This is presented in case studies below.

Case Studies

Case Study 1

This case study of the Tonle Sap fisheries is from the NGO International Rivers. Online at: http://www.internationalrivers.org/resources/protecting-the-fisheries-of-tonle-sap-lake-1742

Protecting the Fisheries of Tonle Sap Lake

By: Carl Middleton

Date: Friday, June 1, 2007. From World Rivers Review, June 2007

Tonle Sap Lake is the largest freshwater lake in Southeast Asia and of great importance to Cambodia and the Mekong River ecosystem as a whole. Located in Northwest Cambodia and connected to the Mekong River via the Tonle Sap River, its ecological value was recognized in 1997 when it was designated a UNESCO biosphere reserve. We talked about the outlook for the lake and those communities dependent upon it with Mr. Mak Sithirith, Executive Director of the Fisheries Action Coalition Team (FACT), a Cambodian NGO that works closely with fishing communities.

WRR: Why is the Tonle Sap Lake so important to Cambodia?

MS: The Tonle Sap Lake is central to the culture, economy, environment and livelihoods of Cambodians. Over four million people live in the six provinces surrounding the lake, and of these more than a million depend on the lake's fisheries for their livelihoods.

It is a critical and unique ecosystem. During the rainy season the lake absorbs the Mekong River's floodwaters, expanding to about six times its dry season size, and preventing flooding further downstream. Then, in the dry season, the flow of the river connecting Tonle Sap to the Mekong River reverses direction and the lake empties. By adding water to the Mekong River it reduces salt water intrusion in the delta region downstream in Vietnam, allowing communities there to grow rice and other crops. This cycle of expansion and contraction is why the lake is sometimes referred to as the "heart beat of Cambodia."

Also, both Tonle Sap Lake and the Angkor Wat temple are an important part of Cambodian's cultural identity, and it is no coincidence that they are located close to each other. The King would have chosen the temple's location close to the lake to provide food, fish, and irrigation water for those who built and lived within the temple complex. We could even say that the lake gave birth to the temple.

Finally, Tonle Sap Lake is also very important to Cambodia's economy. It provides at least half of the total capture fisheries – about 230,000 metric tonnes of fish per year. Because subsistence fishers depend on the lake on a day-to-day basis for their livelihoods, it is also vital to the household economy.

WRR: Are the lake's fishery resources harvested sustainably?

MS: Fish catch data from the government's Fisheries Administration indicate that fish catches from large commercial fishing lots remain relatively constant from year to year. At the same time, over the past ten years there has been a 50-70% decline in household fisheries catch. Importantly, it is widely reported that the composition of the fish catch is changing. Less large fish species and more small fish species are being caught, which is an indication of over-fishing. Reasons suggested by fisheries experts include: an increased subsistence-level fishing population; illegal fishing and weak enforcement of the law; environmental changes, such as localized pollution; and changes in water flows into the Tonle Sap Lake because of major infrastructure developments upstream altering the hydrological cycle of the Mekong River. It is also likely that commercial fishing lots are under-reporting their fish catch.

Small-scale fishers especially have been struggling, because they still need to catch enough fish for their families to survive. This has led them to use higher technology fishing gear and expend more effort to catch enough fish. Whereas before, only two or three of the family would go out to fish, now it is common for the whole family to go fishing to catch enough to eat.

Some experts claim that too many people are fishing the lake, but I disagree. There would not be a problem if more sustainable management arrangements, such as effective community fisheries, were in place.

WRR: How does the Fisheries Action Coalition Team work with fishing communities to improve their livelihoods?

MS: FACT is a coalition of NGOs that work to enable fisherfolk to maintain access to the fish resources that provide their livelihoods. As many fishing communities live in isolation, FACT works directly with fishers to help them build a lake-wide network. This allows the fishers to have a strong collective voice in any decision-making processes that will affect their livelihoods. FACT works closely with fishing-community leaders by building their understanding on legal issues, on major projects underway around the Lake, and on wider issues such as upstream infrastructure development on the Mekong River. This allows community leaders to inform their communities and prepares them for future challenges that might arise. FACT also conducts wider awareness raising activities. For example, in early June 2007 a Boat Parade was organized, in which a flotilla of 15 boats toured Tonle Sap Lake visiting remote villages. It was organized to highlight the fact that peoples' right to access resources must be respected, and that Tonle Sap's environment should be protected.

Case Study 2

The following case study, from IUCN, provides a story of a government policy decision regarding fisheries in the Tonle Sap. Available online at:

http://www.iucn.org/about/union/secretariat/offices/asia/asia_where_work/cambodia/?10502/Cancelling-Fishing-Lots-in-Tonle-Sap

Cancelling Fishing Lots in Tonle Sap

23 July 2012

On February 28, 2012, speaking to students at the Institute of Technology of Cambodia (ITC) in Phnom Penh, Prime Minister Hun Sen said: "I need to send a message to all people in the whole Tonle Sap that there are no longer any fishing lots." The Prime Minister said that he had decided to cancel these lots, because fishers had complained about declining catches, and there were frequent disputes between fishers and the lot owners. He said that some cancelled lots would be turned into conservation zones (Deputy Prime Minister Bin Chhin is now drafting a sub-decree to establish these zones.) and added that next year he would cancel fishing lots on the Mekong River in Kampong Cham and Prey Veng Provinces.

The Prime Minister's surprise decision put an end to the system that dates from the colonial period, based on exploiting the Tonle Sap through a system of privately owned fishing lots. These lots are valuable: some owners pay $35,000/year to the government for a license.

Chea Samnang, a ranger at Beoung Chhmar on the Tonle Sap, supported the decision to cancel the fishing lots, because local fishers can now fish without restriction. He said that fishers were already earning more money—and that some had bought new boats, TVs, and generators.

Pen Thearat, Deputy Director of Beoung Chhmar, and Yann Visak, Chief of Fishery Sankat Peambang, Tonle Sap, welcomed the decision to hand over some fishing lots to local communities and keep others as conservation zones. These will expand the area available for fishing and help recover fish stocks. But both are concerned that the government does not have the capacity to enforce the new rules, and that fishing “anarchy” could result.

On a March 21 visit to the Tonle Sap we found a 300-m long fishing net, with a very small mesh size, located a few kilometres from the Beoung Chhmar ranger station. Pen Thearat said that according to the Fisheries Law, this gear is illegal but he couldn’t confiscate it, because the government had announced that local people had free access the Tonle Sap. According to the boat driver who was with us, the government’s decision risks making rich fishers, who can afford to buy new gear—richer at the expense of poorer fishers.

A lady in a market in Phnom Penh said that this year, there were more fish for sale at lower prices than in previous years. A professor at the Royal University of Phnom Penh who wished to remain anonymous said that this was due to the cancellation of the fishing lots in the Tonle Sap, which has resulted in unrestricted access and increased production. Until this year, fish production had declined steadily, and the professor suspected that this year’s increase is a temporary boom, caused by unsustainable fishing. He also pointed out that the government often made populist announcements in the run up to local elections. He hoped that the government would maintain free access for local fishing communities and at the same time properly protect the new conservation zones.

By: Kimsreng Kong, March 30, 2012

Case Study 3

Freshwater Fisheries in the Ou River Basin, Northern Lao PDR

The Ou River Basin is the longest tributary of the Mekong River, located in an upland area in the northern Lao PDR. Fisheries activities varied among specific resources, (i.e., fishes, *Bor* prawns, and freshwater green algae), and showed mainly seasonal differences. In total, 13 types of fishing gear were observed, and their distribution and use were associated with geographical and ecological conditions. The most frequently used gears were *mong* and *bet,* followed by *hae*. Men often used these methods to fish for large-sized gears. In contrast, *sawing, gneng*, and *katong* were used by women, children, and elders to fish for small-sized quarry. Gear characteristics were associated with fishing ground conditions and available materials, as well as cultural and social factors.

Local people were involved widely in fishing and the harvesting of *Bor* prawn and *Cladophoda* spp., but the extent of this involvement varied with, and was related to, village location, gender, and age group. The generation of cash income from these resources also depended on ecological conditions (e.g., the productivity of each fishing ground). Fish provided villagers with high amounts of animal protein, satisfying more than half of their protein requirements. Households whose cash income depended on fishes earned, on average, as much cash per year as did households whose income was derived from agriculture, waged labor, and/or business. *Bor* prawn productivity varied among fishing grounds, although production per household was higher from grounds where catching rights were granted to a limited number of households; however, access fees levied and spent on community development (60%) and rural government (40%) were higher for these household groups. Algae harvest and production of dry sheets, in which women, children, and elders were primarily engaged, also differed from one village to another. The highest cash income was made in villages near the district center. In these villages, those who earned the most cash obtained the algae through trade between villagers or bought it from other villages. Fisheries were thus important for the survival and livelihood of villagers and for rural development and risk buffering.

Significant systems of aquatic resource management have already been established in the Lower Ou River Basin, including fish conservation zones, seasonal and gear restrictions, community fishing zones in Pak-Ou village, community reserve zones of *Cladophora,* harvesting in Khangmien village, and community-based management and co-management of *M. yui* fisheries. These management systems are used as tools to manage aquatic resources, solve conflicts among resource users, and ensure catches from fish stock are appropriate for sustainable aquatic resource utilization.

Source: *Phousavanh Phouvin. 2012. Aquatic Biodiversity in Lao PDR: Fisheries Resources Utilization and Management in the Ou River Basin. Gaduate School of Southeast Asian and Africa Areas Studies, Kyotu University. 162pp.*

4.2 Hydropower Impacts on Fisheries

Key aspects	The main impacts of hydropower on fisheries are the result of: • **Barrier effects:** dams physically block upstream and downstream movement of fish, preventing migration and fragmenting populations. • **Changes in hydrology:** increased and decreased flows, flow velocities, flow duration, and flow timing. • **Changes in water quality:** changes to oxygen, temperature, and pollutants (including mercury); sediment: in reservoirs, in tailwater, and downstream. • **Other impacts:** fish intake to turbines; impact on fisheries of changed social and economic circumstances.

TRAINING AIDS	
Purpose of session	To provide trainees with an understanding of the main impacts of hydropower dams on fisheries.
Learning objectives	By the end of the session, the trainees will understand: • The variety and scale of the impacts of dams on fisheries.
Key readings	***1)*** Marmulla, G. (ed). 2001. Dams, Fish and Fisheries. *FAO Fisheries Tech. Paper 419*. ftp://ftp.fao.org/docrep/Fao/004/y2785e/y2785e.pdf ***2)*** McAllister *et al.* 2001. *Biodiversity Impacts of Large Dams*. Background Paper No. 1, prep. for IUCN / UNEP / WCD. ***3)*** Dugan, P. (2008). Mainstream dams as barriers to fish migration: international learning and implications for the Mekong. *Catch and Culture* 14: 3. http://ns1.mrcmekong.org/Catch-Culture/vol14_3Dec08/mainstream-dams-barriers.htm

4.2.1 Overview

The following overview notes are taken from Bernacsek, writing in the 2001 FAO Fisheries Technical Paper 419 on *Dams, fish and fisheries*[66]:

[66] Bernacsek, G. Environmental Issues, Capacity and Information Base for Management of Fisheries Affected by Dams. Available at: http://www.fao.org/docrep/004/Y2785E/y2785e05.htm

- Dams impact fish *directly* by blocking or creating hazards to migration in upstream and downstream directions, and by mortality or damage, when fish pass through dam discharge structures.
- Dams affect fish biodiversity, fish stocks and fisheries *indirectly* by modifying and/or degrading the upstream and downstream aquatic environments, including: (i) thermal stratification of the reservoir and release of cool and anoxic hypolimnion water downstream; (ii) downstream flow alteration and termination of inundation of downstream floodplains; (iii) sediment and nutrient trapping in reservoirs; (iv) release of contaminants from trapped sediment into the reservoir food chain; (v) infestation of the reservoir with floating aquatic plants; (vi) ghost fishing by nets snagged on drowned trees in the reservoir; (vii) long distance recession of the shoreline during drawdown; and (viii) pesticide contamination arising from agriculture on the reservoir drawdown zone.

The **Identification, Design and Appraisal Phases** of hydropower projects are essentially planning and approval phases. These are generally not accompanied by any major civil engineering activities, which negatively impact fisheries. At this time no special fisheries management operational needs are called for, over and above measures applied in the unregulated river. However, these phases are information-intensive, due to environmental assessment activities, and are crucial for generating information needed to meet the objectives of fisheries management, if the dam is eventually built—or for supporting the abandonment of the dam project for environmental reasons.

During the **Construction Phase**, the main potential environmental impact on fisheries originates from soil erosion and silt runoff into the river, due to clearing and excavation activities. This impairs water quality and can lead to acute or sublethal toxicity to fish. Siltation can also be dangerous to key breeding, nursery or overwintering habitats. Another hazard to fisheries is the use of explosives. Blast shocks may cause lethal or sublethal damage to fish stocks. Blockage to fish migration is usually not a problem at dam sites where topography allows the excavation of a temporary bypass channel for river discharge; however, the constrained topography of dams, situated in narrow river gorges, will not allow this excavation. Diversion tunnels in the cliff walls are used to conduct river water away from the dam foundations area. Water velocity, tunnel gradient and hydraulic jumps may create conditions unfriendly to fish, effectively blocking upstream migrations.

It is during the **Dam Operation Phase** - which can typically span 50 to 100 years - that the most severe impacts on fisheries and aquatic environments occur. Petts (1984)[67] and Welcomme (1985)[68] produced comprehensive reviews of dam impacts on fisheries and aquatic ecology at global level, while Bernacsek (1984[69]; 1997[70]) carried out detailed analyses of the impacts of dams on aquatic environment and fisheries in Africa and Southeast Asia. Impacts can be grouped into two categories: 1) mpacts which affect fish directly, and 2) impacts which affect the fisheries environments (upstream river, reservoir, downstream river, estuary,

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[67] Petts, G.E., 1984. *Impounded Rivers, Perspectives for Ecological Management*, Chichester, UK: John Wiley & Sons.

[68] Welcomme, R.L., 1985. River fisheries. *FAO Fish. Tech. Pap. No. 262*, Rome.

[69] Bernacsek, G.M., 1984. Dam design and operation to optimize fish production in impounded river basins, based on a Review of the Ecological Effects of Large Dams in Africa. *CIFA Tech. Pap. No. 11*. FAO, Rome.

[70] Bernacsek, G.M., 1997. *Large dam fisheries of the lower Mekong countries: review and assessment, Vol. I Main Report and Vol. II Database*, Bangkok: MRC, Project on Management of Fisheries Resources in the Mekong Basin.

delta, sea) in an indirect manner that leads to a deterioration in fish biodiversity, fish stocks and/or fisheries production.

4.2.2 Barrier Effect

Many fish species must migrate along river systems to find conditions necessary for their life cycle phases, including reproduction, juvenile, growth, and sexual maturation. Successful migration requires connectivity between aquatic habitats. Any barrier that interferes with migration has the potential to affect life cycle activities and species' survival. The degree of impact of a structure, such as a dam, depends on:

- The height and dimensions of the dam, type of turbine, operational head;
- Distance of the river affected;
- The nature of the river (flow, gradient, morphology, etc.,);
- The number of the species that need to migrate and the biomass of the fish that migrate per unit of time, especially the "peak biomasses" at peak times;
- The size, swimming behaviour and, most importantly, the strength and stamina of the fish.

The major impact of a dam on fish is the prevention of upstream migration to reach breeding sites. The blockage can be severe and lead to extinction if no spawning grounds are present in the river or tributaries downstream of the dam. There are numerous examples of the impacts of dams on fish populations; the following are from the UN Food and Agricultural Organisation (FAO)[71] :

- Since the nineteenth century, there has been a continuous and increasing decline in stocks of diadromous species in France: in a large majority of cases, the main causes of decline have been the construction of dams preventing free upstream migration. The negative effects of these obstructions on anadromous species (particularly Atlantic salmon and Allis shad) have been much more significant than water pollution, overfishing, and habitat destruction in the main rivers.
- Obstructions have been the reason for the extinction of entire stocks (salmon in the Rhine, Seine and Garonne rivers) or for the confinement of certain species to a very restricted part of the river basin (salmon in the Loire, shad in the Garonne or Rhône, etc.) (Porcher and Travade, 1992)[72]. Sturgeon stocks have been particularly threatened by hydroelectric dams on the Volga, Don and Caucasian rivers (Petts, 1988)[73]. On the East Coast of the USA, the building of dams has been identified as the main reason for the extinction or the depletion of migrating spe-

[71] Larinier, M. Environmental Issues, Dams and Fish Migration. http://www.fao.org/docrep/004/Y2785E/y2785e03.htm

[72] Porcher, J.P. and F. Travade, 1992. Les dispositifs de franchissement: bases biologiques, limites et rappels réglementaires. In: *Bulletin Français de Pêche et Pisciculture*, Vol. 326-327: 5-15.

[73] Petts, G.E., 1988. *Impounded rivers*, Chichester, UK: John Wiley & Sons Ltd Publishers. 326p

cies such as salmon and shad on the Connecticut, Merrimack and Penobscott rivers (Baum, 1994[74]; Meyers, 1994[75]; Stolte, 1994[76]).

- Zhong and Power (1996) reported that the number of fish species decreased from 107 to 83, because the Xinanjiang dam (Qiantang River, China) interrupted migration. The reduction of biodiversity occurred not only in the flooded section but also in the river below the dam, where spawning has been delayed by 20-60 days by lower water temperatures[77]. Quiros (1989)[78] mentions that dam construction in the upper reaches of Latin American rivers appears to lead to the disappearance of potamodromous species stocks in reservoirs and in the river upstream of the structure. The same occurs in reaches where a whole series of dams and reservoirs have been constructed.

Migration and dams on the Mekong: Poulsen *et al.* (2002)[79] characterised the fish groups of the Mekong according to their ecology and migration patterns as follows:

- **Black fish** such as *Channadae* (snakeheads) and *Anabantidae* (climbing perch) are resident fish with limited lateral migrations from the river onto the floodplains, and no longitudinal migrations (upstream or downstream).
- **White fish** such as cyprinids (*Henicorhynchus* spp, *Cirrhinus* spp and most *Pangasidae* catfishes) migrate long distances along the Mekong, especially between the lower floodplains and the Mekong mainstream.
- **Grey fish** such as *Mystus* catfishes migrate short distances between the floodplain and the channels. When the flood recedes, they tend to spend the dry season in the local tributaries.

It has been estimated that more than 70% of the total fish catch in the Mekong Basin (i.e. more than 1.8 million t, worth USD 1.4 billion at first sale) is dependent on these long-distance migrants. The mainstream Mekong is a corridor for many long-distance migrations. Most fish production originates from floodplains in the middle and lower part of the Basin. Thus dams built on the main river will have a much greater impact than dams built on tributaries, while those located in the middle and lower part of the LMB will have a greater impact on fish production than dams located in the upper part of the basin.

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[74] Baum, .T., 1994. *Evolution of the Atlantic Salmon Restoration Program in Maine.* In: A Hard Look at some Tough Issues (eds S. Calabi and A. Stout). Newburyport, MA, USA: New England Salmon Association

[75] Meyers, T.F., 1994. *The Program to Restore Atlantic Salmon to the Connecticut river.* In: A Hard Look at some Tough Issues (eds S. Calabi and A. Stout). Newburyport, MA, USA: New England Salmon Association

[76] Stolte, L. W., 1994. *Atlantic Salmon Restoration in the Merrimack River Basin*. In: (eds) A Hard Look at some Tough Issues (eds S. Calabi and A. Stout). Newburyport, MA, USA: New England Salmon Association

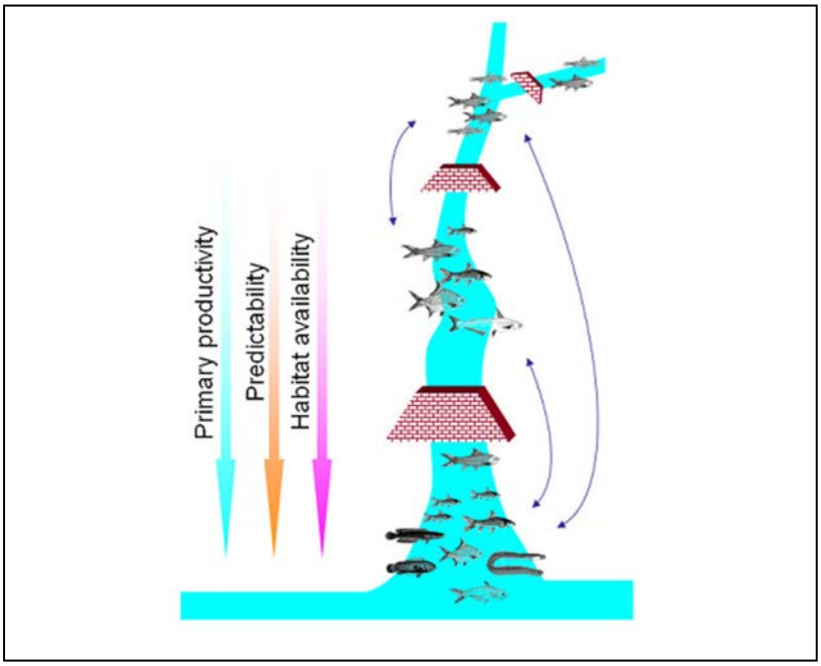
[77] Zhong and Power, 1996. In: Marmulla, G. (ed). 2001. Dams, Fish and Fisheries. *FAO Fisheries Tech. Paper 419*. ftp://ftp.fao.org/docrep/Fao/004/y2785e/y2785e.pdf

[78] Quiros, R., 1989. Structures assisting the migrations of non-salmonid fish. Latin America, FAO-COPESCAL *Technical Paper 5*, UN FAO, Rome

[79] Poulsen A.F., Ouch Poeu, Sintavong Viravong, Ubolratana Suntornratana and Nguyen Thanh Tung. 2002. Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental management. *MRC Technical Paper No. 8*, Mekong River Commission, Phnom Penh. 62 pp. ISSN: 1683-1489

The following figure from the Summary Working Paper of the MRC SEA for hydropower on the Mekong mainstream shows fish communities, migrations, and the impacts of dams along a standard river gradient.

Figure 4-8: Typical Fish Communities, Migration and Impact of Dams



Source: Summary Working Paper: MRC SEA for Mekong mainstream hydropower (2010)

The figure above shows the important of fish migration route from downstream to upstream and its associated tributaries. Table below provide key summary of fish species migration based on ecological system.

Figure 4-9: Seasonal fish migration on the Mekong

Dry season refuge habitat	Deep pools in the Kratie-Stung Treng stretch of the Mekong mainstream. These habitats are extremely important for recruitment for the entire lower Mekong Basin, including floodplains in southern Cambodia (including the Tonle Sap Great Lake System) and the Mekong Delta in Viet Nam.
Flood season feeding and rearing habitats	Floodplains in the Mekong Delta in Viet Nam, in southern Cambodia, and in the Tonle Sap system. These habitats support the major part of Mekong fisheries.
Spawning habitats	Rapids and deep pool systems in the Kratie - Khone Falls, and in the Sesan catchment. Floodplain habitats in the south (e.g. flooded forests associated with the Great Lake).
Migration routes	The Mekong River from Kratie - Stung Treng to southern Cambodia and the Mekong Delta in Viet Nam.

	Between the Mekong River and the Tonle Sap River (longitudinal connectivity). Between floodplain habitats and river channels (lateral connectivity). Between the Mekong mainstream and the Sesan sub-catchment (including Sekong and Srepok Rivers).
Hydrology	The annual flood pattern responsible for the inundation of large areas of southern Cambodia (including the Tonle Sap system) and the Mekong Delta is essential for fisheries productivity of the system. The annual reversal of the flow in the Tonle Sap River is essential for ecosystem functioning. If the flow is not reversed (or if reversal is delayed), fish larvae drifting from upstream spawning sites in the Mekong River cannot access the important floodplain habitats of the Tonle Sap system. A delayed flow reversal would also lead to a reduced floodplain area adjacent to the river and lake, and thus, reduced fish production. Changed hydrological parameters (e.g. as a result of water management schemes) result in changed flow patterns, which, in turn, may change sedimentation patterns along the river. Examples of this already exist in some tributaries where hydropower dams have been constructed, resulting in sedimentation, and thus in disappearance of deep pool habitats.

Source: Adopted from MRC (2010) Impacts on the Tonle Sap Ecosystem (Assessment of basin-wide development Scenarios), Technical note 10.

4.2.3 Changes in Hydrology

Dams affect fish through change of hydrology of the river, specifically the **volume**, **velocity**, **timing** and **duration** of flows. In relation to the Mekong, Barlow (2008) explains the impacts as follows[80]:

> *Dams, particularly those with large storage capacity, also affect river hydrology. Changes to hydrology include modification of the extent, duration and timing of annual floods, which naturally occur between May and November in the Lower Mekong Basin. Smaller floods of shorter duration reduce the available habitat for fish, resulting in lower fish production (Halls et al., 2008). They also reduce the survival rate of eggs and juvenile fish, which in turn decreases the recruitment of younger fish into the natural population. Changes to the timing of the floods, and indeed permanent increases in dry season flows, can disrupt the spawning and migration cues that trigger changes in fish behaviour and which are required for reproduction and ultimately the survival of different species (Baran, 2006).*
>
> *Scientists can roughly estimate the impact of smaller floods of shorter duration on the overall fisheries yield. However, without detailed experimental studies (which are currently not feasible in the Mekong region due to the experimental infrastructure required), it is very difficult to predict how spawning and migration cues will be affected by hydrological changes involving not only reduced wet-season flows, but also markedly increased dry-season flows.*

[80] Barlow, C. 2008. Dams, fish and fisheries in the Mekong River Basin. *Catch and Culture* 14: 2

The MRC SEA for hydropower dams on the mainstream (final report) explained some of the expected upstream and downstream changes in the hydrology of the Mekong if the proposed dams are built as follows:

> *The LMB mainstream dam walls would be sufficiently high that water levels in the reservoirs would be above the highest ever recorded for tens of km upstream. Changes in water levels could be greatly exacerbated by the operational strategy of the projects. “Peaking operation” (i.e. maximizing turbine discharge when buying price for electricity peaks once or twice daily) could greatly increase the speed at which water levels rise and the number of fluctuations from seasonal to daily or even hourly events. There is the potential for hourly spikes in water level of up to 3-6 m at towns and villages located 40-50 km downstream. Under unplanned and emergency release, peaking events could be larger and could travel that distance downstream in 1-2 hours giving little time for notification.*

Changes in hydrology can confuse the signals fish depend on for triggering their biological functions. The MRC SEA report explained this as well:

> *The Mekong River has a strong flood pulse characterized by four distinct seasons and corresponding fluctuations in the water levels. Lower Mekong Basin tributary and Chinese hydropower will disturb the timing and duration of these seasons. With LMB mainstream projects, upper reaches of Zone 2 (i.e. Chian Saen to Luang Prabang) and all reaches of the Mekong inundated by the mainstream reservoirs would no longer experience the ecologically important transition seasons. All other reaches of the Mekong would experience a reduction in the duration of transition seasons which play an important role in triggering biological processes within riverine and floodplain habitats.*

According to the SEA report, if all mainstream projects proceed, 55% of the Mekong River between Chiang Saen and Kratie would be converted to reservoir conditions, shifting the environment from riverine to lacustrine. This means that even if a fish could successfully climb past a dam through a fish pass, it would face roughly 100 km per dam of newly created and unfamiliar lacustrine environment on the other side to pass through for survival.

Box 4-1 The specific impacts of dams and associated storage reservoirs on biodiversity and fisheries

This has been summarised by McAllister *et al*. (2001) as including the following negative and positive issues:

- Blocking movement of migratory species up and down rivers, causing extirpation or extinction of genetically distinct stocks or species.
- Changing turbidity/sediment levels to which species/ecosystems are adapted affects species adapted to natural levels.
- Trapping silt in reservoirs deprives downstream deltas and estuaries of maintenance materials and nutrients that help make them productive ecosystems.
- Filtering out of woody debris that provides habitat and sustains a food chain.
- Changing conditions in rivers flooded by reservoirs: running water becomes still, silt is deposited; deepwater zones, temperature and oxygen conditions are created, which are unsuitable for riverine species.
- Possibly fostering exotic species which may displace indigenous biodiversity.
- Reservoirs may be colonised by species that are vectors of human and animal diseases.
- Flood plains provide vital habitat to diverse river biota during high water periods in many river basins. Dam management that diminishes or stops normal river flooding of these plains will impact diversity and fisheries.
- Changing normal seasonal estuarine discharge can reduce the supply of entrained nutrients, impacting the food chains that sustain fisheries in inland and estuarine deltas.
- Modifying water quality and flow patterns downstream.
- The cumulative effects of a series of dams, especially where the impact footprint of one dam overlaps with that of the next downstream dam(s).
- Providing new habitats for waterfowl which may increase their populations.

Source: Adopted from Allen,David, William Darwall, Mark Dubois, Kong Kim Sreng, Alvin Lopez, Anna McIvor, Oliver Springate-Baginski, and Thuon Try (2008) Integrating people in conservation planning: An integrated assessment of the biodiversity, livelihood and economic implications of the proposed special management zones in the Stung Treng Ramsar Site, Cambodia. IUCN and University of East Anglia, UK.

4.2.4 Changes in Water Quality

In addition to the barrier effect and the impact of hydrological changes on fisheries, dams also affect fisheries by changing river water quality, both during construction and operation. Key impacts are on oxygen levels (including supersaturation as well as the release of anoxic layers from reservoirs), temperature changes (reservoir releases are often cooler than normal river flows), pollution (including the creation of highly toxic methylmercury in reservoirs), and sediment, which can block light, smother spawning habitat, and clog fish gills.

Dams also alter nutrient flows. Retained and diverted sediment and water can greatly change downstream conditions by reducing the nutrient status and therefore the primary productivity of downstream waters. (Note: the oft-quoted example of the collapse of the sardine fishery off the Nile Delta in the 1980s following construction of the High Aswan Dam some 600 km upstream is actually a complex topic with numerous factors, such as security limitations on fishing areas. See Biswas & Tortajada for details[81]).

On the Mekong, as explained in the Final Report of the MRC SEA for Mekong mainstream hydropower:

[81] Biswas, A.K. & C. Tortajada. 2012. Impacts of the High Aswan Dam. In: C. Tortajada et al. (eds.). 2012. *Impacts of Large Dams: A Global Assessment.* Springer-Verlag, Berlin & Heidelberg.

The impacts on water quality differ during construction and operational phases. Depending on the phasing of mainstream projects, the construction period impacts could be drawn out well beyond a single project construction phase of some 5 to 8 years.

Construction: *the adverse water quality impacts during construction are likely to be worst in the dry season:*

- ***Increased sediment loads:*** *rock blasting and earth moving activities are likely to increase sediment loads, which could have significant localized implications smothering gravel beds and riffles downstream and impacting on fish spawning.*
- ***Increased organic matter:*** *increased solid and wastewater loading with localized implications.*
- ***Increased oxygen demand:*** *the Cambodian projects would flood large land areas causing decomposition of vegetation matter.*
- ***Spillages:*** *localized implications from fuels, oils, toxic compounds, concrete & other construction materials into the downstream areas.*

Operational phase: *the long-term implications of the LMB mainstream projects to water quality of the Mekong River would be less severe than during construction:*

- ***Reduced turbidity:*** *the sediment load would drop by 75% (1/3 of which is directly related to the mainstream dams) this would in the long term reduce the turbidity of the water column.*
- ***Reduced organic matter transport:*** *the Mekong River transports a significant amount of vegetative and woody debris along its length; this movement plays an important role in the recycling of nutrients back into the Mekong system. The mainstream dams would concentrate this matter within the reservoirs severing one of the important longitudinal bio-chemical connections between the headwaters and floodplains of the Mekong system.*
- ***Cumulative effects:*** *predictions suggest that by 2030, phosphorous and nitrogen levels would increase by 100% and 85%, respectively, while waste water discharges would increase by 35%, potentially leading to seasonal localized reductions in water quality in some of the mainstream reservoirs.*
- ***Increased risk of major pollution events:*** *products used during operations, for example, transformer oil, have the potential to cause catastrophic impacts of water quality through spillages, leaks and component failure.*

4.2.5 Other Impacts

Fish passing through turbines and spillways are subject to stresses, injuries, and mortalities. The following descriptions are based on FAO Fisheries Technical Paper 419[82].

[82] Marmulla, G. (ed). 2001. Dams, Fish and Fisheries: opportunities, challenges and conflict resolution. *FAO Fisheries Technical Paper 419.* FAO, Rome.

- **Turbine intake:** fish passing through hydraulic turbines are subject to various forms of stress, likely to cause high mortality: shocks from moving or stationary parts of the turbine (guide vanes, vanes or blades on the wheel), sudden acceleration or deceleration, very sudden variations in pressure and cavitation. Numerous experiments have been conducted in various countries (USA, Canada, Sweden, Netherlands, Germany and France), mainly on juvenile salmonids and, less frequently, on clupeids and eels, to determine the mortality rate due to passage through the main types of turbine.

  The mortality rate for juvenile salmonids in Francis and Kaplan turbines varies greatly, depending on the properties of the wheel (diameter, speed of rotation, etc), their conditions of operation, the head, and the species and size of the fish concerned. The mortality rate varies from under 5% to over 90% in Francis turbines. On average, it is lower in Kaplan turbines, from under 5% to approximately 20%. The difference between the two types of turbines is due to the fact that Francis turbines are generally installed under higher heads.

  Mortality in adult eels (*Anguilla* spp.) is generally higher, because of their length. The mortality rate may be 4 to 5 times higher than in juvenile salmonids, reaching a minimum of 10% to 20% in large low-head turbines (as against a few per cent in juvenile salmonids), and more than 50% in the smaller turbines used in most small-scale hydroelectric power plants.

  The mortality rate may be higher for certain species. In physostomous species (e.g. salmonids, clupeids and cyprinids), the pressure in the swim bladder can be regulated relatively quickly through the air canal and the mouth, and these species will resist sudden variations in pressure. In physoclistic species (e.g. percids), pressure is regulated much more slowly by gaseous exchange with the blood vessels in the wall of the swim bladder. The risk of rupturing the swim bladder following a sudden drop in pressure is thus much greater, and physoclistic fish are thus much more susceptible to variations in pressure.

- **Damage due to passage through spillways:** passage through spillways may be a direct cause of injury or mortality, or an indirect cause (increased susceptibility of disorientated or shocked fish to predation). The mortality rate varies greatly from one location to another: between 0% and 4% for the Bonneville, McNary, and John Day dams (about 30 m high spillways) on the Columbia River, 8% at the Glines dam (60 m high spillway), and 37% at the Lower Elwha dam (30 m high spillway) on the Elwha river for juvenile salmonids (Bell and Delacy, 1972[83]; Ruggles and Murray, 1983[84]).

  Mortalities have several causes: shearing effects, abrasion against spillway surfaces, turbulence in the stilling basin at the base of the dam, sudden variations in velocity and pressure as the fish hits the water, physical impact against energy

[83] Bell, M.C. and A.C. Delacy, 1972. *A Compendium on the Survival of Fish Passing through Spillways and Conduits*. Report Fish. Eng. Res. Prog., U.S. Army Corps of Eng., North Pacific Div., Portland, Oregon, USA.

[84] Ruggles, C.P. and D.G. Murray, 1983. *A review of fish response to spillways*. Canadian Technical Report of Fisheries and Aquatic Sciences 1172, Freshwater and Anadromous Division., Resource Branch Department of Fisheries and Oceans, Halifax, Nova Scotia.

dissipators. The manner in which energy is dissipated in the spillway can have a determinant effect on fish mortality rates.

Experiments have shown that significant damage occurs (with injuries to gills, eyes and internal organs) when the impact velocity of the fish on the water surface in the downstream pool exceeds 16m/s, whatever its size (Bell & Delacy, 1972). A column of water reaches the critical velocity for fish after a drop of 13 m. Beyond this limit, injuries may become significant, and mortality will increase rapidly in proportion to the drop (100% mortality for a drop of 50-60 m).

Passage through a spillway under free-fall conditions (i.e. free from the column of water) is always less hazardous for small fish, insofar as their terminal velocity is less than the critical velocity. For larger fish, hazards are identical, whether they pass under free-fall conditions or are contained in the column of water.

Further impacts on fisheries may result from changed social conditions: better access may encourage in-migration and higher fishing pressure - or people displaced by construction and operation may move into the headwaters, clear land and cause sediment problems.

TRAINING AIDS	
Discussion topics	***1)*** Is it possible to extract energy from rivers without harming fish? ***2)*** Are hydropower impacts on fish and fisheries reversible? ***3)*** Dams have a limited lifespan, fisheries do not; how can society trade off short-term gain against long-term loss?
Exercises	• List the possible ways a hydropower project could affect fish. • For a dam you know, summarise the changes in hydrology upstream and downstream. How might these affect fish? How have they affected fish and the fisheries?
Additional reading and resources	***1)*** Hydropower Dams Hamper Migrating Fish Despite Passage Features, Study Finds. University Communications. Jan 16, 2013. http://uanews.org/story/hydropower-dams-hamper-migrating-fish-despite-passage-features-study-finds 2) Chris Barlow. 2008. Dams, fish and fisheries in the Mekong River Basin. *Catch and Culture* 14: 2. http://ns1.mrcmekong.org/Catch-Culture/vol14_2Sep08/dams-fish-fisheries.htm ***3)*** The MRC Final Report of the SEA for Mekong mainstream hydropower (2010). http://www.mrcmekong.org/assets/Publications/Consultations/SEA-Hydropower/SEA-FR-summary-13oct.pdf ***4)*** *Review of downstream effects of dam design and operation*. Chap. 6 in: FAO: Dam design and operation to optimize fish production in impounded river basins. http://www.fao.org/docrep/005/AC675E/AC675E06.htm ***5)*** Video clips on dams at: http://videos.wisegeek.org/videos/495322408.htm

Case Studies

This case study concerns the Pak Mun Dam in Thailand. The case study was developed for the World Commission on Dams and is available online at http://geocompendium.grid.unep.ch/reference_scheme/final_version/GEO/Geo-2-054.htm

Pak Mun Dam, Thailand

The Pak Mun Project: Description

The Pak Mun Dam is located on the Mun River, 5.5km upstream from its confluence with the Mekong, in the province of Ubon Ratchathani, in Northeast Thailand. The dam is categorized as roller compacted concrete, with a maximum height of 17m and total length of 300. The reservoir has a surface area of 60 square km at normal high water level of 108 metres above the mean sea level (MSL) and a capacity of 225 million cubic metres. The Electricity Generating Authority of Thailand (EGAT) built and operates the dam as a run-of-the-river hydropower plant. Its operating rules are designed to ensure that the water level does not rise above 106m MSL during the dry season, from January to May, and retains a maximum level of 108m MSL for the rest of the year. The storage capacity of the dam's reservoir is essentially that of the pre-existing river channel.

The Environmental Impact Studies conducted in 1982 indicated that approximately 4000 households would be displaced if the reservoir was impounded to a level of 113 MSL. Therefore an alternative design, with a normal water level of 108 MSL, was agreed upon in 1985. The relocation of the dam site significantly minimised the extent of displacement to an estimated 248 households. The original project design was further modified by relocating the dam 1.5km upstream to avoid the submergence of Kaeng Tana rapids—an important environmental and tourist site. EGAT also decided to lower the reservoir to 106 MSL during dry season from January to May and to adjust the dam's operating regime to uncover the upstream Kaeng Saphue rapids. However a new environmental impact assessment (EIA), which may have identified and anticipated some of the new environmental impacts arising from the new location, was not conducted at this stage.

Benefits - Fisheries

About 7% of the project benefits were attributed to fisheries in EGAT's 1988 project documents.

The 1981 EIA predicted that fish production from the reservoir would increase considerably, though some fish species may be affected by the blockage of river flows by the dam. The fish yield expected from the 60 square km Pak Mun reservoir was 100 kg/ha/year, without fish stocking, and 220 kg/ha/year with the fish-stocking programme. However, run-of-the-river reservoirs cannot sustain such high yields, as they do not provide the appropriate habitat for pelagic fish species. In Thailand even storage reservoirs that perform better under fish stocking programmes have a fish yield of about 19 to 38 kg/ha/year. The predicted fish yield from Pak Mun head pond was too high. A more realistic estimate would have been around 10 kg/ha/year. There has been no evidence to indicate that the fish productivity of Pak Mun reservoir has reached anywhere near the anticipated 100 kg/ha/year.

The 1981 EIA valued the total annual predicted fish catch in the head pond at US$ 320 000, at the rate of 20 Baht per kg, without stocking. With the stocking program, the predicted catch would be worth US$ 693 000, at the rate of 20 Baht per kg. The 1981 EIA underestimated the total value of fishing yields that could be obtained from the free-flowing river. After the completion of Pak Mun dam, the lower Mun River experienced a decline in fishing yields with an estimated value of US$ 1.4 million per annum at 20 Baht/kg. In addition to this, the decline in fish species upstream led to the closure of 70 Tum Pla Yon traps. At the price of 18 Baht/kg at the end of 1980s, the value of annual catch from these traps is calculated at US$ 212 000 per annum (1 US$ = 38 Baht). EGAT and the World Bank expressed their disagreement with the study team's findings. A detailed basis for the conclusion is presented in the annex related to EGAT's comments.

Impacts

The 1982-83 Environmental Planning Survey predicted 241 households displaced. The actual number of households displaced by Pak Mun dam was 1,700. Not predicted by the EIA, a large number of households were adversely affected due to declining fishing yields. Until March 2000, 6,202 households were compensated for loss in fisheries during the 3-year construction period. Compensation for the permanent loss of fisheries has not been given.

What were the unexpected impacts, if any?

Impact on Fish Migration & Fish diversity

Of the 265 fish species recorded in the Mun-Chi watershed before 1994, 77 species were migratory, and 35 species are dependent on habitat associated with rapids.[3] Available evidence does not indicate disappearance of any species before 1990, and nearly all species are common to the region. Out of 265 species, about 10 were introduced.

The decline has been higher in the upstream region. The latest survey recorded 96 species in the upstream region. Out of 169 species not found in the present catch, 51 species have been caught less significantly since the completion of the project. At least another 50 species of rapid dependent fish have disappeared, and many species have declined significantly. Migratory and rapid dependent species were affected seriously as their migration route is blocked in the beginning of the rainy season, the head pond has inundated their spawning ground, and the fish pass is not performing. Long-term studies are required to arrive at a firmer conclusion on the exact number of species that disappeared from Chi - Mun river basin after the construction of Pak Mun dam. The fish catch directly upstream of the dam has declined by 60-80% after the completion of the project.

Views diverge with regard to the dam’s impact on the decline in fish species—particularly, if this decline could be attributed soley to the dam. Some argue that the decline might have started prior to the study.

The Pak Mun case study concludes that the difference in number of species in fish surveys before and after dam construction may be exacerbated by the cumulative impact of many different developments in the watershed. These include: water resources and hydropower development in Chi-Mun river watershed, deforestation, domestic waste water discharge, agriculture intensification and development, fisheries, industrial waste water discharge, saline soils and enforcement of water quality standards and classification. All these developments have contributed to a decline in fish species in the Mun/Chi watershed as a whole. The Pak Mun Dam cannot be blamed for the apparent disappearance of all these fish species. Cumulative impacts of all developments including the Pak Mun Dam have led to disappearance of fish species. Downstream of the Pak Mun project, one or two species of fish have completely disappeared from the catch after the dam construction.

Location of the dam on the Mun river 5.5 km upstream from its confluence with the Mekong has affected several migrating and rapid-dependent fish species. Thus, decline in and disappearance of several migrating and rapid-dependent fish species are directly attributable to the Pak Mun dam.

Performance of Fish Pass

The project provided several mitigation measures, including a fish ladder to facilitate fish migration. Provision of a fish ladder was based on very little knowledge and experience. This mitigation plan came out at the time the dam construction was almost completed; and even then this important plan was not well prepared.

The 1981 EIA did not consider the construction of a fish ladder necessary for the Pak Mun dam but recommended the feasibility study of a fish way. The plan for a fish pass came at a time when dam construction was almost completed. In effect, the fish pass was constructed after the completion of the dam at the cost of 2 million Baht (US$ 0.08 million). The fish pass has not been performing and is not allowing upstream fish migration. Project authorities have discontinued monitoring the fish pass.

A vertical slot fish pass, or a Denil fish pass, instead of a pool and weir fish pass, may have been more effective.

Reservoir Stocking as Mitigation

Reservoir fishery was developed by EGAT in response to claims of declining fish catch. Total cost of stocking the head pond with freshwater prawn (*Macrobrachium rosenbergi*) ranged between US$ 31 920 and US$ 44 240 annually between 1995-98. The Department of Fisheries estimates the total annual revenue of fishing yield to range between 1.2 to 3.2 million Baht. However the estimated annual catch and revenue for fishermen are too high. The Department of Fisheries, in their revenue estimate, included the naturally occurring *Macrobrachium* species that can breed in fresh water. The *M. rosenbergi* spawns in salt water and migrates to fresh water and therefore cannot establish a population under reservoir conditions. For this reason, it may well turn out that the stocking of *M. rosenbergi* in Pak Mun head pond is not generating any income for the fishermen. The project has discontinued fish and prawn stocking.

Impact on Livelihoods

In the post-dam period fishing communities located upstream and downstream of the dam reported 50-100% decline in fish catch and the disappearance of many fish species. The number households dependent on fisheries in the upstream region declined from 95.6% to 66.7%. Villagers who were dependent on fisheries for cash income have found no viable means of livelihood since the dam was built, despite efforts to provide training opportunities. As their food security and incomes destabilised, they sought various ways to cope, including migration out to urban areas in search of wage labour.

Some households had to settle in forest reserve areas or on other common property as the compensation money was insufficient to buy alternate land. The Thai economic crisis affected households that did not use the compensation money to buy productive assets. Cropping incomes have declined, and there has been a reduction in livestock as people are selling both, due to a shift from farm based occupations, as well as reduced grazing land.

Next to fisheries, loss of access to common property, such as forest and grazing land, has been among the other adverse impacts. Forests and riverbank dry season gardens were not compensated.

Since the completion of the project, several committees were set up to assess the number and extent of households affected by loss of fisheries income. In all, over 6 202 fishermen demonstrated to the committee that they were engaged in fishing and their income affected following construction and operation of Pak Mun dam.

Based on the committee's findings, EGAT paid 90 000 Baht to each of the 3 955 fishermen in 1995, and it approved payment of 60 000 Baht each to another 2 200 fishermen in March 2000. Still, a large number of households located upstream of the dam are still waiting to be recognised for compensation. Unexpected costs of the project included the compensation for fisheries (488.5 million Baht had been paid up to March 2000) and investment on fish and prawn stocking programme. Till March 2000, 488.5 million Baht (US$ 19.5 million) had been paid as compensation for loss of fisheries livelihood.

While the government acknowledged the impact on fisheries and agreed to compensate eligible households at the rate of 90 000 Baht as compensation for loss of income during the three-year construction period, mitigation for the long-term loss of fisheries livelihood is under negotiation. On January 25, 1997, the villagers from Pak Mun joined the 99-day protest in Bangkok, demanding fair compensations for the permanent loss of their fishing livelihood. Land and cash compensation promised by the government in April 1997 was retracted under a new political regime in 1998. From March 1999 villagers began demonstrations to be compensated by the Government and the World Bank for permanent loss of income from fisheries.

4.3 Fisheries Mitigation

Key aspects	• Fisheries mitigation begins with **avoidance**. • If a project is to be built, then **fisheries interests must participate in the design process** to achieve mitigation. • Mitigation requires design decisions and also affects operating rules, so **fisheries scientists must work with engineers** – and also social scientists and economists. • **Fish passes only work for some species under some conditions**. • **Reservoir fisheries can be successful**, but need management. • There is increasing experience with the **removal of dams** to restore fisheries. • Fisheries are complex and **require a high level of information** and data for successful mitigation and decision-making.

TRAINING AIDS	
Purpose of session	To introduce trainees to the range of decisions and measures needed for effective fisheries mitigation.
Learning objectives	• To understand the challenges involved in fisheries mitigation. • To understand the need for high levels of information for fisheries mitigation. • To understand that fisheries objectives need to be established in order to plan fisheries mitigation. • To understand that fish passes are unlikely to mitigate the impacts of hydropower projects except under very specific circumstances. • To understand that reservoir fisheries can be important but need careful design and management. • To be aware of the emerging movement for dam removal and river restoration, to restore healthy rivers.
Key readings	***1)*** Larinier M. & G. Marmulla. Fish Passes: Types, Principles and Geographical Distribution: an Overview. http://www.fao.org/docrep/007/ad526e/ad526e0g.htm

4.3.1 The Objectives of Fisheries Management in Relation to Dams

When planning a hydropower project on a fish-bearing river, the first step is to determine the objectives of fisheries management. As stated by Bernacsek[85], there is a large amount of diversity in dam designs, dam operations, affected environments and climatic zones world-wide. Nonetheless, it is possible to specify sets of fisheries management objectives that will apply to most dams. Firstly, conventional or normative management objectives, which are not unique to dam-impacted fisheries but apply to most fisheries throughout the world, generally include some or all of the following:

- To maintain stock abundance at high levels.
- To reduce the risk of overexploitation and stock collapse.
- To achieve sustainability of production of commercially important species.
- To prevent the loss of fish biodiversity.
- To maintain levels of employment and enhance incomes within the fisheries sector.
- To supply domestic consumers with good quality fish at affordable prices.
- To produce fish products for export.

Secondly, because dams impose very specialized and rigorous conditions on fisheries and aquatic environments, a further set of dam-specific objectives may be formulated to support and elucidate the above general objectives. These include:

- To provide effective bypass facilities for fish (and other animals) migrating upstream across the dam.
- To provide safe and effective bypass facilities for fish migrating downstream across the dam.
- To develop the new fisheries potentials created in the reservoir of the dam.
- To maintain fish biodiversity and production in affluent streams entering the reservoir.
- To maintain fish biodiversity and production in the riverine environments downstream from the dam.
- To maintain fish biodiversity and production in the saltwater environments (delta, estuary and adjacent sea) downstream from the dam.

Achievement of all of these objectives is a difficult undertaking for most dams, and the degree of difficulty generally increases with increasing dam wall height. Sound planning of management strategies and operations, founded on a reliable and comprehensive information base, is essential for achieving successful outcomes. Some general recommendations to minimise the effects of dams on fisheries are given in **Box 4-2**.

[85] Bernacsek, G. 2001. Environmental Issues, Capacity and Information Base for Management of Fisheries Affected by Dams. In: FAO Fisheries Technical Paper 419.

Box 4-2: Recommendations on Dams and Fisheries

Avoid blocking migrations. Avoid blocking short- and long-distance migrations—and hence the loss of genetically distinct stocks, and/or the extirpation or extinction of species. Blocking upstream migrations of anadromous species means impacts on species and nutrient transport into upstream ecosystems.

Maintain seasonality of flow. The natural seasonal pattern of flow vital is vital in life history stages such as migrations, spawning and feeding.

Maintain discharge volume. Zero discharge from dams should be avoided except in very extreme emergencies. A sufficient volume of flow is required to inundate flood plains, recharge wetlands and connect oxbows with the main stem, as well as provide sufficient depth for larger species.

Sustain water quality. Appropriate temperatures, oxygen, turbidity and sediment levels are necessary for well-being or survival of aquatic species. **Pollution should be avoided.**

Guard unique species habitats. Certain watershed will have unique habitats that require maintenance or protection, *e.g.* woody debris, springs, cave streams, reeds, deltas, mangroves, or keystone species that sustain other species.

Avoid cumulative impacts of dams. Establish limits to numbers or proximity of dams that will prevent extinctions through additive or synergistic effects in rivers and estuaries. At the same time, take into consideration existing impacts of other sectors when planning a new dam.

Monitor impacts at old and new dams. One of the most serious information gaps is the lack of follow-up information on the environmental and biodiversity impacts following dam construction. One, five, 10, 15, 20 and 25 year follow up studies on dam impacts are required. The information in hand is largely *ad hoc*, gathered at random times for other purposes, such as identifying endangered species. How can we plan more environmentally friendly dams without serious programs of follow-up studies, carried out by individuals and organisations at arm's-length?

Enhance situations at existing dams. The delivery of 'products' and the conservation of biodiversity at extant dams should be enhanced. More power can be generated by retrofitting existing systems, making more water available for biodiversity.

Retrofit turbines and control systems. Installing new and efficient turbines and electronic control systems can deliver more power for the same—or even lesser—amounts of water. With 39,000 large dams (WRI 1994) already in existence by the early 1990s, a certain proportion are not functioning at peak capacity. This represents both an enormous entrepreneurial prospect and an enormous environmental opportunity. Retrofitting existing dams for high modern efficiency provides an opportunity to deliver more electricity or irrigation water with minimal additional environmental impact. Dorcey *et al.* (1997) outline some of the ways in which existing dam projects may be upgraded. They state that it is often possible to boost the performance of existing projects with relatively little incremental environmental or social impact, and to avoid or delay the construction of new dam projects.

Install efficient electrical devices. Cost-effective programmes have shown that electric power demand can be cut through use of efficient lights, motors, *etc.*

Eliminate leaks in dam and irrigation systems. The elimination of leaks and the reduction of evaporation can save water for other uses. Existing irrigation canals in particular older or less well constructed can be re-lined to prevent leakage. Rubber liners provide only one of many options for re-engineering.

Decommission dams. Dams which have reached the end of their life cycle or which are no longer productive can be decommissioned. The river system can then be restored to its natural state. This is not without its problems.

Research and install devices for migrating species. Research is needed to improve the design of devices to facilitate the up and downstream migration of species. These can be installed on dams lacking them, or existing devices can be upgraded.

Create aquatic and terrestrial protected areas. The creation of land and aquatic protected areas as part of integrated dam projects can offer more efficient dams and better protection of biodiversity.

Source: McAllister *et al.* 2001. *Biodiversity Impacts of Large Dams*. Background Paper No. 1, prep. for IUCN / UNEP / WCD.

4.3.2 Avoidance and Minimisation

Minimisation of impacts on fisheries depends on many choices during both project design and operation. In addition, in some cases, steps can be taken to minimise impacts on fisheries during construction. The fundamental approach to mitigation of the impacts of hydropower on fish and fisheries is to avoid the impacts in the first place. This requires strategic water and energy development planning to determine the need for hydropower against other sources of energy, and then to select sites and hydropower technologies that avoid or minimise impacts on fish.

Site selection is critical: some steep mountain streams have little or no fish fauna and can be developed with very low biological impacts, but these are generally small-scale schemes. For larger projects, it is generally a better strategy to develop tributaries rather than the main stem of a river, since this leaves the main stem free for fish migrations to remaining upstream habitat. This approach can be overwhelmed, however, if development is sufficiently intensive (**Box 4-3**). Another strategic approach is to maintain at least one complete river in its wild state, whilst focusing hydro development elsewhere.

Box 4-3: Damming the Mekong Tributaries – Impacts on Fish

The Mekong River Basin, site of the biggest inland fishery in the world, is undergoing massive hydropower development. Planned dams will block critical fish migration routes between the river's downstream floodplains and upstream tributaries. Here we estimate fish biomass and biodiversity losses in numerous damming scenarios using a simple ecological model of fish migration. Our framework allows detailing trade-offs between dam locations, power production, and impacts on fish resources. We find that the completion of 78 dams on tributaries, which have not previously been subject to strategic analysis, would have catastrophic impacts on fish productivity and biodiversity. Our results argue for reassessment of several dams planned, and call for a new regional agreement on tributary development of the Mekong River Basin.

Source: Ziv *et al.* 2012. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. Proc. Nat. Acad. Sci. Vol. 109, No. 15 http://www.princeton.edu/~slevin/PDF/Levinpubs/466_ZivMekong.pdf

For any particular site, minimisation of impacts on fisheries can be achieved by measures directed towards (i) **protection of fish habitat**, and (ii) **protection of fish movement**. After applying these measures, further efforts can be directed towards **fisheries enhancement** (e.g. hatcheries and reservoir fisheries).

Measures to protect habitat centre on instream flow requirements (IFRs), with typical approaches being to minimise the length of dewatered reaches, ensuring instream flows in dewatered reaches, and implementing environmental flow programmes for releases to mimic pre-dam flow regimes downstream. Habitat protection can also include measures to control the temperature of released water (which requires upstream intakes capable of drawing water from a variety of depths in the reservoir), and artificial destratification of reservoir waters—for example, by bubbler-pipes laid across the reservoir near the dam wall.

Measures to protect fish movement have to consider both upstream and downstream movement at different stages of the life cycle. Upstream movement past dams requires some sort of fish pass (see 4.3.4). Downstream movement must include consideration of measures to minimise mortality, such as fish excluders at intakes and different turbine designs to minimise pressure differences and thus improve the survival of small fish passing the blades.

Fisheries enhancement can involve a wide range of measures, for example, improved management of river fisheries downstream, habitat improvement in remaining spawning areas, or hatcheries. Habitat can also be improved on other river systems – this is a form of conservation **offset**.

A major feature of many hydropower projects with storage dams is the **reservoir fishery** (see 4.3.5).

An increasingly important approach, applied to existing dams, is dam removal. This returns the river to a free-flowing condition (see 4.3.6).

All of these topics are highly technical and require a significant input of information to be successfully applied. Some introductory sources of information are given in the Additional Reading table. The topics Fishes Passes, Reservoir Fisheries and Dam Removal are introduced below.

4.3.3 Environmental Flows

See Session 7.2.

4.3.4 Fish Passes

4.3.4.1 International Experience

The following overview is based on Larinier & Marmulla (2003)[86]:

[86] Larinier, M. & G. Marmulla. 2003. *Fish Passes: Types, Principles and Geographical Distribution – an Overview*. In: Proc. Second Int. Symp. on the Management of Large Rivers for Fisheries. 11-14 Feb. 2003, Phnom Penh. http://www.fao.org/docrep/007/ad526e/ad526e0g.htm

Upstream fish passage: these technologies are well developed for certain anadromous species, mainly salmonids (e.g. salmon, trout) and clupeids (e.g. shad, alewives, blueback herring) in North America and Europe. Upstream passage can be provided through several types, including pool-type fish passes, Denil type (or baffle-type) fish passes, nature-like bypass channels, fish lifts and fish locks, or collection and transportation facilities. Special designs for catadromous species (mainly eel) have been developed in Europe, Japan, New Zealand and Australia.

The design of a fish pass must take into account the behaviour of the target species. Effectiveness is closely linked to water velocities and flow patterns. Thus the water velocities in the pass must be compatible with the swimming capacity and behaviour of the target species. A large water level difference between pools, excessive aeration or turbulence, large eddies, or low flow velocities can act as a barrier for fish. In addition to hydraulic factors, fish are sensitive to other environmental parameters (level of dissolved oxygen, temperature, noise, light, odour, etc.), which can have a deterrent effect.

The main passive structures for adult fish are (i) pool-type fish passes, (ii) Denil fish passes, and (iii) nature-like fish passes. (i) Pool-type fish passes divide the ascent into a series of pools, separated by drops, which the target species are able to ascend, using the pools for resting; the pools also provide energy dissipation in the water, with specific parameters for specific species; there are many different designs, some of which allow fish passage despite large variations in water levels and flows. (ii) Denil fish passes rely on baffles, placed within a single flume and although allowing for highly efficient energy dissipation, they have no resting places; they were developed in Europe and are suitable for large individuals of some fish species such as salmon. (iii) Nature-like fish passes are low-gradient channels, built to simulate a natural stream bed with rocks, riffles and pools; adapting these passes to cope with variations in upstream water level is difficult, because the necessary control structures may interfere with fish passage.

A critical design feature of upstream fish passes is the downstream entrance. This must be sited as near the obstruction (dam) as possible and have sufficient flow to attract the target species. Since hydraulic conditions downstream of dams and associated powerhouses are usually highly complex and variable, the design and location of fish pass entrances remains a major challenge.

Active fish pass facilities include (i) fish lifts, whereby fish enter into a trough or trap and are is then physically lifted, with fish and water, and emptied above the obstruction; (ii) fish movement upstream via the normal use of navigation locks; and (iii) trapping and transport, sometimes used during dam construction.

As reported by Larinier & Marmulla (2003), when the causes of poor performance (in terms of effectiveness and/or efficiency) of fish facilities are analysed, certain factors are frequently revealed:

- Lack of attraction of the facility, resulting from a poor position of the fish pass or insufficient flow at the entrance of the facility in relation to the flow discharge into the river.
- Poor design of the facility, with regard to the variations in water levels upstream and downstream during the migration period, resulting in undersupply or oversupply of flow to the fish pass, or excessive drop at the entrance. This may be due to poor appreciation of the range of the upstream and/or downstream water levels during the project planning phase, or a subsequent change in these levels.

- Poor dimensions,i.e. pools with insufficient volume causing excessive turbulence and aeration, excessive drop between pools, insufficient depth for the fish, or the flow pattern in the pools not suitable for the target species.
- Frequent clogging or obstruction of the passage facility, resulting from inadequate protection against debris, too exposed a position, or, quite simply, inadequate maintenance on the part of the operator.

Other factors may also come into play at fish passes, including their attraction for predators, typically birds and humans: if unprotected, fish passes can result in 100% mortality, since they are excellent locations to catch fish by nets.

Downstream fish passage technologies are much less advanced than those for upstream passage and are in need of research. This is partly due to the fact that efforts towards re-establishing free movement for migrating fish began with the construction of upstream fish passage facilities; downstream migration problems have only been considered more recently. In addition, the development of effective facilities for downstream migration is much more difficult and complex. Research continues. As a general rule, problems concerning downstream migration have been thoroughly examined in Europe and North America with regard to anadromous species—and, more particularly, to salmonids. Comparatively little information is available for other species.

As stated in a recent summary report[87], fish that migrate downstream past hydropower projects have three primary routes of passage. They may be (i) drawn into the power plant intake flow (entrainment) and pass through the turbine, (ii) diverted via bypass screens into a gatewell and to a collection facility or the tailrace, or (iii) passed over the dam in spilled water. Entrained fish are exposed to physical stresses (e.g., rapid changes in pressure, shear, turbulence, blade strike), which may be injurious. In the best conventional turbines up to 5% of turbine-passed fish may be injured or killed, and mortalities in some turbines may be 30% or more. Several new advanced turbine concepts have been tested or are under development that may reduce mortality of turbine-passed fish to 2% or less.

Non-turbine passage routes pose some risk to fish as well: weak swimmers, such as juvenile lamprey and small resident fish, may be impinged or injured upon contact with bypass screens. The design and location of outfalls from fish bypasses are also critical to minimize exposures of bypassed fish to predatory fish in the dam tailrace.

Fish that pass via the spill of high-head dams are subjected to extremely high and variable water velocities, may be abraded by contact with the dam face, and may collide with submersed structures below the dam, including those designed to dissipate the high energy of spilled water. However, project spills may reduce residence time of migrating fish immediately above the dam during which they are vulnerable to predators in the reservoir. Thus, design of the entire project from forebay entrance to tailrace exit impacts the safe and efficient passage of fish.

Entrainment: a large number of systems exist to prevent fish from being entrained into water intakes; however, they are by no means as effective as bypasses. They may take the form of physical barriers, which physically exclude fish from turbine intakes (e.g. nets or

[87] National Hydropower Association, Oak Ridge National Laboratory, Hydro Research Foundation. 2010. *Environmental Mitigation Technology for Hydropower: Summary Report on a Summit Meeting*, Washington, DC June 2-3, 2010.

screens), or behavioural barriers that attract or repel fish by means of applying stimuli to elicit behavioural responses. Bypasses for downstream passage can be complemented with such systems. The design of effective facilities for assisting the downstream passage of fish must take into account the swimming ability and behaviour of the target species and the physical and hydraulic conditions at the water intake.

Effectiveness: there are many success stories at individual dams for certain species, but these are largely confined to the world's temperate zones or mountain regions, with cold-water fish. Even so, as a strategy to maintain fisheries in the presence of dams, fish pass facilities are not a certain answer (see **Box 4-4**).

Box 4-4: Fish and Hydropower on the US Atlantic Coast

Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies

Globally, diadromous species are at risk from fragmentation by damming of rivers, and a host of other anthropogenic factors. On the United States Atlantic Coast, where diadromous fish populations have undergone dramatic declines, restoration programs, based on fishway construction and hatcheries, have sustained remnant populations; however, large-scale restoration has not been achieved. We examine anadromous fish restoration programs on three large Atlantic Coast rivers—the Susquehanna, Connecticut, and Merrimack—with multiple mainstem hydropower dams, with relatively low generating capacity. Mean passage efficiencies through fishways on these rivers from the first dam to the spawning grounds for American shad are less than 3%. The result is that only small fractions of targeted fish species are able to complete migrations. **It may be time to admit failure of fish passage and hatchery-based restoration programs and acknowledge that significant diadromous species restoration is not possible without dam removals.** The approach being employed on the Penobscot River, where dams are being removed or provided the opportunity to increase power generation within a plan to provide increased access to habitat, offers a good model for restoration. Dammed Atlantic Coastal rivers offer a cautionary tale for developing nations intent on hydropower development, suggesting that lasting ecosystem-wide impacts cannot be compensated for through fish passage and hatchery technology.

Source: Jed Brown *et al.* 2013. Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies. *Conservation Letters*. [88] Abstract online at: http://onlinelibrary.wiley.com/doi/10.1111/conl.12000/abstract

4.3.4.2 Fish Passes - Mekong

Fish passes have been developed largely in North America and Europe for a very limited number of species, mainly salmonids and clupeids. A major challenge for assessing the likely success of fish passes as mitigation measures in the Mekong region is that, given the great diversity of species and the large associated biomass, scientific knowledge about the biology, fishery, size, stamina, ability to jump and swimming behaviour of the fish species remains very limited. The feasibility of fish pass facilities to handle the diversity and biomass of the Mekong is highly questionable.

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[88] *Hydropower Dams Hamper Migrating Fish Despite Passage Features, Study Finds*. University Communications. Jan 16, 2013 http://uanews.org/story/hydropower-dams-hamper-migrating-fish-despite-passage-features-study-finds

Consequently, in early 2008 the MRC established a group of 17 international specialists in the area of fisheries science and engineering. A meeting of the Expert Group was held in September 2008 with the objectives of (i) drawing lessons learnt from the Columbia, Fraser and Parana rivers, their fish and fisheries; and (ii) applying this information to the Mekong.

The knowledge obtained from the meeting was written up in early 2009. The major concern of the Expert Group meeting was that fish passage facilities on dams on the Mekong will have to meet three obvious requirements to be successful:

1. Fish must find entrances;
2. Fish must be able to ascend/ descend;
3. Fish must exit and continue migration.

At present the MRC's Design Guidance for dams requires, for example, that:

60. Fish passage must be incorporated – upstream and downstream
61. Safe passage for 95% target species and individuals, at all flow conditions
65. Adopt best international practice, utilize core expert group (developer pays)
73. Adequate flows through fish pass
71. Mortality through fishways < 5%
89. Contingency fund for modification - 20% of initial cost of fish pass

However, the Group concluded that currently no evidence exists of fish-passage facilities in large tropical rivers in Latin America, Africa and Asia, which can cope with the Mekong's massive migrations and biodiversity. Even the strongest evidence from South America (Oldani & Baigin, 2002) revealed low success of fish ladders and lifts in safely transporting the volume of species—a lower number than in the Mekong.

Similarly, the Group agreed that the technologies used on high dams in North America and Europe (mainly fish ladders and fish lifts) have been developed for a very limited range and number of fish species (generally about only 5 to 8 species). Most of this experience has been with salmonid fish, which have remarkable jumping abilities, enabling them to scale waterfalls and fish ladders more successfully than any other group of fish. The biomass of fish involved is also relatively small, for example, at around 3 million fish per year on the Columbia River in the USA. This experience from North America and Europe contrasts with the Mekong, where at least 50 important, non-salmonid, migrant species, and biomass in the order of 100 times greater[89].

Even where an individual fish pass is effective, the a cumulative effect of an existing series of dams and passes must be taken into consideration. As explained in the MRC SEA for the Mekong mainstream hydropower:

> *"Whatever the fish pass model considered, an additional element must also be taken into account: the cumulative impact of dams. For example, should the passage effi-*

[89] Patrick Dugan (2008). Mainstream dams as barriers to fish migration: international learning and implications for the Mekong. Catch and Culture. Vol. 14, number 3, 2008.http://ns1.mrcmekong.org/Catch-Culture/vol14_3Dec08/mainstream-dams-barriers.htm

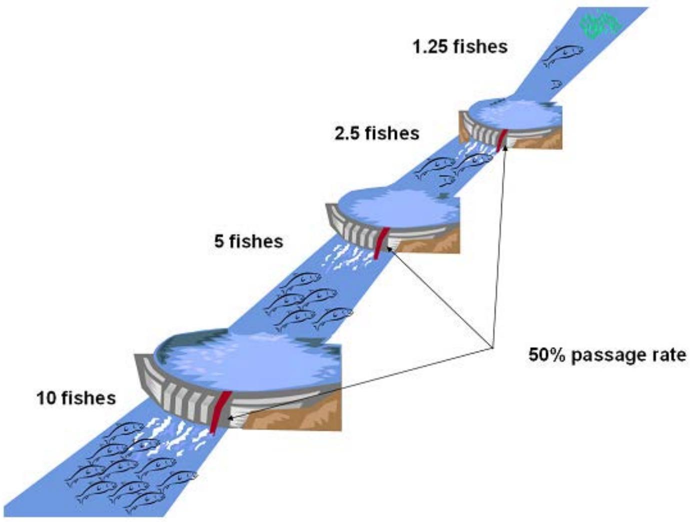
ciency of a given facility reach 50%, meaning that 50% of the fish in the river can get though the fish pass (which is considered a good performance), then only half of the initial stock would be able to continue migration after the first dam.

Each additional dam would thus reduce further the size of the migrant population, to the extent that only 12.5% of the stock would remain after only the third dam. In the case of the Mekong, under the assumption of similarly efficient fish passes at each dam, only about a tenth of the Tonle Sap fish undertaking a migration upstream would be able to keep migrating towards their breeding grounds past the Latsua or Lower Sesan 2 dams.

Ultimately, it should be noted that the presence of an "efficient" fish pass is not a sufficient condition to ensure mitigation, since migrating fish also need to find appropriate conditions in the environment above the passage (e.g., access to spawning grounds and nursery areas)"

The figure below explains the cumulative effects of a sequence of fish passes.

Figure 4-10: Reduction of Fish Stocks by Successive Fish Passes



Source: Summary Working Paper. MRC SEA for Mekong mainstream hydropower (2010)

Box 4-5: Laos Leads to the way for fish futures in ASEAN

Laos now has the first ever fish passage built for Mekong species in the entire ASEAN region. The passage will help fish to move between the Mekong River and the Pak Peung wetlands to access a vital spawning and nursery habitat, which was previously limited by irrigation infrastructure. In addition it will also provide researchers and fisheries experts with invaluable data about the behaviour and characteristics of different freshwater fish and their ability to traverse fish migration ladders.

The research project was started in 2008 and is being backed by the Australian Centre for International Agricultural Research (ACIAR), who funded a total of AUD$2 million (16 billion kip), with the fishway itself costing AUD$130,000 to construct. The passage is a collaborative effort between the National University of Laos, the Living Aquatic Resources Research Centre, the National Agricultural and Forestry Research Institute, and several Australian partner organisations.

Australian Ambassador to Laos, Ms. Lynda Worthaisong, visited the project site on Wednesday. She praised the initiative, saying the 120-metre long structure will play a vital role in ensuring food security and boosting the regional economy. “This ACIAR funded project in Borikhamxay province is a project that is unique in this region. It takes advantage of new research and technology to build this fish passage here, which is quite a significant construction effort.”

The conical structure, known as the “Naga Teeth Design Fishway,” will allow fish to pass over low weirs, generally less than six metres in height. Currently, over 10,000 low irrigation weirs and flood gates block the passage of fish into adjacent wetlands in the Lower Mekong Basin. These obstacles severely impact the ability of fish to reproduce and provide local villagers with a sustainable food and income (the other being rice).

Source: Vientiane Times, April 26, 2013
http://mekong.waterandfood.org/archives/2733

4.3.5 Reservoir Fisheries

Worldwide about 60,000 large reservoirs (>15 m dam height) exist, totalling 400,000 km^2 in water surface and about 6,500 km^3 in volume. Asia possesses the greatest amount of large reservoirs, followed by North America. The construction of large dams in the ex-Soviet Union and the United States peaked in the 1950s and 1960s, and in Africa during the 1960s and 1970s. There is now a second boom in East and SE Asia.

As stated by Miranda (2001)[90], reservoirs provide a significant contribution to global fisheries. In North America and Europe, and more recently Australia, recreational fisheries are economically important, and the trend is for increased importance elsewhere. For instance, in the USA, reservoirs attracted about 21 million recreational anglers in 1990 and supported over half of all freshwater fishing. Commercial fisheries are most important in Asia, but are also important in Africa and South America. In some parts of the world, reservoir commercial fisheries are essential for subsistence and often represent an irreplaceable source of high-quality and low-cost animal protein crucial to balancing human diets. Fish harvested from reservoirs are generally marketed regionally and contribute to the livelihood of impoverished people and local economies.

The main challenges to maintaining and enhancing reservoir fisheries and associated social and economic benefits are (i) fish habitat and environmental degradation, (ii) inadequate fish assemblages, (iii) inefficient harvesting systems, (iv) stakeholder conflicts, and (v) insufficient institutional and political recognition.

Deep reservoirs tend to stratify, especially in the tropics, creating an environment with little or no oxygen along the bottom, where fish cannot survive. This effectively limits fish habitats to the near-shore region and the open water. Where pelagic species are present, these will

[90] Miranda, L.E. 2001. *A Review of Guidance and Criteria for Managing Reservoirs and Associated Riverine Environments to Benefit Fish and Fisheries*. In: FAO Fisheries Technical Paper 419.

quickly proliferate and form large populations that can be exploited. However, in river systems without permanent lakes, few or pelagic species may exist—a and a large part of fish fauna may not be able to adapt to life in the standing water of a reservoir.

In Asia some indigenous species, particularly carnivorous species, such as catfish and ophicephalids, are known to breed in reservoirs and augment most reservoir fisheries. However many reservoirs in Asia largely depend on colonisation by indigenous species, which do not spawn in lacustrine waters. Indian major carps and Chinese major carps are two examples. Consequently, fisheries have developed around exotic species, which have established self-recruiting populations—as in Sri Lanka—and/or regular stocking of appropriate carp species to augment natural recruitment from the rivers upstream.

In large tropical reservoirs fish productivity varies considerably, from 6.5 kg/ha/yr for the Thacba reservoir in Vietnam to 1,508 kg/ha/yr for the Magat reservoir in the Philippines (various authors, quoted in De Sena, 2001)[91]. Some, but not all, of the differences can be accounted for by climatic, geographic and/or edaphic factors. Consequently fish production in large reservoirs may be enhanced by managerial measures.

Cage culture: successful cage culture in large reservoirs depends on adequate feed supplies at low cost and available markets. In China there is a very large mandarin fish production industry in reservoirs—and similarly in Indonesia and Malaysia, focused on red tilapia (De Silva, 2001). On some large reservoirs, artisanal fishers work with cage culture, typically in the upper reaches. This can affect both local spawning habitat and surrounding forests (due to the demand for timber and fuelwood).

Habitat-related issues to consider when developing management strategies for reservoir fisheries include:

- **Reservoir preparation:** (i) removal of pollutants in areas to be flooded (e.g. at workshops, fuelling stations, industrial premises); (ii) removal of vegetation to (a) avoid rapid decomposition and the development of anoxic conditions (and incidentally methane generation), and (b) selective removal of large vegetation to create underwater habitats with three-dimensional variety; this needs to be done in close consultation with future fishing communities because of the impact of underwater trees on nets, and as navigational hazards.
- **Reservoir operating rules:** rule curves need to be developed in close consultation with the operator to optimise the overall economic and social benefits of the project. In relation to fish, typical criteria include target reservoir levels and drawdown restrictions.
- **Habitat enhancement:** lacustrine species need spawning habitat; it may be possible to create additional habitat accessible at biologically appropriate times of year, for example, by adding gravel to shallow-water areas around the margins of the reservoir or by enhancing habitat conditions on stream entering the reservoir.
- **Shoreline erosion:** in some large reservoirs waves and drawdown effects can result in significant shoreline erosion, which reduces fish-friendly shoreline habitats and af-

[91] De Silva, S.S. 2001. *Asian Reservoir Fisheries: Broad Strategies for Enhancing Yields*. In: Reservoir , Culture-based Fisheries Biology and Management (Ed. Sena S. De Silva), pp. 7-15. Australian Center for International Agricultural Research, Canberra, Australia.

fects water quality. Steps may need to be taken to stabilise shorelines, preferably with eco-friendly techniques such as bioengineering.

- **Watershed condition:** watershed condition is critical for sustainable reservoir fisheries, since the input of sediment, nutrients and pollutants determines reservoir life, water depth and water quality.

Management-related issues include the critical issue of influencing decision-makers. The following notes on this and related issues are taken from Miranda (2001).

- **Political marginalisation:** as stated by Miranda (2001), an important barrier to reservoir fisheries development and management is that fishery administrators find it difficult to defend the interests of their sector. Decisions over developments affecting fisheries and aquatic environments are often made with minimum or no consideration of these sectors, mainly for lack of reliable economic valuation and lack of political clout by the users. Given this lack of political power, the interests and needs of fishers and fisheries managers are often not properly represented within existing political frameworks—and thus neglected or ignored. Fishery administrators and stakeholders should seek every opportunity to communicate their needs, demonstrate the value of fisheries and the aquatic natural resource integrated by fish, and participate in the political process. Clear and effective policies for reservoir development can enhance an agency's influence in developing mitigation. The more thoroughly an agency can back-up mitigation recommendations with established regulations, policies, and specific scientific objectives, the more influence the recommendation will have. Broad policy and goals must be transformed into clearly defined targets and objectives.
- **Adaptive management:** our understanding of impounded rivers and ability to predict how they will respond to management actions is limited. Together with changing social and economic values, these knowledge gaps lead to uncertainty over how best to manage impounded rivers. Despite these uncertainties, managers must make decisions and implement plans. Adaptive management is a way for managers to proceed responsibly in the face of such uncertainty. It provides a sound alternative to either charging ahead blindly or being paralysed by indecision, both of which can foreclose management options, and have social, economic and ecological impacts.
- **Monitoring:** sound management of impounded rivers depends on an ability to understand the effects of natural and human-induced change, which make management of impounded river basins extremely complex. Properly designed monitoring programmes that include repeated observations over time can separate natural effects from human ones—and distinguish effective management practices from less effective or harmful ones. Monitoring programmes are needed to support a comprehensive, scientifically-based evaluation of the present and future condition of the environment and its ability to sustain present and future populations.

Box 4-6: Freshwater fish production in the Mekong

In the Lower Mekong Basin (LMB), most of the 25,000 dam/reservoirs have been constructed for irrigation. While the larger ones were built for flood control and electricity generation, reservoirs can be used as sources of fish production.

Estimation of annual consumption of freshwater fish products, including other aquatic animals in the Lower Mekong Basin by country and by source, expressed in whole fresh weight equivalents, as recalculated by Hortle and Bush 2003 (cited in Van Zalinge *et al.* 2003 **)** is presented in Table 1**.** Total fish consumption is 3.133 million tons. Of this number, 2.642 million tons is from wild fish capture and 0.232 million tons from reservoirs. Approximately 0.259 million tons of fish are consumed annually in the Lower Mekong Basin**.**

Table 1. Estimated annual consumption of freshwater fish products, including other aquatic animals in the Lower Mekong Basin by country and by source, expressed in whole fresh weight equivalents, (as recalculated by Hortle and Bush 2003).

Country	Population (million)	Average per capita consumption (kg)	Total[1] fish consumption (tons)	Capture[2] fisheries catch (tons)	Reservoirs[3] fish catch (tons)	Aquaculture[4] production (tons)
Cambodia	11.0	65.5	719,000	682,150	22,750	14,100
Lao PDR	4.9	42.2	204,800	182,700	16,700	5,400
Thailand	22.5	52.7	1,187,900	932,300[5]	187,500	68,100
Viet Nam	17.0	60.2	1,021,700	844,850	5,250	171,600
Total LMB	55.3	56.6	3,133,400	2,642,000	232,200	259,200

[1] Sjorslev 2001 recalculated by Hortle and Bush 2003

[2] Total consumption minus Reservoir catch and Aquaculture production

[3] MRC Management of Reservoir Fisheries data

[4] Phillips 2002

[5]Includes a large part of the probably more than 50,000 tons of freshwater fish products exported from Cambodia to Thailand (Van Zalinge *et al.* 2001)

Source: Van Zalinge *et al.* 2003

4.3.6 Dam Removal

The best mitigation measure for hydropower dams affecting fish is to remove the dam and restore the river to its original, free-flowing state. There are many reasons why dams should be decommissioned; primarily, safety and economics. When dams require re-licensing (which assumes an effective dam licensing and relicensing system), they may require expensive safety upgrades (Box 4-7). Equally, reservoir sedimentation may have reduced power production potentials so that the facility is no longer economically viable. The foregone value of the fishery affected by the dam may, on the basis of modern, inclusive accounting, outweigh the benefits from the power produced. Legal rights of indigenous peoples to their ancestral fishery, and/or laws requiring protection and restoration plans for endangered species, may also be a driver for dam removal.

Box 4-7: Removal of the Dillsboro Dam

Companies will sometimes propose restoring one area of a river (or even a different river altogether) in exchange for building a new dam or renewing dam licenses. This occurred in western North Carolina, where Duke Power operates 11 dams. Duke's operating permits for the dams are set to expire over the next two years. To get new permits, Duke is required to provide recreational and environmental compensation over the 30- to 40-year life of the new permits. As part of their environmental compensation, Duke proposed the removal of the Dillsboro dam on the Tuckasegee River. Representatives with the U.S. Fish and Wildlife Service and the N.C. Department of Environment and Natural Resources have agreed to waive other environmental mitigation in exchange for removing the dam.

Source: http://www.smokymountainnews.com/issues/02_04/02_18_04/fr_feds_begin_review.htm

So far decommissioning of dams has been concentrated in the US and Europe. During this century the trend is likely to go worldwide as dams age, safety standards are raised, climate change takes effect, licensing systems become established, insurance becomes an even more important issue and, not least, the value to society of free-flowing rivers and the associated healthy ecosystems are fully recognised.

As listed by International Rivers, there are various ways to restore a dammed river—from fully removing the structure to modifying its operation:

- **Dismantling:** the complete dismantling of all physical barriers to stream flow is the only way to fully restore the natural flow of the river, including peak flows and seasonal flooding. This is the best way to restore fish passage and the transport of gravel and organic debris downstream. Dam removal is usually staged to avoid sudden release of the sediments that have accumulated behind the dam wall. This is the most costly (and rarest) restoration option.
- **Partial Decommissioning:** some of the dam remains with this approach. Altering the dam structure will restore some flow and change the dam's original function.
- **Modification:** various options have little or no impact on dam function. For example, the addition of fish ladders can be used to improve fish access to spawning habitat above the dam without altering the function of the dam itself.
- **Re-operation:** improving the release of water from dams usually allows the dam to continue with its original functions. Re-operation can improve fish survival downstream by releasing more water from the reservoir during critical times, such

as spawning season. While more effective management of dams can help mitigate environmental impacts, it should be noted that many dams around the world presently lack the mechanisms needed to control water discharge.

TRAINING AIDS	
Discussion topics	How can fisheries interests be incorporated in hydropower decision-making? Dams last for a few generations; extinction is forever. Discuss. How can engineers and politicians be sufficiently educated as to the difficulties or impossibilities of mitigating the effects of dams on fish and fisheries? Can reservoir fisheries compensate for loss of riverine fisheries? Discuss. Imagine the removal of a hydropower dam on a river in SE Asia. What reasons could there be for such an action?
Exercises	Evening homework assignment: Divide into groups. Each group is to develop and/or find arguments for and against the feasibility of fish pass facilities in the context of a large tropical river the size of the Mekong. The groups present their arguments to the plenary in the next morning.
Additional reading and resources	Ziv *et al.* 2012. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proc. Nat. Acad. Sci*. Vol. 109, No. 15 http://www.princeton.edu/~slevin/PDF/Levinpubs/466_ZivMekong.pdf Environmental Mitigation Technology for Hydropower: *Summary Report on a Summit Meeting Convened by Oak Ridge National Laboratory, the National Hydropower Association, and the Hydropower Research Foundation* Washington, DC June 2-3, 2010. Federal Energy Regulatory Commission. 2004. *Evaluation of Mitigation Effectiveness at Hydropower Projects: Fish Passage*. Division of Hydropower Administration and Compliance, Office of Energy Projects International Rivers. 2013. Interview: Do Not Pass Go: The Failed Promise of Fish Ladders. *World Rivers Review* March 2013. Clearing House for Dam Removal Information (CDRI): http://library.ucr.edu/wrca/collections/cdri/ Overview of dam decommissioning by advocacy NGO: http://www.internationalrivers.org/dam-decommissioning *French Dam Removal Opens Way for Atlantic Salmon*: http://www.internationalrivers.org/resources/french-dam-removal-opens-

	way-for-atlantic-salmon-1632 Demolition of Dillsboro Dam: http://www.smokymountainnews.com/archives/item/6939-tuckasegee-river-revival-demolition-of-dillsboro-dam-restores-aquatic-life

Case Studies

Case Study 1

This case study indicates the scale of damage to fisheries caused by dams in North America, despite many efforts to design-in or mitigate their effects.

Fish unable to pass through dams in U.S. presents 'cautionary tale' for developing world

Dams create a largely impenetrable barrier for fish even when the dams were installed with specially-built passages, according to a new study in Conservation Letters. The scientists found that migrating fish largely failed to use the passages in the U.S., resulting in far fewer moving through the state-of-the-art hydroelectric dams than had been promised. The researchers say that their findings are a "cautionary tale" for developing nations.

"It may be time to admit failure of fish passage and hatchery-based restoration programs and acknowledge that ecologically and economically significant diadromous species restoration is not possible without dam removals," the scientists write, dealing a large blow to the idea that hydroelectric projects can be fish-friendly. Diadromous fish refer to species that migrate between salt and fresh water, such as salmon, sturgeon, shad, river herring, and eel. Many diadromous have seen historic declines worldwide, in part due to rapidly multiplying hydropower projects, many of which are now being constructed across the developing world.

The researchers looked at three river systems - the Merrimack, Connecticut and Susquehanna - in the northeastern U.S. After over a century of dam-building, these systems contain hundreds of dams, including several on the main stems, but the fish passageways built into the dams aren't working.

The scientists found that some fish - such as sturgeon - don't use the fish passageways at all. Others, such as American shad, have dwindled down to 2% of the conservation target on the Merrimack river system and zero percent on the other two rivers.

"These dams are contributing to reduced resilience of not only shad, but all diadromous species," said co-author Adrian Jordaan of the University of Massachusetts Amherst. "The result is that other factors including climate change will have a greater impact on these populations that are at fractions of their historical levels."

The result has been a decimation of U.S. fisheries, food production, and wildlife across the river systems.

"Once these rivers supported tens of millions of pounds of biomass of these species and provided valuable protein to a growing nation," noted another co-author, Karin Limburg, with the SUNY College of Environmental Science and Forestry.

The researchers write that the plummeting of fish in America's rivers provide "a cautionary tale for developing nations intent on hydropower development, suggesting that lasting ecosystem-wide impacts cannot be compensated for through fish passage and hatchery technology." Mega dams are going up worldwide - from Brazil to China to Borneo - with governments and corporations often promising that fish will be little impacted.

Solutions to the problem in the U.S. may be dam removal - many of the dams generate little electricity - or more creative methods.

"The approach being employed on the Penobscot River, where dams are being removed or provided the opportunity to increase power generation within a plan to provide increased access to habitat, offers a good model for restoration," the researchers conclude.

Citation: J. Jed Brown, Karin E. Limburg, John R. Waldman, Kurt Stephenson, Edward P. Glenn, Francis Juanes, Adrian Jordaan. *Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies.* Conservation Letters. 2013.

Case Study 2

This case study illustrates use of a variety of mitigation measures to address loss of fish and fish habitat caused by construction and operation of a dam.

Hungry Horse Dam Fisheries Mitigation Programme

The Hungry Horse Mitigation Programme, sponsored by Montana Fish, Wildlife and Parks, began in 1992 to address fish losses associated with the construction and operation of Hungry Horse Dam. The dam isolated approximately 38% of the Flathead Lake drainage and changed the physical and biological characteristics of the lake and river. The programme's goals are to restore and reconnect critical habitat, reduce the negative interactions between native and non-native fish, and improve dam operations for native trout recovery.

The Flathead River system in Northeast Montana is a regional stronghold for migrating west slope cutthroat trout—part of Montana's natural heritage. Installation of the dam completely blocked fish migrations from Flathead Lake to the South Fork Flathead River upstream. In order to improve fish passage to critical spawning and rearing habitat, the program initiated several culvert replacement projects. These combined projects re-opened 16% of available spawning and rearing habitat to migratory fishes in the reservoir system. Monitoring surveys have shown significant increases in adult and juvenile fish upstream of each passage improvement site. The programme is also using innovative natural channel restoration techniques to improve native fish habitat throughout the upper Flathead River drainage. In one instance, improvements to Emery Creek included removing sections of a logging road that had distorted the natural meandering of the stream, degrading habitat and barring fish migration. The improvements enhanced fish habitat and restored a two-mile section of channel to aid the spawning and rearing habitat for native trout.

Dam operations had also created unnatural flow and temperature fluctuations in the Flathead River downstream of Hungry Horse Dam. In 1996, a temperature control structure was installed on the dam to correct the problem. It allows dam operators to take water from the appropriate depth in the reservoir so the water flowing through the dam turbines matches the natural, seasonal temperature pattern in the river. As a result, normal temperatures were restored in the Flathead River downstream of the dam, helping to increase favourable stream and habitat conditions for fish.

Source: Northwest Power and Conservation Council: http://www.nwcouncil.org/fw/stories/hungryhorse.htm

Case Study 3

The following excerpt from Dam Removal Success Stories presents a case study of successful dam removal in Baraboo, Wisconsin, U.S. (Friends of the Earth, American Rivers, and Trout Unlimited, Dam Removal Success Stories, 1999). The full document is available online at:

http://www.michigandnr.com/publications/pdfs/fishing/dams/SuccessStoriesReport.pdf

Baraboo River

Removal of the Waterworks Dam in Wisconsin

Summary

A stretch of the Baraboo River runs free for the first time in 140 years, following the 1997 removal of the defunct Waterworks Dam in downtown Baraboo, Wisconsin. Two other small dams within a five-mile stretch historically known as the "Baraboo Rapids" will come down within three years as part of the same fish passage project. Removal of the series of dams, all between 9 and 20 feet high, is expected to dramatically improve the sport fishery, and will allow state threatened and federal species of concern, including the lake sturgeon and prehistoric paddlefish, to return to waters they once inhabited for spawning. Recently published studies document dramatic improvements already in the water quality and fisheries at this site, including the smallmouth bass sport fishery. Local paddlers are increasing their use of the river for recreational purposes, and revitalization of the waterfront is underway, including plans for a new Riverwalk, which promises to literally reconnect the city's downtown to the river.

The River

The Baraboo flows over 100 miles from its headwaters near Hillsboro to its confluence with the Wisconsin River. Its watershed encompasses 650 square miles, or about 415,000 acres. Through its course, the river drops over 150 feet in elevation; 45 feet of that gradient occurs in a four- to five-mile stretch through the City of Baraboo. Historically known as the "Baraboo Rapids," such a concentration of steep gradient is rare in southern Wisconsin. The Baraboo served as an important "nursery" for fish from the larger Wisconsin River, a major tributary to the Mississippi River. Early white settlers recognized the river's drop for its potential to generate mechanical power. From the middle to late 19th century, dams were the life and economic engine that drove the local economy, powering grist, lumber, and other essential milling enterprises.

The Impact Prior to Removal

The name Baraboo comes from the French "Riviere a la Barbeau," meaning "Sturgeon River" and the Native American name, "Ocoochery," meaning "plenty of fishes." But this abundance of fish and fish species began to disappear after the dams were built. Together, the Waterworks, Oak Street, and Linen Mills Dams transformed the "Baraboo Rapids" from a fast-moving stream with riffles and diverse and healthy fish populations into a series of sluggish impoundments supporting primarily carp and black crappie. Prior to removal of the Waterworks Dam, studies conducted by the Wisconsin Department of Natural Resources (DNR) showed ten species of fish below the lowermost dam that were not present above the others, indicating that the dams were blocking fish passage. Unobstructed movement is important to many fish species, including smallmouth bass, walleye, catfish, lake sturgeon, and paddle-fish, and to other forms of aquatic life, including mussels, which depend on fish to move around. In addition, the dams served no flood control function; in fact, in high-water situations, the already-elevated water levels of the impoundment led to flooding on adjacent properties.

The Removal Decision & Process

For the Waterworks Dam, the question of removal was triggered by public safety concerns. The old structure failed a 1994 safety inspection due to major deterioration and inadequate spillway capacity. The City of Baraboo, ordered to repair or remove it, began to explore its options. Initially, there was much resistance to the idea of removal. As in most small communities that grew up around a dam, emotional attachments to the impoundment and the dam ran high. But repair cost estimates ranged from three to five times more than removal estimates. By removing the dam, the city could permanently eliminate its current and future liability for less than one-third the cost of repairing the dam. City officials determined it was not fiscally prudent to repair the structure and voted to remove it.

While economics were the key determining factor, the restoration would not have been possible without the support of Mayor Dean Steinhorst and other community leaders, who had the foresight to recognize environmental and social benefits potentially associated with dam removal. The most vocal opponent to removal was a non-profit business located on the impoundment, which effectively delayed the removal process on several occasions and increased costs for the city; however, the business eventually dropped their opposition. Historical assessments determined that adverse impacts from the removal would be minimal, and mitigation measures were worked out that included historical interpretation of the role of the three dams in the growth of the community. Meanwhile, the Oak Street and Linen Mill Dams were each producing a small amount of hydropower, and both were in need of repairs. The Federal Energy Regulatory Commission (FERC) claimed jurisdiction over the dams. While the state's scrutiny had been limited to public safety, the federal agency's review of dams addresses a wide array of public interest criteria, including environmental considerations.

As part of the FERC licensing process, expensive studies could be requested on the dams' impacts on fish and wildlife, recreation and water quality—and to this expense would be added any needed repairs and upgrades. The dams, which produced only a miniscule amount of hydropower and were already marginally economical, were becoming an economic burden on the owner, who became increasingly amenable to the idea of removal. City officials were interested in removal of the Oak Street Dam in particular. With it gone, the city would save an estimated $300,000, which could be used for making much-needed road repairs to Water Street, the gateway to the main tourist attraction in Baraboo-Circus World Museum, and former winter quarters of the Ringling Brothers Circus. The River Alliance of Wisconsin, a statewide citizen advocacy organization for rivers, served as a catalyst for the Baraboo River restoration project. Because of the potential high quality and scale of the river restoration, the non-governmental organization raised funds from a variety of sources to begin a fish passage demonstration project. The effort became a collaborative project, involving the private owner of the two hydro dams, the City of Baraboo, the state, and non-governmental groups, including the River Alliance and the Baraboo River Canoe Club. Public education played an important role in gaining support for removal of Waterworks and the other dams. Lack of funding precluded a comprehensive, pro-active education effort. Nonetheless, project collaborators identified public education needs on a continuing basis and provided information designed to help improve the decision-making process for the public officials, local community leaders, and federal and state agencies involved, as well as concerned citizens.

Flooding and sediment transport issues were considered in timing the removal of the Waterworks Dam, and an effort was made to avoid interference with fish spawning. The dam was breached in December 1997 and the impoundment drawn down. The Baraboo River Canoe Club sponsored several river cleanups to remove debris from the newly exposed mudflats; the first cleanup immediately followed the drawdown. The bulk of the dam was removed with a backhoe-mounted jackhammer. Due to use of heavy reinforced steel in the dam below the riverbed, explosives experts helped complete removal of the structure. Dam rubble (and timber and rock from earlier versions of the dam at that site) were used to stabilize the banks. The dam was completely removed by late April. The mudflats were extremely fertile and contained ample seed. Without benefit of artificial seeding, the former impounded area began to "green up" within two weeks, and within six weeks the banks were fully vegetated.

Restoration of the River

Positive changes in river habitat were evident very soon after the removal of the Waterworks Dam. When spring floods completely submerged the lowermost dam (allowing fish to pass over it), fisheries biologists identified sturgeon at the former Waterworks Dam site. Eighteen months after the removal, the number of fish species above the former dam site had more than doubled from 11 to 24 species, according to a Wisconsin DNR survey. The survey also indicated that water quality had improved numbers of smallmouth bass, a species that cannot tolerate poor water quality, had increased from only 3 to 87 in the former impoundment. Three-quarters of a mile of high-quality riffle habitat, rare in southern Wisconsin rivers, has been restored to its free-flowing condition. Some other communities in Wisconsin that have removed small dams have enjoyed an increase in recreational opportunities, especially canoeing, that have attracted visitors and resulted in important economic development opportunities. These and other improvements promise to serve as an economic boost to this small town, and once again make the river an integral part of the community.

The Significance of this Removal

The Baraboo River restoration has been called a model for both its natural resource benefits and its collaborative process. The public-private partnership involves many stakeholders, including the private owner of the two hydropower dams, city and state officials, and non-governmental organizations.

When all four dams - the three blocking the Baraboo Rapids and the LaValle Dam upstream - are finally removed, 120 miles of the Baraboo will be restored to free-flowing conditions. Research indicates that this may be the longest main stem stretch of river ever restored in the United States through dam removal.

5 WATERSHED MANAGEMENT AND RESERVOIR SEDIMENTATION

MODULE 5: WATERSHED MANAGEMENT & RESERVOIR SEDIMENTATION		
Scope	**Session/Sub-Topic**	**Scope**
Watershed management; reservoir sedimentation control	**Session 5.1: Reservoir Sedimentation**	
	Reservoir Sedimentation	Introduction to the scale of the problem; examples; consequences (need for cascades); WCD findings; need for least-cost power generation strategies incorporating full externalities; need for IWRM.
	Sediment Sources	Review of sediment sources; geology; slope processes; sediment storage & transport; landscape evolution; periodic events; anthropomorphic acceleration (land use, infrastructure (especially roads).
	Reservoir Sedimentation: Design Options	Review of design options for managing sediment issues; sediment routing; sediment flushing; designing for eventual run of river operation (no live storage).
	Session 5.2: Watershed Management	
	Watershed Management	Review of principles; review of likelihood of watershed interventions affecting hydrology at different scales; other benefits of watershed approach.
	Watershed Interventions	Review of approaches to watershed management; soft and hard management; community-based approaches; vegetation and land use; incentives; basin authorities.
	Session 5.3: Payment for Ecosystem Services	
	Payment for Ecosystem Services	Introduction; principles.
	PES: Examples	Examples of effective PES (e.g. Ecuador).

5.1 Reservoir Sedimentation

Key aspects	• Reservoir sedimentation is a major problem, worldwide. • Sedimentation rates have often been under-estimated in feasibility studies. • Reservoir bank collapse is a major problem for some reservoirs. • Geological sediment inputs cannot be reduced. • Sediment inputs from accelerated (man-made) erosion can be reduced – with effort. • There are various options for designing hydropower projects to minimise sediment problems.

TRAINING AIDS	
Purpose of session	To introduce the topic of reservoir sedimentation, its causes, and some management response options.
Learning objectives	• To understand the scale of the sedimentation problem. • To understand the basic causes of sediment supply to reservoirs. • To understand that there are various approaches to designing for sediment.
Key readings	***1)*** Chapter 1, Introduction, in: Morris, G.L. & Jiahua Fan. 1998. *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs and Watersheds for Sustainable Use*. McGraw-Hill Book co., New York. Available from: http://reservoirsedimentation.com/ ***2)*** Kummu, Matti, Dan Penny, Juha Sarkkula and Jorma Kopene (2008) Sediment: Curse or Blessing for Tonle Sap Lake? Ambio, Vol,32., No.3, Royal Swedish Academy of Sciences. ***3)*** Sarkkula, Juha, Jorma Koponen, Hannu Lauri, Markku Virtanen (2010) Origin, fate and role of Mekong sediments. Mekong River Commission, Vientiane.

5.1.1 Reservoir Sedimentation

Mekong sediment discharge plays an important role for the entire river ecosystem. The recent study conducted by Wang et al. (2009), cited in Sarkkula, Koponen, Lauri, and Virtanen (2010), classifies sediments into four major zones:

Upper Basin - The sediment load at Khong Chiam ranged from 119 to 162 million tonnes/year, (106 million tonnes/year) during four sub-periods, with an average of 145 million tonnes/year during the entire period of 1962–2003. This is in line with previous estimates. For the mean annual sediment load at Pakse (41 km downstream to Khong Chiam), 147 million tonnes/year (Walling, 2005) and 128 million tonnes/year (Lu and Siew, 2006) have been estimated.

Lancang - The observed pre-Manwan dam sediment load at Chiang Saen is approximately 90 million tonnes/year, ranging between 90-110 million tonnes/year (see Figure 1). This is in line with Walling's results (2005; 2008).

3S rivers – It is estimated by Kummu et al. in press, that the sediment load from the 3S river basins is around 10 million tonnes/year. This could be an underestimate, with the probable range for the sediment load being around 10-25 million tonnes/year. These figures are supported by the TSS (Total Suspense Solids) measurements in various stations along the Se San and Sre Pok rivers. The issue needs further analysis, however. Taking the above estimates together, it can be inferred that:

- The average annual sediment load at Kratie is around 165 million tonnes/year (145 million tonnes/year at Khon Chiam + 20 million tonnes/year from the 3S)
- China contributes to this by 55 - 65 % (pre-Manwan situation).
- The 3S contribute to the load at Kratie by 5 - 15 % .
- The rest of the watershed contributes to the Kratie load by 20 - 40 %.

Using these averages, sediment loads contributions are as follows: China 60%, 3S 10% and rest of the basin 30 %. In average annual loads these translate to 99, 17 and 50 million tonnes/y respectively.

Reservoir sedimentation is a major cause of under-performance of dams worldwide. Sediment fills dead storage and eventually live storage, affecting power generation; in the worst cases, intakes may be blocked, or projects have to be converted to run-of-river operation, if economically viable. Sediment also affects turbine blades and water quality. Nutrients and pollutants carried into reservoirs by sediment may affect fish. Downstream, reduced sediment transfer due to trapping upstream may affect fisheries due to lower nutrient inputs to the system.

The actual effects of sediment are very much project and site-specific. The comprehensive survey carried out by the World Commission on dams (WCD) found that, in general, smaller dams had higher specific sedimentation rates, as did dams on lower reaches of rivers (

Figure 5-1 and **Figure 5-2**). Global losses of storage volume are about 0.5-1% per year[92]. In China, some large reservoirs are losing volume at 2.3% per year, and in El Salvador a team from the US Army Corps of Engineers concluded in 1993 that sedimentation could reduce the life of the 135 MW Cerron Grande Dam to 30 years – compared to the pre–construction prediction of 350 years.[93]

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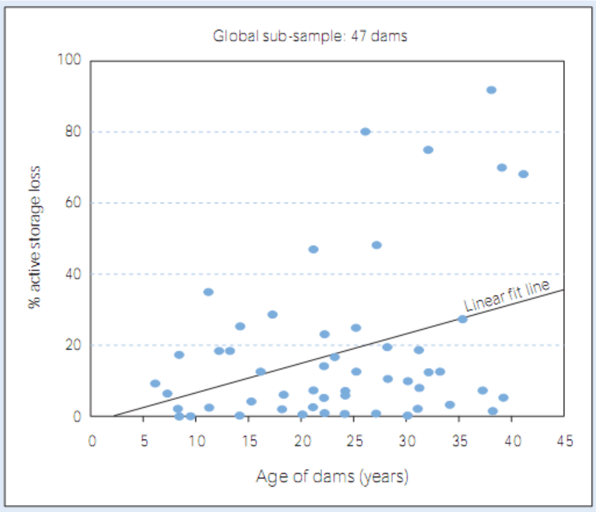
[92] Mahmood, K. (1987) *Reservoir sedimentation – impact, extent and mitigation.* World Bank Technical Paper No 71.

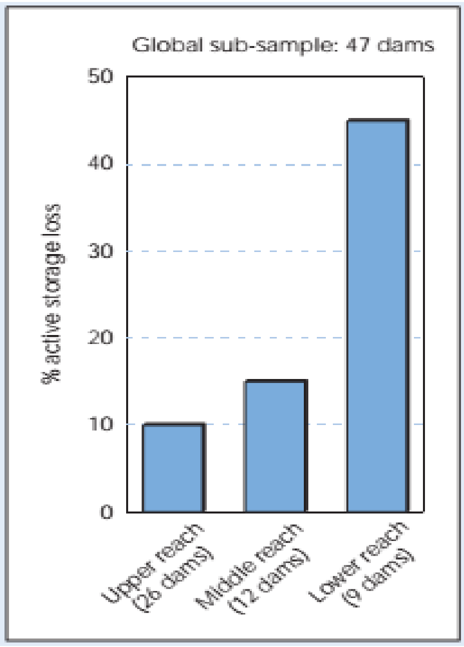
[93] International Rivers, accessed 20 May 2013: http://www.internationalrivers.org/sedimentation-problems-with-dams

Figure 5-1: Storage Loss in Reservoirs over Time



Source: WCD. 2000. *Dams and Development.*

Figure 5-2: Loss of Active Storage Due to Sedimentation by Reach of River



Source: WCD. 2000. *Dams and Development.*

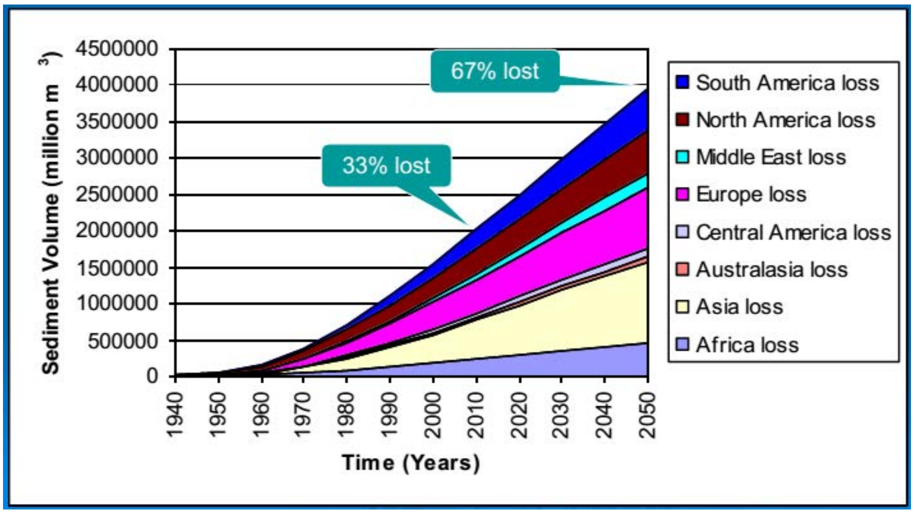
In many cases large dams have been built on rivers with high sediment loads, for example, the Tarbela Dam on the Indus in Pakistan. The Tarbela reservoir lost 18% of its live storage after only 25 years, and the build-up of sediment is threatening operation of the project well before the end of its design life (WCD, 2000). Continued operation of this dam will eventually require a system to bypass sediment—a volume of some 150 M m^3/yr. In Tajikistan sedimentation of the 10.5 km^3 Nurek reservoir threatens operation of the 300 m high Nurek Dam on the Vakhsh River (**Figure 5-3**).

Figure 5-3: Nurek Reservoir, Tajikistan

Loss of storage volume drives the need for cascades of dams, with reservoirs higher up the river acting as sediment traps to extend the life of reservoirs further downstream.

The WCD concluded that "Sedimentation and the consequent long-term loss of storage is a serious concern globally and the effects will be particularly felt by basins with high geological or human-induced erosion rates, dams in the lower reaches of rivers and dams with smaller storage volumes" (WCD, 2000). This reinforces the need for least-cost power generation strategies, which incorporate the full range of externalities affecting the project – and affected by it. The overall picture is illustrated in **Figure 5-4**.

Figure 5-4: Global Reservoir Volume Loss, by Region



Source: Basson, 2008. http://www.chr-khr.org/files/u8/Bern_Basson.pdf

5.1.2 Sediment Sources

Sediment entering reservoirs results from three main processes, or sources:

- Directly into the reservoir
- Geological erosion
- Accelerated erosion

Directly into the reservoir: sediment may enter reservoirs directly from (i) erosion of the reservoir banks due to wave action; (ii) the continuing erosion of borrow pits at water-level around the reservoir; or (iii) bank collapse and landslides directly into the reservoir. These last may be triggered either by undermining due to wave action, or as a result of rapid draw-down of the reservoir and consequently high pore-water pressures in the surrounding slopes. A typical example is shown in **Figure 5-5**. In China, bank collapse into the Three Gorges reservoir is so serious that it has developed a whole academic industry (see, e.g., Wang & Li, 2009).[94]

Figure 5-5: Bank Collapse into Nurek Reservoir, Tajikistan

Geological processes: landscapes evolve through the movement of material downhill, transported under the influence of gravity, wind and – most importantly – water. As the land rises, due to tectonics, pre-existing rivers erode their beds, cutting downwards. Periodically, triggered by seismicity, heavy rainfall, or other losses of strength; over-steepened slopes above the river fail, and sediment moves downslope into the river channel. From here it is transported downstream, with most geomorphic work being done in the annual periods of high flow or in rare 'catastrophic' events, such as landslide-dam outburst floods **(**

Figure 5-6). Where mountains rise fast, the volume of material transported by the major rivers – the Indus, Brahmaputra, etc. - is immense. Maximum mean annual specific suspended sediment yields are in excess of 10,000 t/km^2/yr (Walling & Webb, 1996). Erosion and sediment transport on this scale is geological and cannot be altered. Hydropower projects built on intercept major sediment-carrying rivers must be designed in recognition of this fact.

An inverse relationship between specific suspended sediment yield and drainage basin area has been widely reported in the literature – the larger the basin, the lower the yield. The inverse trend of the relationship is commonly accounted for in terms of the increased opportunity for deposition of transported sediment as it moves through the fluvial system and into

[94] Fawu Wang & Tonglu Li. 2009. *Landslide Disaster Mitigation in Three Gorges Reservoir, China*. Springer. 563 pp

areas with reduced slope gradients and well-developed floodplains (Walling & Webb, 1996).[95]

Figure 5-6: Landslide Dam, Young River, New Zealand

Photo: info.geonet.org.nz

Accelerated erosion: Much of the world's surface has altered natural conditions, accelerating erosion. Typically this takes two forms: (i) degradation or removal of natural vegetation, so that surface erosion is accelerated and widespread, and (ii) alteration of slopes – most often by roads - so that mass movements (landslides) become common. In medium and small catchments, accelerated erosion can make significant differences in the rates of sediment input to reservoirs. Reconstruction of a 20,000 year history of sediment inputs to the Black Sea suggests that sedimentation has increased by a factor of 3 over the last 2000 years, presumably as a result of deforestation and agricultural development (Degens *et al.*, 1991).[96]

5.1.3 Reservoir Sedimentation: Design Options

There are nine basic strategies for dealing with reservoir sedimentation:

- Build on low-sediment rivers.
- Protect or restore watershed condition (see section 5.2).

[95] Walling & Webb, 1996: http://www.irtces.org/isi/isi_document/iahs236/iahs_236_0003.pdf

[96] Degens, E.T., Kempe, S. & Richey, J.E. (1991) *Summary: biogeochemistry of major world rivers.* In: Biogeochemistry of Major World Rivers (ed. By E.T. Degens, S. Kempe & J.E. Richey), 323-347. Wiley, Chichester, UK

- Build cascades, with upstream reservoirs acting as sediment traps to extend the life of downstream reservoirs.
- Raise the dam wall to increase volume.
- Prevent sediment deposition - by sediment routing.
- Remove sediment - by excavation or dredging.
- Remove sediment - by flushing.
- Design the project for eventual conversion to run-of-river operation.
- Design the original project without a storage reservoir – i.e. as a run-of-river operation.

The following notes discuss sediment routing, sediment flushing, and sediment removal.

Sediment routing: this refers to any attempt to manipulate a reservoir's geometry and hydraulics so that sediment passes through the reservoir rather than being deposited. Typically, most sediment arrives during floods, and these high flows can be managed to minimise deposition. Morris and Fan (1998) categorise sediment routing techniques as follows:

Sediment Pass-Through

1. Seasonal drawdown
2. Flood drawdown by hydrograph prediction
3. Flood drawdown by rule curve
4. Venting turbid density currents (through low-level outlets)

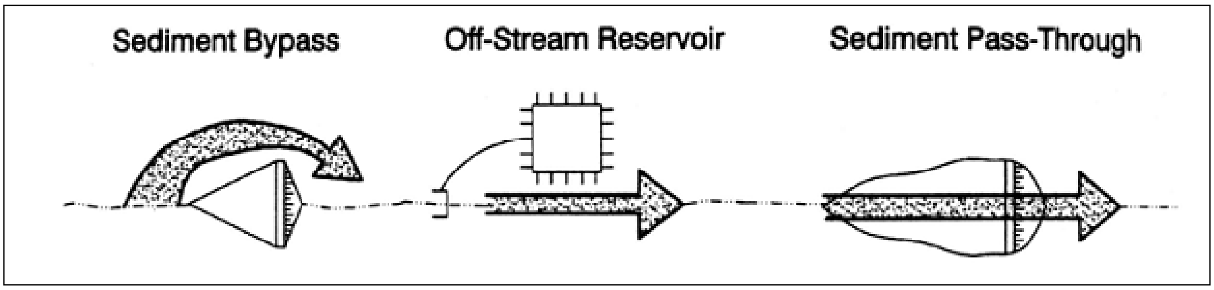
Sediment Bypass

1. On-channel storage
2. Off-channel storage
3. Subsurface storage

The basic sediment routing strategies are diagrammed in

Figure 5-7**.** A major disadvantage of sediment routing is that a large volume of water must be released in order to pass the sediments downstream. Sediment routing is most easily applied to relatively small reservoirs with storage volumes much lower than annual flows.

Figure 5-7: Sediment Routing Strategies



Source: Morris & Fan, 1998 (see Additional Reading).

Sediment flushing: the basic principle of sediment flushing is simple: gates low in the dam wall are opened to create a flow of water with sufficient velocity in the reservoir to erode deposited sediment and carry it downstream. This differs from sediment routing in that flushing deals with already deposited sediment, rather than trying to prevent its deposition in the first place.

Maintenance of storage capacity in large reservoirs requires very large low-level discharge outlets to create the flows necessary for sediment erosion within the reservoir.

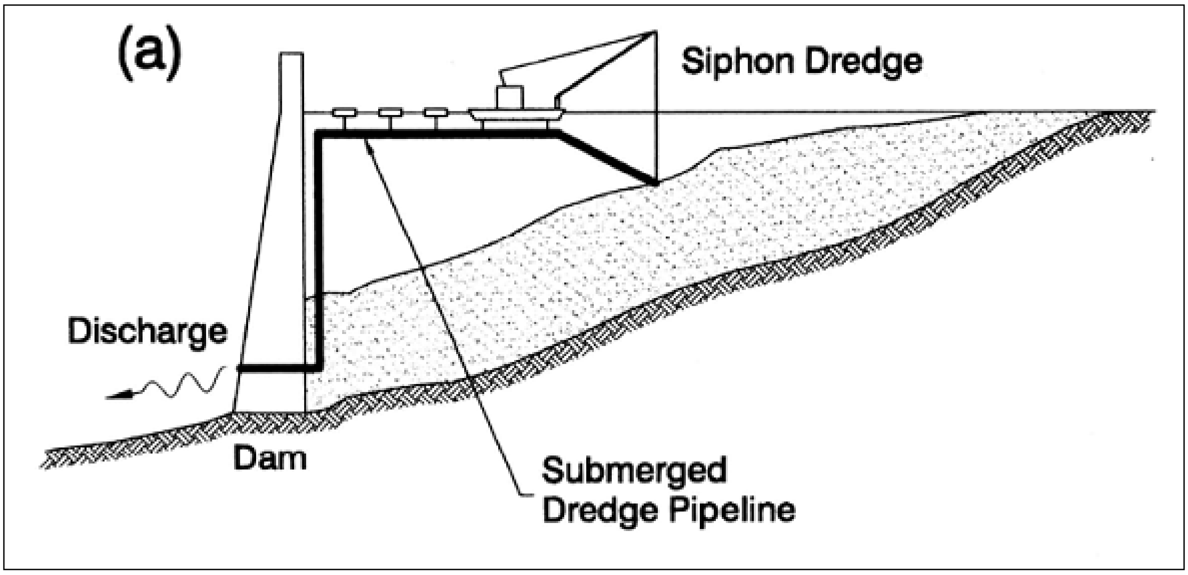
The first limitation of flushing is that it requires reservoir drawdown or emptying, thus limiting the technique to relatively small reservoirs. The second is that the discharge of sediment downstream is generally of very high concentration over a short period of time (up to or over 1000 g/l), a situation very different from pre-project conditions. Flushing is not feasible at many sites because of the downstream impact on water quality. It may also be limited by channel morphology, with large flows needed to keep the downstream channel clear.

Excavation or dredging: once a reservoir's live storage has filled with sediment, few options exist but to remove it—or decommission the powerplant, converting it to run-of river operation. Sediment must be removed mechanically, by hydraulic dredging or dry excavation. The method selected will depend on factors such as water levels, sediment volume, geometry and grain size of the deposit and—very importantly—the disposal site or method. All methods are expensive because of the large volumes of material involved and the need for disposal at some distance, requiring pumping of dredged spoils or trucking. In some cases it may be environmentally feasible to dispose of the sediment directly into the river downstream of the dam; however, this requires particular circumstances of flows, channel morphology and downstream values.

One unusual dredging type is a siphon dredge. This has no mechanical pump—instead relying on the siphon principle to suck water and sediment from the deposit in the reservoir and discharge it downstream (

Figure 5-8). The main constraints on this system are (i) limited deployment (max. approx. 2 km from the dam), due to basic physics and head losses, and (ii) environmental limitations of discharge into the downstream watercourse.

Figure 5-8: Siphon Dredge



Source: Morris & Fan, 1998 (see Additional Reading).

Reservoir sedimentation and sediment management are complex topics. Barron (2008) lists some key considerations in reservoir sedimentation analysis as follows:

- Unsteady hydrodynamic simulations (long-term, up to 100 years).
- Non-equilibrium fine sediment transport (cohesive).
- Deposition and erosion—also bend scour.
- Calibration required, particularly of bed roughness and critical erosion bed shear stress.
- Problems arising as dam engineers underestimate the complexity and importance of reservoir sedimentation analysis—including sediment yield and sedimentation profile prediction—and use crude approaches.
- Not limiting reservoir sedimentation studies to the reservoir, but accounting for down-stream fluvial morphology, which could be several hundred kilometres, and include ecological and economic aspects.

TRAINING AIDS	
Discus-sion top-ics	Reservoirs fill with sediment after 50 to 100 years. What will we do then? Should cascades be built from upstream to downstream – or from down-stream to upstream? What happens when all reservoirs in a hydropower cascade have filled with sediment? Since dams are not eternal structures, should we only build run-of-river hy-dropower schemes?
Exercises	• Imagine you are the manger of a design study for a major hydropower dam on a large river. There is only one possible dam site, and sediment loads are high. Brainstorm criteria needed to make design decisions—taking into account sediment—and draw a flow-chart of the process to help focus on the optimum solution.
Additional reading and re-sources	1) Walling, D.E. & B.W. Webb. 1996. *Erosion and sediment yield: a global overview*. In: Erosion and Sediment Yield: Global and Regional Per-spectives (Proceedings of the Exeter Symposium, July 1996). IAHS Publ. no. 236, 1996 2) Basson, G. 2008. *Reservoir Sedimentation - An Overview Of Global Sedimentation Rates, Sediment Yield & Sediment Deposition Predic-tion*. International Workshop on Erosion, Transport and Deposition of Sediment , Berne, 28-30 April 2008. http://www.chr-khr.org/files/u8/Bern_Basson.pdf 3) Morris, G.L. & Jiahua Fan. 1998. *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs and Watersheds for Sustainable Use*. McGraw-Hill Book co., New York. Available from: http://reservoirsedimentation.com/ 4) Fruchart, F. 2008. *Why and How to Flush a Reservoir without Environ-mental Impacts*: http://ns1.mrcmekong.org/download/Presentations/sediment-monitor-ing/S4_Fruchart_flushing_reservoirs_without_environmental_impacts.pdf

Case Studies

Case Study 1

This case study concerns excavation of sediment in a relatively small reservoir in California.

Cogswell Reservoir

The 11 M m^3 Cogswell rockfill dam in Los Angeles was constructed in 1933 for flood detention and water conservation. At this site, water conservation is practiced by slowly releasing floodwaters to maximize groundwater recharge in the downstream riverbed.

During 1994-1996, 2.4 M m^3 of sediment, primarily silt, was excavated from Cogswell Reservoir. All finer sedimentation in the main part of the reservoir was removed, leaving behind only the coarse sediment, deposited far upstream along tributaries. The maximum haul distance was about 2 km, with a maximum uphill haul (bottom of reservoir to top of fill) of 230 m.

Excavated material was placed in an adjacent canyon as engineered fill. The unit cost for excavation and disposal was $5.60/$m^3$.

Engineering, environmental permitting, and mitigation work cost about $2 million more (an additional $0.87/m). Environmental mitigation activities included revegetation of the fill, fish population studies downstream of the reservoir, water quality and other monitoring costs, and sediment removal from pools below the dam.

The project was designed to minimize the downstream release of sediment. To minimize sediment release the reservoir was only partially drawn down during the first years of excavation; full drawdown was timed to coincide with the dry season, and sediment traps were dug within the reservoir area immediately upstream of the outlet and below the dam. The trap upstream of the outlet was excavated in the deposits by heavy equipment, supported on the soft sediment by mats. Below the dam, in the area of the plunge pool and at several sites within about 0.5 km below the dam, sediment traps were constructed by building temporary instream barriers about 1 m tall, using sandbags.

Because of these measures, only 5,000 m^3 of sediment was deposited in pools beyond the last instream sediment basin below the dam. Fine sediment that escaped downstream and deposited in pools was subsequently suction-dredged by portable equipment.

Source: Morris, G.L. & Jiahua Fan. 1998. *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs and Watersheds for Sustainable Use*. McGraw-Hill Book co., New York. Available from: http://reservoirsedimentation.com/

Case Study 2

This case study describes the successful use of flushing in a hydropower reservoir in Costa Rica.

Flushing the Cachi Hydropower Reservoir

The 54 M m^3 Cachí hydropower reservoir was constructed in 1966 on the Reventazón River in Costa Rica. It was first emptied for flushing in 1973, and over the next 18 years, was flushed 14 times. Flushing maintained the power intake free of sediment and reduced the reservoir trap efficiency from

82% to 27%. Flushing operations at this reservoir have been both well-documented and highly successful in preserving storage capacity.

The Cachí Dam is a single-purpose hydroelectric facility. It is a 76 m tall and 184 m long concrete arch structure, with two radial crest gates, and a 3.8-m-diameter power tunnel running 6.2 km to the power house. Three Francis-type impulse turbines were installed with 100.8 MW of capacity and 246 m of usable head. The dam has a single bottom outlet with two bottom gates. There is a vertical sluice at the upstream end and a radial gate at the downstream end of the outlet tunnel through the dam. Guides for an emergency sluice gate are provided at the upstream entrance to the bottom outlet. The bottom outlet was placed near the thalweg of the original river channel and immediately adjacent to the intake screen—a location that facilitates flushing of sediment from in front of the intake.

In 1966 the reservoir had an original capacity of 54 M m^3 and surface area of 324 ha. It is approximately 6 km long with maximum and minimum widths of 1.5 and 0.13 km, respectively. A narrow section, about 4 km upstream from the dam, divides the pool into "upper" and "lower" basins. The floor of the lower basin of the impoundment consists of a series of relatively flat river terraces, onto which fine sediment is depositing, with a deep river channel maintained by flushing. In contrast, the upper basin is filling with sand and coarser material, which is not removed by flushing. During drawdown for flushing, the river exhibits a braided pattern across these coarse delta deposits in the upper basin.

The power intake at Cachí Dam is located near the original riverbed elevation. A portion of the suspended load entering the reservoir is transported by turbidity currents to the area of the dam, and within several years of construction, sediments accumulating near the dam began to be drawn into the turbines and interfere with hydropower production.

The reservoir was emptied for the first time in October 1973 to flush the accumulated sediments through the bottom gate, which was located immediately adjacent to the intake screen. Because of the success of the first flushing operation, it was decided to repeat this operation every year during the wet season when the reservoir could be refilled quickly. From 1973 to 1990 the reservoir was flushed 14 times.

Flushing occurs in three stages: slow drawdown, rapid drawdown, and free flow. During the slow drawdown period, the reservoir level is lowered from 990 m to 965 m at the rate of 1 m/day, with turbines operating at full capacity. If inflow is too large to achieve the drawdown schedule by turbine flow alone, the discharge is augmented by opening the crest gates when water levels are above the spillway crest, or by opening the bottom outlet at lower water levels.

When the water level reaches 965 m, the turbines are stopped, and the bottom gate is opened to initiate the rapid drawdown phase and evacuate the remaining water from the reservoir—a process, which may require 5 to 10 hours. This is followed by the free-flow phase, which occurs when the pool has been completely drawn down, and the river flows freely along the original river channel and through the bottom outlet. Free flow typically lasts 2 to 3 days; during this period, inspection and maintenance is performed on the power tunnel and other facilities. The bottom gate is then closed, and the reservoir is refilled to the 990 level, which requires 16 to 21 days, depending on inflow and power generation requirements.

The amount of sediment released in each stage of flushing varies widely from one event to another, reflecting year-to-year variation in sediment inflow and accumulation along the flushing channel, different periods between flushing events, flushing duration (as long as 15 days in one year because of maintenance requirements), and operation of the bottom gate during drawdown. The power intake is at a higher elevation than the bottom outlet, and when drawdown occurs through the turbines, relatively little sediment is evacuated. However, when high inflow requires the use of the bottom outlet to maintain the drawdown schedule, more sediment is released. Thus, use of the bottom outlet during drawdown increases sediment release during this phase.

During the drawdown period, sediment deposits in the upper portion of the reservoir are scoured and transported downstream, where they become redeposited within the still- submerged portion of the river channel. As water levels continue to decline, this material is again exposed to scour and is transported closer to the dam. During a flushing event, an individual particle may be scoured and redeposited several times before reaching the dam.

Of the average inflow of 807,000 tons/year, 148,000 tons is released through normal hydropower and gate operations for an average release efficiency of only 18% (trap efficiency of 82%) in the absence of flushing. With annual flushing operations, the sediment release efficiency is increased to 73%. Most of the inflowing fines are transported and deposited within the flushing channel by turbidity currents. Essentially, all these in-channel deposits are removed by flushing. Only the coarse bed material and the fines deposited on terraces remain trapped.

Source: Morris, G.L. & Jiahua Fan. 1998. *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs and Watersheds for Sustainable Use*. McGraw-Hill Book co., New York. Available from: http://reservoirsedimentation.com/

Case study 3

Sand mining and river erosion: an example from Vietnam

Severe erosion resulted in the Son Tay riverbed (in Hanoi) decreasing by approximately 2m between 2001 and 2009; in addition, several deep creeks were observed.

These incidents had several causes:

- Construction of reservoirs upstream reducing the sediment load downstream;

- Sand mining exceeding its threshold;

- Deforestation in upstream catchments (an important, sometimes overlooked, factor when considering sediment load). As an example, the coverage of forestry in Da catchment was reduced dramatically from 77.44% in 1943 to 14.13% in 1972. In 1981, coverage was only 8.9%.

In 1996, a report was published, which reviewed scientific research downstream of Hoa Binh after construction. The report estimated the total suspended load through Son Tay at 66 million tons per year, with a bed load of about 15% of the suspended load, and a total sediment load of about 10 million tons per year. After construction of the Tuyen Quang Reservoir on the Gam River and the Son La Reservoir on the Da river (upstream of Hoa Binh), the sediment load is expected to be reduced—but not significantly, compared with Hoa Binh.

Figure 5-9: Water level at Long Bien station in Hanoi

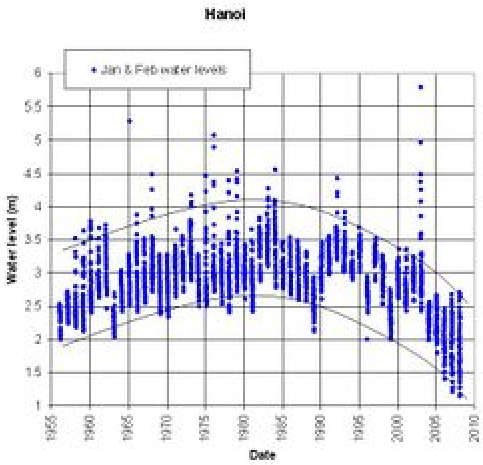


Figure 5-10: Discharge level at Long Bien station in Hanoi

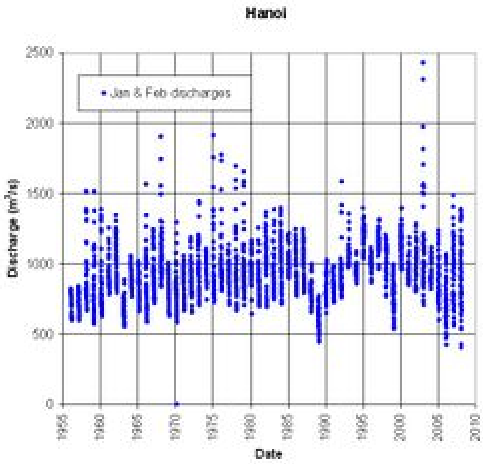


Figure 5-9: A decreasing river bed led to lower water levels. Data from Long Bien station (Hanoi) on Red River.

Figure 5-10: From 2000 to 2009, water levels in Hanoi in January and February were recorded to be decreased by 0.8m, whereas discharge variation was negligible.

Figure 5-11: A small scale deposite site along Red River

Figure 5-12: Sand mining along Lo River

The 2 figures above illustrate sand mining practices along Red River and deposition sites, situated along the riverbanks, receiving sand from mining ships. A ship could start the trip tens of kilometers away, sweep the river for sand, and finally gather it at a deposition site. It is apparent that estimating the volume of mined sand through observation is difficult, since the state of a deposition site does not reflect sand mining at that point—but of the whole river section.

Until now, no official data exists on annual amounts of sand mining. Sand mining sites are heavily located along the rivers; however, a lot of these sites are illegitimate, thus impeding any completed assessment. A few researchers have attempted to make a quantitative analysis of the riverbed incision along Red River. Among those, Vu Tat Uyen (2008) estimated nearly 18 million m^3 of sand was mined each year from 2002 to 2008 and raised a warning that sand mined along Red and Duong River exceeded sediment transported from upstream.

Using surveyed cross sections of rivers in different years, as well as the mobilization of appropriate river morphology models, could help analyzing sediment transport, and thus provide a more complete picture of the effects from flow regimes to river bed incision downstream.

Source: Institute of Water Resources Planning, 2012

5.2 Watershed Management

Key aspects	• Watershed management involves changing the land surface to cause changes in the hydrology of the watercourse flowing from it. • Watershed management can affect hydrology in small, and sometimes medium, sized catchments. • Watershed management is not effective in large catchments, since at this scale, human intervention is outweighed by natural processes. • Achieving changes in land management is very difficult, when watersheds are inhabited. This requires changes in the knowledge, attitude, and practice of local resource users. • Measuring the effects of watershed management on hydrology is difficult and requires long time-series data. • Watershed management cannot be relied on to mitigate sediment problems in poorly sited dams.

TRAINING AIDS	
Purpose of session	To introduce trainees to the concept of watershed management.
Learning objectives	• To appreciate the long history of attempts to alter river flow and water quality by changes in land management. • To understand the limitations of watershed management. • To understand the need for an inclusive approach to planning and implementing watershed management programmes. • To understand how a watershed management programme can be integrated into the EMP for a hydropower project.
Key readings	1) Executive Summary and Chapter 1, Introduction, in: Darghouth *et al.* 2008. *Watershed Management Approaches, Policies and Operations: Lessons for Scaling Up.* Water Sector Board Discussion Paper No. 11, World Bank. http://www.unwater.org/downloads/442220NWP0dp111Box0327398B01PUBLIC1.pdf

5.2.1 Overview

A watershed is an area that supplies water by surface or subsurface flow to a given drainage system or body of water—be it a stream, river, wetland, lake, or ocean (World Bank, 2001)[97]. The characteristics of the water flow and its relationship to the watershed are products of interactions between land and water (geology, slope, rainfall pattern, soils, and biota) and their use and management. A watershed is thus the basic unit of water supply and the basic building block for integrated planning of land and water use (World Bank, 2008)[98].

Table 5-1: A Note on US-British Terminology

UK	USA	General
Catchment	Watershed	Basin
Watershed	Divide	

Watershed management is a term that emerged in the USA, referring to the manipulation of the land surface in order to achieve changes in the hydrology of streams and rivers flowing from it—volume, quality and timing of flow. Watershed management was first applied in a landscape largely devoid of people (although often with many cattle). When the science was transferred to watersheds in developing countries, a completely different paradigm emerged as land management in most of the tropics and sub-tropics is carried out by large numbers of smallholders. Changes in farming systems, overgrazing, deforestation, roads and road construction, and the invasion of alien plants, are all among the most common causes of rural watershed degradation.

Under these circumstances, changes in land management must be achieved through multiple individual decisions which must necessarily be based on incentives and not coercion. Regulating land management seldom works; farmers will react much better to positive incentives, specifically economic or labour-related. Consequently, 'watershed management,' in the international development sector, is often thought of as a large-scale erosion control exercise, involving the full range of rural development interventions ('integrated watershed management'); its roots in hydrological adjustment become diluted, if not lost.

From the point of view of sustainable hydropower, anything that can be done to increase the predictability of flows, reduce flood peaks and minimise erosion is beneficial – and given that most catchments above reservoirs are inhabited, land management will involve working with local residents and resource users (

[97] 2001. Watershed Management Window, Technical Note. Bank-Netherlands Water Partnership Program (BNWPP), World Bank, Washington, D.C

[98] Darghouth *et al.* 2008. *Watershed Management Approaches, Policies and Operations: Lessons for Scaling Up.* Water Sector Board Discussion Paper No. 11, World Bank. http://www.unwater.org/downloads/442220NWP0dp111Box0327398B01PUBLIC1.pdf

Figure 5-9).

Figure 5-13: Watershed Management: Why and What?

Why and What?

- *Manage the land to change the hydrology*

↕

- *Manage the land to benefit the people*

There is a prevailing myth in engineering circles that 'watershed management' can provide the answer to issues of sedimentation; this is rather like the myth that fish passes are 'the answer' to building dams on rivers with migratory fish. In reality, the situation is complex. The most important questions when considering a watershed management initiative are: "Does it work"? and "Is it really possible to change flows within a reasonable time on a significant scale"? Answers to these questions are site-specific. In general, measurable hydrological changes can be achieved in small catchments (1 to 10 km^2) within 5 to 10 years; major investments in medium size catchments (10 to 100 km^2) may bring results, over a period of decades; but in large catchments the scale of natural processes - geological erosion and major storm events - far outweighs the consequences of human intervention on human timescales. In many cases watershed management is carried out for its socio-economic benefits alone, with any benefits to hydrology being incidental (although welcome).

As stated by FAO[99], to date, watershed management has generally achieved only partial success, largely due to the fact that biophysical factors have been emphasised at the expense of socio-economic concern—and the fact that hydrologic boundaries are not congruent with political boundaries. To be seen as responding to flooding problems, government officials and development agencies regularly launch new watershed-management programmes and projects. The activities under these initiatives typically focus on maintaining or expanding forest cover and encouraging soil and water conservation practices in agricultural areas. Attention is also usually given to curtailing shifting cultivation and stabilising rural settlements. However, sporadic short-term efforts in soil and water conservation and reforestation on individual plots (selected on the basis of farmers' willingness to participate or direct payments for co-operation) are unlikely to have a discernible flood mitigation effect, even at the level of a small watershed.

Furthermore, watershed management that is heavily reliant on improved farming technologies often ignores the many water resource-related problems that are caused by non-agricultural land uses. Mining and physical infrastructure, such as roads, for example, can affect local hydrology far more than agricultural practices and can lead to uncontrolled runoff and sedimentation of rivers. Effective watershed management identifies the main problem areas or 'hot spots' of risk and sets appropriate priorities for mitigative interventions. Under

[99] Towards more effective watershed management: http://www.fao.org/docrep/008/ae929e/ae929e07.htm#bm07

this approach, there is no pre-determined assumption that agriculture and farmers (or forestry and loggers) are the major sources of problems.

Another important question is: "How can we measure the effects of watershed management"? As with all hydrological monitoring, long time series data are required to establish what is 'normal' with reasonable confidence. 30 years of record is widely regarded as a minimum, given natural climate variability – and even if this type of record is available, the effects of climate change may make trend projections unreliable.

5.2.2 Watershed Interventions

The **goal** of watershed management is to change the hydrograph of the river flowing from a specific catchment. To achieve this, watershed managers establish physical and social objectives:

Physical objectives:

- Slower runoff – due to increased infiltration and detention.
- Reduced flood peaks – due to slower runoff and lengthier concentration.
- Less erosion and sediment transport – due to reduced flood peaks and lower flow velocities.
- Higher baseflow – due to increased infiltration.
- It is also possible to manage *increased* runoff by converting forests to grasslands (one example).

Socio-economic objectives: are more difficult to establish because of uncertain causality:

- Better land management, resulting in a higher quality of life; or
- Higher standards of living - resulting in better land management

Sustainable watershed management principles include[100]:

- **Integrated resource management,** by linking water quality and quantity and the management of other resources; recognizing hydrological, ecological, social and institutional systems; and recognizing the importance of watershed and aquifer boundaries.
- **Water conservation and the protection of water quality,** by recognizing the value and limits of water resources, the cost of providing water, acknowledging both consumptive and non-consumptive values; and balancing education, market forces and regulatory systems.
- **Resolve water management issues by transparent, participatory processes**. These might include multi-stakeholder collaborative planning sessions, monitoring,

[100] Adapted from West Coast Environmental Law website: http://www.bcwatersheds.org/wiki/index.php?title=Watershed_Planning

researching, consulting, negotiating for consensus, and ensuring accountability through open communication, education, and public access to information.

The World Bank has reviewed project experience and developed ten steps towards watershed management (**Box 5-1**).

Box 5-1: 10 Steps to Watershed Management

10 Steps to Watershed Management

Although every situation is different, some of the lessons recorded in this report have been used to set out a simple checklist for designing and implementing watershed management programs. The intention of the list is to illustrate possibilities rather than to provide a blueprint.

At the national level, establish a supportive policy and institutional framework.

1. Mainstream watershed management concerns and practices within relevant institutions, especially those concerned by or affecting watershed hydrology (for example, power and transport sectors, agriculture, forestry, agribusiness, and local governments).

2. Set up or strengthen institutions specifically in charge of watershed management, and provide capacity building (for example, to a river basin agency, or forestry department).

At the watershed level, develop and implement watershed management plans in partnership with government agencies and local stakeholders.

3. Identify linkages between upstream land uses and practices and downstream environmental conditions, and identify key socioeconomic and environmental characteristics of upland areas.

4. Define broad criteria to target critical watersheds and subwatersheds, and interventions within these areas.

5. Adopt a sequencing and up-scaling strategy, whereby a few subwatersheds would be targeted for interventions first, and others in following years to test and refine the approach.

6. Engage communities in targeted subwatersheds, and develop community watershed management plans that would include both livelihood development and conservation measures.

7. Carry out a detailed financial and economic analysis to assess the financial feasibility of the plan and the economic interest to society.

8. Implement the management plans.

9. Monitor the project to ensure that it is on track to achieve the desired livelihood and environmental objectives, and adapt plans as needed.

10. Quantify downstream positive externalities and, if necessary and feasible, value the costs that upland stakeholders should be compensated for, and develop an incentive stricture for sustainable land and water management.

Source: Pagiola and Platais, 2006, in: Darghouth *et al.* 2008. *Watershed Management Approaches, Policies and Operations: Lessons for Scaling Up.* Water Sector Board Discussion Paper No. 11, World Bank. http://www.unwater.org/downloads/442220NWP0dp111Box0327398B01PUBLIC1.pdf

The following notes review watershed management from the perspective of the development of an Environmental Management Plan (EMP) for a hydropower project. The term “catchment management’ is synonymous with ‘watershed management’.

Catchment management can be conceptualised as integrated water resources management (IWRM) within the limits of a catchment or basin. IWRM, in turn, is defined as[101]:

> *"IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems".*

The catchment, or river basin, is the preferred scale for water resources management. This is irrespective of whether the basin is transboundary—a common feature of the SADC region. Article 26 from the WSSD Plan of Implementation called for the development and implementation of:

> *"…..national/regional strategies, plans and programs with regard to integrated river basin, watershed and groundwater management….."*

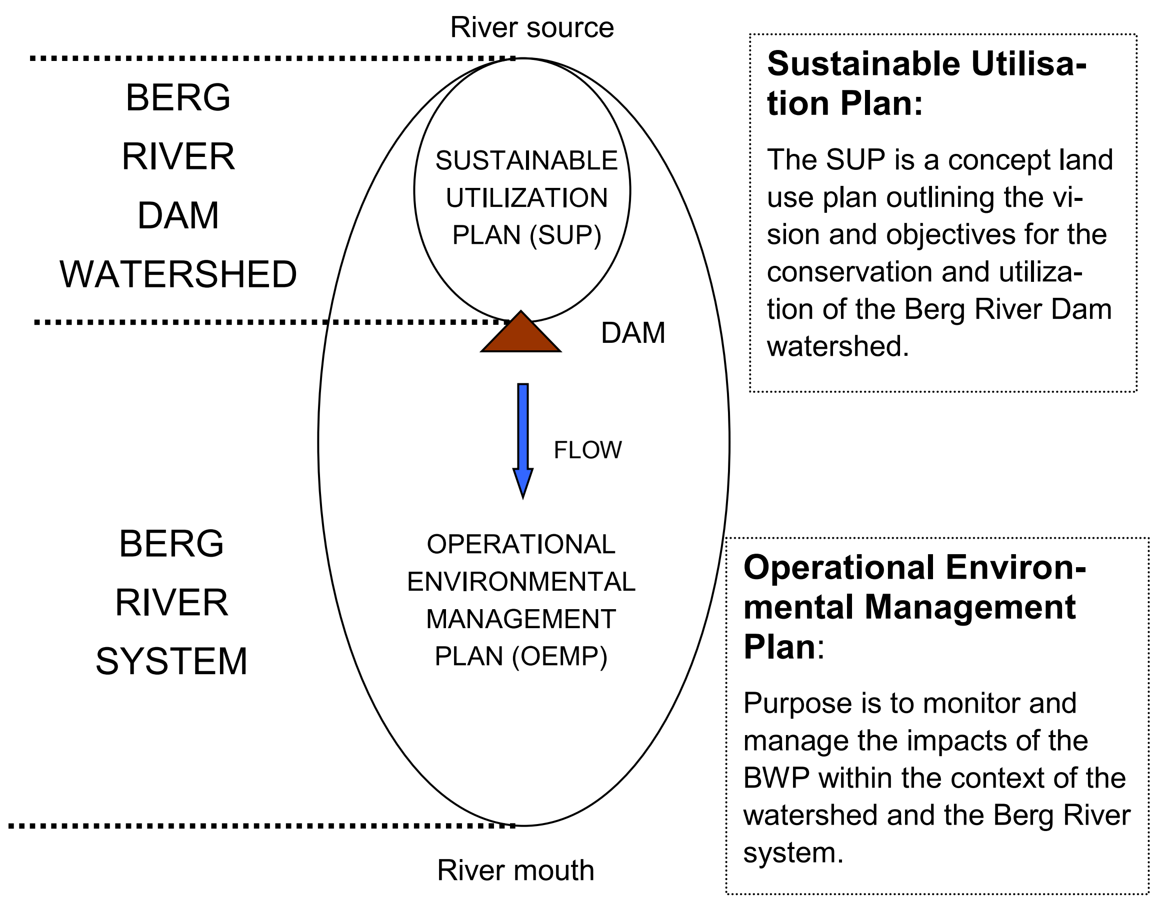
A catchment management approach is particularly important potential exists for a cascade of dams to be built. Such an arrangement can have synergistic impacts of both a positive and negative nature. A cumulative environmental impact assessment is necessary to determine the overall effect; thus, an EMP at catchment scale is necessary. In these circumstances EMP concepts and catchment management overlap, eventually becoming indistinguishable.

A headwaters-to-estuary approach in an EMP brings with it a need for greater coordination with other planning initiatives in the basin and beyond.

Water infrastructure is highly dependent on the natural and social conditions of the upstream catchment supplying runoff. Therefore, an EMP can beneficially include projects at basin scale that can improve runoff and river water quality. Increasingly, this direct connection is being recognized in practical terms by formally linking water resource schemes with management and development activities in contributing headwater areas. In the Berg Water Case, the removal of alien vegetation in the headwaters lead to increased river flows. This part of the EMP was deemed a sustainable utilisation plan, and included the immediate dam and lake area.

[101] Global Water Partnership. *Integrated Water Resources Management*. TAC Background Paper No 4. 2000. p22. www.gwpforum.org.

Figure 5-14: Catchment Management Concept: an Example



Source: Nigel Rousseau (TCTA) Personal Communication

On the Nam Ngum Hydropower Project, implementation was concurrent with other projects, and with a broader initiative to improve management of the catchment. The project consequently defined activities within an Integrated Watershed Development Plan, with specific objectives as follows[102]:

- *"Improve the knowledge of the various habitats and their biodiversity values;*
- *Compensate for and increase the area covered with forest vegetation within the project influence zones (including the biodiversity offsets), and therefore increase and improve, in the long term, natural wildlife habitats;*
- *Implement effective measures to ensure a no-net-loss of biodiversity affected by the inundation of a 64 km long river stretch and critically reduced flows in a downstream stretch of 15.7 km.*
- *Reduce the risk of soil erosion and sedimentation in the catchment, particularly during flood events;*

[102] NN3 Power Company. 2011. *LAO: Greater Mekong Subregion: Nam Ngum 3 Hydropower Project. Final Environmental Impact Assessment*. Project No 41385. P151

- *Reduce the potential for hunting, collecting and trade of wildlife;*
- *Maintain and improve the livelihoods of local people by maintaining and increasing the amount of available non timber forest product."*

Six factors contribute to adopting a catchment management approach:

- Poor catchment condition, which can dramatically reduce project life;
- The rights of basin residents;
- Participatory project planning processes, which are becoming more common and effective. Using these processes, residents of affected areas are better placed to demand and achieve benefits—often in the form of community development schemes;
- Regional effects of major water infrastructure schemes, which can be catalysts for regional economic and social development and watershed protection—including transboundary protection. A well-known example from the 1930s is the Tennessee Valley Authority in the United States. (See http://www.tva.gov/abouttva/history.htm);
- Efforts to reverse environmental degradation at the river basin level, which are becoming more common; for example, in Tanzania's Pangani River basin (**Box 5-2**) (See http://www.panganibasin.com/project/index.html);
- Climate change, which is changing the parameters upon which many existing projects were designed, as well as increasing uncertainty for new projects.

Case Study 1

Catchment management in the LMB: an example of deforestation in Vietnam

Forestry in Northern Vietnam is critical to environmental, economic, and national security. Because of its higher land slope and complex terrain, any land coverage, such as deforestation, will have immediate consequences on flow concentration and distribution. For instance, research on the upstream part of the Hoa Binh reservoir on the Da River shows that when forest coverage was reduced, an increase in peak discharge and total volume of water would occur, flooding in the region. Moreover, due to the absence of forest cover, the duration of concentration will be shorter, resulting in more rapid and destructive flooding incidents.

According to a report prepared by the Forest Inventory and Planning Institute (FIPI) in 2003, the Da River basin had 1.137.185 ha forest coverage (38.6% total basin area). Table 2 summarizes this coverage in comparison with with other basins.

No	Basin	Forestry area (hectare)	Coverage of basin area (%)
1	Red River	3,270,161	36.2
2	Da River	1,137,185	38.6

3	Thao River	486,599	41.4
4	Lo-Gam River	1,029,747	46.8
5	Cau-Thuong River	462,512	36.7

Table 2. Forestry in Red-Thai Binh River Basin in 2003

Forestry has made an important contribution to the economy and environment of Vietnam. Its production (processing, exporting, etc.) accounts for about 1% of total annual GDP in Vietnam and creates millions jobs for local people. Compared to 2005, the forest area cover in Northern Vietnam (including Northwest, Northeast and the Delta) in 2009 has risen from 37% to 39.1%, with a yearly average increase of 0.4%. In 2009, the forest cover in the region was 5,062,300 ha.

Deforestation in Srepok river basin in Vietnam (Lower Mekong Basin part).

Photo: Ha Thanh Lan

Rapid socio-economic development in Red – Thai Binh Delta has put enormous pressure on the forestry sector. An increasing appetite for agricultural land and resettlement needs from an expanding population have sent natural forests into unstoppable deterioration. The area of natural forest shrunk by more than 10% between 2000 and 2005. The effort from government in reforestation has helped it increase by 50.8%. However, the poor quality of the newly planted trees has already shown its weakness in biodiversity preservation and flood protection.

Deforestation increased spectacularly when large reservoirs were constructed (Hoa Binh, Son La etc.). For example, forest cover in the Da catchment has dramatically reduced from 77.44% in 1943 to 14.13% in 1972. In 1981, cover was just 8.9%. This trend is easing up in recent years, due to policy changes that aim to discontinue rapid deforestation. A report from Ministry of Planning and Investment (MPI) in 2012 revealed that the forest coverage in 2010 was 54.2%, while vacant land area accounted for 25.1% of total natural land area. Forest cover is expected to increase to 55.4% and 56.4% in 2015 and 2020, respectively.

In addition, reforestation in the reservoirs' upstream parts (Hoa Binh, Son La, Huoi

Quang, Lai Chau, and others) will be extended, in an attempt to maintain a moderate ratio of forest cover. Nevertheless, future forest cover trends are still unclear as they depend on both socio-economic growth and national policies. Climate change is another critical factor in forestry development; however, projections still lack concrete scientific evidences.

3 **Source:** Institute of Water Resources Planning, 2012

Box 5-2: Catchment Management in the Pangani River Basin, Tanzania

Currently, there is not enough water to meet the demand in the Pangani Basin, yet the Pangani Basin Water Board continues to receive requests for new water permits from local, municipal and industrial investors. The Water Board has little data on the economic, social and environmental costs and benefits of various water allocation scenarios to guide its water permit provision. Climate change and reducing water supplies have yet to be taken into consideration in the allocation process.

The Government of Tanzania, IUCN (through its Water & Nature Initiative (WANI)) and the Global Environment Facility (GEF) (through UNDP) are committed to preparing water users and water managers in Pangani Basin for reducing water supplies. Their goal is to mainstream the negative effects of climate change into Integrated Water Resources Management in the Pangani River Basin, in order to support the equitable provision of freshwater for the environment and for livelihoods for future generations.

The Pangani River Basin Management Project will address this goal through several approaches, including: 1) an Environmental Flow Assessment 2) establishing forums for community participation in water management and 3) raising awareness about climate change impacts and adaptation strategies.

Source: http://www.panganibasin.com/project/index.html

EMPs, as high-level planning and management documents, can encompass and refer to activities undertaken in catchment areas. It is important to include inter-sectoral activities. The case studies provide examples of attention to catchment management (**Box 5-3**).

Box 5-3: Catchment Management in the DDP Case Studies

Case Study	**Description**
Berg Water Project, South Africa	The South African National Working for Water Programme added a project that removed alien vegetation from the catchment area of the supply dam in order to increase run-off. The project had the additional benefits of improving ecological integrity, restoring land, promoting sustainable resource use, and employment for local residents

National Water Fund or Water Conservation Fund (Fondo para la Conservación del Agua - FONAG), Ecuador	A special water fund was created to finance the protection of the catchment area of the water supply to a city and for hydropower. The fund was to protect and conserve watershed values, giving both upstream and downstream social, economic and environmental benefits. The key elements funded were: • Watershed valuation • Land purchase or compensation measures • Enforcement of protection • Targeted land management • Sustainable production systems
King River Power Development, Tasmania, Australia	Remediation works were designed and implemented to reduce metals from mine waste entering the new storage.
Source: Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.	

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Discussion topics	Can watershed management reduce reservoir sedimentation? If watershed management has no measurable effect on river hydrology, what other reasons exist for implementing an integrated watershed management programme? What are the ethical considerations in establishing watershed reserves and removing resource users?
Exercises	• Consider a major hydropower project that you know. List the types of information you would need to (i) determine the need for a watershed management programme, and (ii) design the programme. • For a project you know, list all institutions and organisations responsible for land management decisions – including local resource users. Now develop a process of consultation that might result in effective agreement on changes in land management.
Additional reading and resources	1) Randhir, T.O. 2007. *Watershed Management Issues and Approaches*. IWA Publishing, London. 2) Darghouth *et al.* 2008. *Watershed Management Approaches, Policies and Operations: Lessons for Scaling Up.* Water Sector Board Discussion Paper No. 11, World Bank. http://www.unwater.org/downloads/442220NWP0dp111Box0327398B01PUBLIC1.pdf 3) FAO/CIFOR. 2005. *Forests and floods: Drowning in fiction or thriving on facts?* RAP Publication 2005/03, Forest Perspectives 2. http://www.fao.org/docrep/008/ae929e/ae929e00.htm 4) FAO. 2007. Why Invest in Watershed Management? http://www.fao.org/docrep/010/a1295e/a1295e00.htm 5) FAO. 2006. *The new generation of watershed management programmes and projects: A resource book for practitioners and local decision-makers based on the findings and recommendations of a FAO review*. FAO Forestry Paper 150. http://www.fao.org/docrep/009/a0644e/a0644e00.htm 6) Online citizen's guide to watershed law in British Columbia, Canada, with case studies: http://www.clicklaw.bc.ca/resource/1434 7) Watershed modelling tools: http://ebmtoolsdatabase.org/resource/watershed-modeling-tools

Case Studies

Case Study 1

This case study concerns improvement of small watersheds in a rural area of China by a comprehensive planning approach.

A case study of successful watershed management in Wuhua County, Guangdong Province, China

Wuhua county is located at the mid-eastern part of Guangdong Province, China. The county has serious erosion and watershed degradation problems. Population density is 280/km^2, and the average arable land per capita is only 0.1 ha. Soil and water erosion in the county is responsible for weak geo-morphology, poor soils and vegetation, hydrological problems, irrational land-use and many socio-economic problems.

Although soil and water conservation work in the province began in 1949, this sector only was designated as a high priority in 1982. Accordingly, the provincial government passed many related resolutions to effectively execute soil and water conservation programmes in Wuhua county.

Comprehensive management of small watersheds (5-40 km) has been very popular in Wuhua county. At present, the county has 62 small watersheds under this system. Planning and selection of these watersheds were carried out by a multi-disciplinary team of technicians, NGOs, village leaders and farmers. Under this system, local county government and farmers provide financial support, whereas the provincial government provides necessary materials, tools and equipment to implement the program at a watershed level. People's participation in land management is through various contractual arrangements such as Family Contract System, Collective or Group Contract System, Sub-lease Contract System, Professional Contract System and Specialized Contract System. Because of these systems of people's participation, soil and water conservation works in China have been carried-out successfully. These systems have significantly improved the rural economy and standard of living of farmers of Wuhua county. This is achieved by soil and water conservation techniques, which give quick economic benefits.

The concept of small watershed based development is practised successfully in Wupi river watershed of Wuhua county. The overall plan for the management of a small watershed focuses on comprehensive erosion control measures, including measures for hill slope and gully stabilization. regulating the river system, and rearranging farm lands. Principles of soil erosion control have been further developed by combining soil erosion control measures with the optimum utilization of biological measures. Under these principles, short-term, medium-term and long-term objectives have been formulated. Short-term objective is to upgrade agricultural production, medium-term objective is to increase fruit production and long-term objective is to develop forestry and eventually to combine ecological and economic benefits. The focus on economic benefits is based on the fact that the people would participate actively in soil erosion control works only if it results into quick economic benefits to them.

Source: Wu Deyi: http://www.fao.org/docrep/X5669E/x5669e05.htm

Case Study 2

This case study refers to attempts to safeguard the hydropower sector against climate change by improving watershed conditions.

World Resources Report Case Study: Maintenance of Hydropower Potential in Rwanda Through Ecosystem Restoration

Although it is not possible to state with confidence how climate change may alter precipitation patterns in Rwanda, it is clear that this process will affect the management and generation capacity of its hydroelectric sector in the future. The Government of Rwanda sought to restore the degraded Rugezi-Bulera- Ruhondo watershed by halting ongoing drainage activities in the Rugezi Wetlands and banning agricultural and pastoral activities within and along its shores, as well as along the shores of Lakes Bulera and Ruhondo. These response measures, however, also meant that rural households in the region were no longer able to access key resources, adversely affecting the productivity of their livelihoods. Recognizing this, the Government implemented a suite of agricultural and watershed management measures to offset the initial adverse impacts of their watershed protection policies and render rural livelihoods more sustainable in the longer-term.

Source: http://cdkn.org/resource/world-resources-report-case-study-maintenance-of-hydropower-potential-in-rwanda-through-ecosystem-restoration/

5.3 Payment for Ecosystem Services

Key aspects	• Payment for Ecosystem Services (PES) is a direct approach to conservation. • PES is a useful tool for maintaining the provision of watershed services: clean, sediment-free water. • PES is now used worldwide, and is becoming recognised by the legal framework of some countries in SE Asia (Vietnam's Decree 99/ND-CP Payment for Forest Environmental Services).

TRAINING AIDS	
Purpose of session	To introduce the concept of Payment for Ecosystem Services.
Learning objectives	• To understand the basic principles of PES. • To be aware of PES as an increasingly important conservation tool.
Key readings	1) Sven Wunder (2005). Payments for environmental services: Some nuts and bolts. *CIFOR Occasional Paper No. 42*. ISSN 0854-9818. http://www.cifor.org/publications/pdf_files/OccPapers/OP-42.pdf 2) USAID. 2007. *USAID PES sourcebook: lessons and best practice for pro-poor payment for ecosystem services*. October 2007. 3) *Payments for ecosystem services: A short introduction*. October 2010. DEFRA's Archive. http://archive.defra.gov.uk/environment/policy/natural-environ/documents/payments-ecosystem.pdf

5.3.1 Introduction

In recent years, Payment for Ecosystem Services (PES) has emerged as a new approach to encourage the protection, restoration, and sustainable use of ecosystems. The idea behind Payments for Environmental Services is simple: those who benefit from ecosystem services should pay for the maintenance of those services. PES is a direct approach to conservation, whereby service providers receive payments that are conditional on acceptable conservation performance. This is the characteristic that most distinguishes PES from previous approaches.

The principles of PES can be summarised as:

- Users / beneficiaries of ecosystem services pay stewards / providers of those services.
- Usually voluntary
- Usually direct payments
- Payments are additional to normal financing.
- Payments are conditional on receiving the services.

The theoretical foundations of PES lie in the principle of mutually beneficial bargaining, as suggested by economist Ronald Coase[103]. Through such bargaining, two parties may arrive at an adequate allocation of an environmental resource that is socially efficient.

Definition: the Ecosystem Knowledge Network[104] gives the following definition of Payments for Ecosystem services (PES):

> *"Payments for Ecosystem Services" (PES) is a term used to describe a range of schemes through which the beneficiaries, or users, of ecosystem services provide payment to the stewards, or providers of those services. The beneficiaries may be individuals, communities, businesses or public bodies. Some principles that help to characterize PES are:*
>
> - *Those involved enter on a voluntary basis.*
> - *The beneficiaries of ecosystem services make direct payments to the stewards, or providers of those services.*
> - *Payments are made for actions that are additional to those that would usually be anticipated from those managing the area of land or marine habitat under consideration.*
> - *Payments are conditional on the delivery of ecosystem service benefits.*

Note: the term 'investments in watershed services' is sometimes used to cover the broad diversity of incentive or market-based mechanisms used to protect the natural infrastructure of watersheds, including payments for ecosystem services (PES), payments for watershed services (PWS), water quality trading markets, and reciprocal or in-kind agreements.

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[103] Jindal & Kerr. 2007. *Basic Principles of PES*. In: USAID PES Sourcebook.

[104] http://ekn.defra.gov.uk/resources/tools-guidelines/pes/

5.3.2 Types of Ecosystem Services Involved in PES

The ecosystem services commonly found in current PES schemes are: carbon sequestration, watershed protection, biodiversity, and landscape beauty. The USAID PES Sourcebook[105] explains these types of services as follows:

- **Carbon sequestration:** forests absorb (or sequester) significant amounts of carbon dioxide from the atmosphere, which helps in mitigating global warming. Many governments, corporations, and even individuals are willing to pay landowners and communities to adopt land-use practices that promote carbon sequestration.
- **Watershed protection:** ecosystems such as wetlands and forests regulate hydrological flow and control soil erosion. Better management of agricultural chemicals protects water quality. As clean water becomes scarce and people are more concerned about its quality and quantity, downstream consumers (e.g., hydropower plants, water utilities, irrigators and other downstream farmers, fishermen, and aquaculture.) In some places people are willing to pay upstream land users for watershed services.
- **Biodiversity conservation:** a significant proportion of the world's biodiversity exists in tropical forests and other threatened ecosystems, but local people often cannot directly benefit from it. Some agricultural practices are more compatible with local biodiversity than others, and small payments to land users might make them sufficiently profitable to replace practices that destroy biodiversity. Several companies and international non-governmental organizations (NGOs) now support biodiversity conservation through PES.
- **Scenic beauty:** natural areas provide aesthetic beauty, which is treasured by most human societies. Local land-use practices can enhance or destroy scenic beauty, affecting local quality of life and affecting nature-based tourism opportunities. Tourism companies and even private foundations are paying local farmers or other landowners to preserve this valuable environmental service.

As noted above, a PES scheme is a voluntary agreement between sellers and buyers to deliver actions that increase or enhance ecosystem service delivery. Typically the 'seller' or provider is the land manager, who will deliver different actions on their land leading to enhanced ecosystem service delivery. The 'buyer' is generally linked to beneficiaries or users of ecosystem services that would be enhanced under PES. Different potential beneficiaries might include, for example:

- Water companies: improving water quality and hydrology
- Local residents: interest in reduced flooding
- Insurance groups: interest in reduced flooding or storm/hazard regulation
- Recreational users: interest in enhanced recreational opportunities
- Conservation groups: interest in enhanced wetland habitat

[105] USAID. 2007. http://moderncms.ecosystemmarketplace.com/repository/moderncms_documents/pes_sourcebook.1.pdf

5.3.3 PES Payment Approaches

According to DEFRA's short introduction to PES[106], payment approaches can be classified into two main categories:

- **Output-based payments** based directly on the delivery of ecosystem services (this can also be referred to as payments for results).
- **Input-based payments** for the adoption of particular land uses or land management practices that are expected to deliver additional ecosystem services and benefits (typical of many agri-environment subsidies).

Payments for ecosystem services are not primarily designed to reduce poverty. Rather, PES primarily offers economic incentives to foster more efficient and sustainable use of ecosystem services. Nevertheless there are opportunities for designing PES which can enable low-income people to earn money by restoring and conserving ecosystems" [107].

Isabel van de Sand (2012)[108] noted that:

> *Apart from carbon sequestration, payments are thus not necessarily made for the direct provision of the ecosystem service, but for management or land-use practices that are expected to enhance or secure the service, as is also evident in Wunder's definition. Biodiversity, for example, is not an ecosystem service itself, but the establishment of, e.g., conservation areas to protect biodiversity through a PES scheme* can contribute to enhanced cultural, regulating, and provisioning services.

The types of payment are explained in the USAID PES Sourcebook[109] as follows:

> *In general, payments can be made in cash, or non-cash incentives. In fact, many people argue that the term "payment for environmental services" should be replaced by "rewards for environmental services" or "compensation for environmental services," reflecting the idea that payments need not be in cash. For this Sourcebook, we use "payment for environmental services" as shorthand to cover all kinds of ar-*

[106] http://ekn.defra.gov.uk/resources/tools-guidelines/pes/

[107] Forest Trends, The Katoomba Group, and UNEP. *PES Getting Started: A Primer*. ISBN: 978-92-807-2925-2. Job Number: DEP/1051/NA. Produced by Forest Trends and The Katoomba Group.

[108] van de Sand, I. 2012. Payments for ecosystem services in the context of adaptation to climate change. *Ecology and Society* **17**(1): 11. http://dx.doi.org/10.5751/ES-04561-170111

[109] *USAID PES sourcebook. Lessons and best practice for pro-poor payment for ecosystem services*. October 2007. http://moderncms.ecosystemmarketplace.com/repository/moderncms_documents/pes_sourcebook.1.pdf

rangements that directly provide natural resource managers a conditional incentive for environmental services.

Depending on the local context and institutional arrangements of a particular program, payments can take several forms, including individual or group payments, or non-cash rewards such as tenure rights, employment opportunities, economic development investments, or access to government services. For non-cash rewards, care must be taken that conditionality is maintained, i.e., that the reward can be withdrawn if the environmental service is no longer supplied. Intermediaries may select group payments or provide local infrastructure development with a view to reduce transaction costs of dealing with individual service providers. However, community payments can introduce other kinds of transaction costs associated with organizing the individual members into a cohesive group and ensuring that all members receive their fair share. In addition, some non-cash payments such as land tenure security may be difficult or impossible to revoke if the environmental service is no longer supplied.

The advantages and limitations of PES are identified in **Box 5-4**.

Box 5-4: Advantages and Limitations of PES

Advantages

Efficiency: PES conserves only what is considered worth conserving from the economic standpoint. It can make differentiated payments according to the degree to which services are provided.

Sustainability: PES generally requires that service providers be paid indefinitely for the services they provide. This requires that service users be satisfied that they are receiving the services they are paying for. Hence, sustainability depends on objectively verifiable quality of service.

Autofinancing: PES generates its own funding without requiring substantial budgetary outlays from the government.

Limits

A good understanding of upstream and downstream linkages is needed: PES has to be based on valuation of services provided by upstream management interventions.

Needs continuous readjusting: Changes in market conditions may make a PES payment that is acceptable today insufficient tomorrow.

Market based: PES can only value quantifiable services that can be priced. Externalities that cannot be quantified or priced—biodiversity, for example—may not be suitable for the approach.

Transaction costs for setting up and administering the payment mechanism may be high, especially if beneficiaries are not already organized or if the watershed is large and densely populated.

Not necessarily a poverty reduction mechanism: In many upper watersheds, a large proportion of the population is likely to be poor, but even within watersheds with primarily poor populations, there is no guarantee that payments will reach the poorest.

A substantial role for governments will remain: A need for public financing still exists. Financing for research and monitoring is a clear role for governments. Governments also have to help develop and supervise the institutional and regulatory framework.

Source: Pagiola and Platais, 2006, in: Darghouth *et al.* 2008. *Watershed Management Approaches, Policies and Operations: Lessons for Scaling Up.* Water Sector Board Discussion Paper No. 11, World Bank. http://www.unwater.org/downloads/442220NWP0dp111Box0327398B01PUBLIC1.pdf

5.3.4 International Uptake of PES by Governments

According to Waage (2013)[110]:

In Asia, China and Vietnam are exploring eco-compensation and PES, respectively. Local governments in China have been considering various approaches for eco-compensation, such as transferring funds from the central government to maintain public forests, placing taxes and fees on mineral resources, and establishing payment mechanisms on upstream parties within watersheds. Two reports released in 2011 by the Asian Development Bank focus on institutional challenges and sources of finance for these initiatives. Even earlier, in 2009, Vietnam passed Decision 380, the pilot policy for developing a legal framework and national policy on payment for its forest environmental services. In 2010, Vietnam issued Decree 99/ND-CP focused on Payment for Forest Environmental Services, with implementation across all forests in the country.

In Latin America, the nations of Brazil, Costa Rica, and Peru continue to explore financial incentives for investing in the restoration and maintenance of ecosystem services. In 2012, the Peruvian Ministry of Environment and NGO Forest Trends launched the Watershed Services Incubator to help Peruvian cities develop financing mechanisms for watershed protection. Their intention is to create a watershed-services investment approach that can be applied in other countries.

In Brazil, the states of Acre and Amazonas have passed laws to establish a legal framework for measuring and valuing ecosystem services so that they can implement PES programmes.

Costa Rica has implemented a nationwide PES program since 1997; Mexico since 2003; Ecuador since 2008. Between them, these programs are currently helping to conserve over 3 million ha of forests.

[110] BSR. Global Public Sector Trends in Ecosystem Services, 2009-2012. http://www.bsr.org/reports/BSR_Ecosystem_Services_Policy_Synthesis.pdf

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Discussion topics	1) Discuss the applicability of PES for cases where ecosystem services are produced in one country, but the beneficiaries are in another country.
Exercises	1.) For a watershed you are familiar with, identify several ecosystem services it provides. List the beneficiaries Make some assumptions about the value of the services, then design a consultation process to involve all stakeholders in developing a PES system.
Additional reading and resources	1) World Bank - *Introduction to PES* http://siteresources.worldbank.org/EXTEEI/Resources/IntroToPES.pdf?&resourceurlname=IntroToPES.pdf 2) CIFOR - *PES*. http://www.cifor.cgiar.org/pes/_ref/home/index.htm 3) Bennett, G. N. Carroll & K. Hamilton. 2013. *Charting New Waters: State of Watershed Payments 2012.* Washington, DC: Forest Trends. Available online at http://www.ecosystemmarketplace.com/reports/sowp2012 4) DEFRA. 2007. *An Introductory Guide to Valuing Ecosystem Services*. http://www.defra.gov.uk/wildlife-countryside/natres/pdf/eco_valuing.pdf 5) Mountain Forum Bulletin, Vol. 10, Issue 1, Jan. 2010. Special Issue *Payments for Environmental Services in Mountain Areas.* Mountain Forum Secretariat, Kathmandu. 6) *Rewarding Upland Poor for Environmental Services*. http://www.worldagroforestrycentre.org/sea/Networks/RUPES/index.asp 7) The Katoomba Group (Regional Network for China and East-Asia) http://www.katoombagroup.org/ 8) *Ecosystem Marketplace*. http://www.ecosystemmarketplace.com/

Case Studies

Case Study 1

The following case study from Southgate and Wunder (2007)[111] provides a summary of PES in Costa Rica.

[111] *Paying for Watershed Services in Latin America: A Review of Current Initiatives.* Prepared by Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP) Office of International Research, Education, and Development (OIRED), Virginia Tech Working Paper No. 07-07-July 2007. http://www.oired.vt.edu/sanremcrsp/documents/research-themes/pes/Sept.2007.PESLatinAmerica.pdf

Payments for Environmental Services Program - Costa Rica

Costa Rica, a country with advanced cumulative deforestation, pioneered the use of conservation payments for developing countries by establishing its Payments for Environmental Services (PSA) Program in 1997. Forest Law 7575 (1996) established four primary purposes for the Program: (1) mitigation of greenhouse gas emissions; (2) hydrologic services, including provision of water for human consumption, irrigation, and energy production; (3) biodiversity conservation; and (4) protection of scenic beauty for recreation and ecotourism. The same law established a regulatory framework for contracting with landowners for the provision of these services. It also established the semi- autonomous National Fund for Forest Financing (FONAFIFO) to manage the PSA.

To participate in the PSA Program, landowners submit a plan for sustainable forest management, prepared by a licensed forester. Once this plan is approved, specified practices (i.e. timber plantation, forest conservation or forest management) must be adopted, which triggers payments. In 2006, for example, annual payments for forest conservation averaged US$64/hectare.

For forest plantations, approximately US$816/hectare are disbursed over a 10-year period. Recently, payments for agro-forestry were added. Although an initial disbursement can be requested upon contract signing, all subsequent annual payments require verification of compliance.

To date, the PSA Program has been funded primarily with revenues from a national tax on fossil fuels, which averages about US$10 million per annum. Additional support has included two grants from the Global Environment Facility, a World Bank loan, and a grant from the German aid agency, KfW. In 2005, a new water tariff came into effect, which increased PSA revenues. In addition, new opportunities will be created as global carbon markets continue to develop.

The area enrolled in the PSA Program in late 2005 represented about 10 percent of the. The area enrolled in the PSA Program in late 2005 represented about 10 percent of the country’s forests. The effects of payments on deforestation are difficult to pinpoint. Deforestation had levelled off during the early 1990s, prior to the Program’s beginnings. An important reason for this was a decline in the cattle economy, which previously accounted for most of the encroachment on tree-covered land. Almost certainly, the Program has affected land use since 1997, although existing data and a lack of monitoring make precise quantification impossible.

Regardless, the PSA Program is very popular with landowners, with requests to participate far outstripping available financing. Partly because it is built on previous forest subsidy schemes, it makes relatively uniform payments (fixed rates for each land use category) and has a low degree of spatial targeting. One important finding from the Costa Rican program is the need to remain flexible and to adapt to lessons learned and changing circumstances, including differentiating payments and focusing efficiency.

Sources: Pagiola (forthcoming); Wünscher *et al*., (2006).

Case Study 2

This case study concerns a PES mechanism established in Ecuador to protect watersheds critical to major downstream cities, including the capital, Quito. Source: Case Study 8 in: Ramsay, J. 2006.

National Water Fund (FONAG), Ecuador

Quito is an expanding capital city with a population of around 1.5 million. 80% of the city's water supply is derived from transfers from two Amazonian watersheds in protected areas ,high in the Andean mountains, to the east. These watersheds are also important for hydropower. Water quality is poor due to bacterial contamination and sediment. The upland water source areas have high biodiversity values, a poor and expanding rural population, and are subject to degradation, with consequent impacts on hydrological functioning.

As described by Echavarria and Arroyo (2003),[112] in the 1990s the Ministry of Environment commissioned a local environmental NGO, Fundación Antisana (FUNAN), to design management plans for the two reserves to control these threats. FUNAN's analysis identified five key actions for improving the knowledge base and protecting local hydrology:

- Watershed valuation
- Land purchase or compensation measures
- Enforcement of protection
- Targeted land management
- Sustainable production systems

To implement these measures, funding was necessary. The Ecuadorian park service lacked sufficient resources to fulfil its mandate. To overcome this problem, Fundación Antisana, with support from the United States Agency for International Development (USAID) and The Nature Conservancy (TNC), developed the idea of a new independent water fund - FONAG - dedicated to financing watershed protection around Quito to complement other conservation efforts.

The objective of the project was to establish a sustainable fund to protect and conserve watershed values, giving both upstream and downstream social, economic and environmental benefits. The fund was to be financed partly from payments for ecosystem services (water) and partly from endowments (gifts of capital).

Developer: the project developer was a local NGO, Fundación Antisana (FUNAN), with support from a major US-based NGO, The Nature Conservancy (TNC).

Timeframe: the fund was launched in April 1998 and became operational in 2000, after the Ecuadorean financial crisis, which peaked in 1999. The first projects came on line around 2003.

Cost: seed capital provided in 2000 was US$ 20,000 from the water utility and US$ 1,000 from The Nature Conservancy. In 2005 FONAG's resources had risen to some US$ 2.5 million, invested in an international portfolio, giving annual returns of 6% to 8%. This base revenue stream is augmented by contributions from the members of the fund, principally Quito's water supply and electricity utilities, which contribute 1% and 0.5% respectively of gross annual profits.

Source: Ramsay, J. 2006. *Compendium on Relevant Practices on Improved Decision-Making, Planning and Management of Dams and their Alternatives. Key Issue - Environmental Management Plans, Final Report*. UNEP-DDP, Nairobi.

Case Study 3

[112] Echavarria & Arroyo, 2003, p2
http://ww.iucn.org/themes/wcpa/wpc2003/pdfs/programme/workshops/broader/support/**fonag**echevarria.pdf

This case study concerns piloting of PES in Vietnam.

Field-based Payments for Ecosystem Services (PES) activities in the Mae Sa-Kog Ma Man and Biosphere (MAB) Reserve were launched in early 2012, with plans to continue through January 2016 by the Department of National Forest. Its goal is environmental conservation and integration into Reduced Emissions from Deforestation and Degradation (REDD) + activities.

The Reserve, situated in northern Thailand, occupies of about 427 km^2 total area. Over half of the Reserve area covers a large portion of three national parks, including Suthep-Pui, Khun Kan and Ob Kan, and four national reserved forests: Doi Suthep, Samoeng, Mae Kan-Mae Wang and Tha Chang-Mae Kanin. Thai and Hmong ethnic groups are the dominant populations in the Reserve. The Reserve is not only a prosperous and diverse place for flora and fauna diversity but also of hydrological importance as it encompasses the watershed of the Sa River, a tributary of the Ping River, which is a major water source for Chiang Mai City.

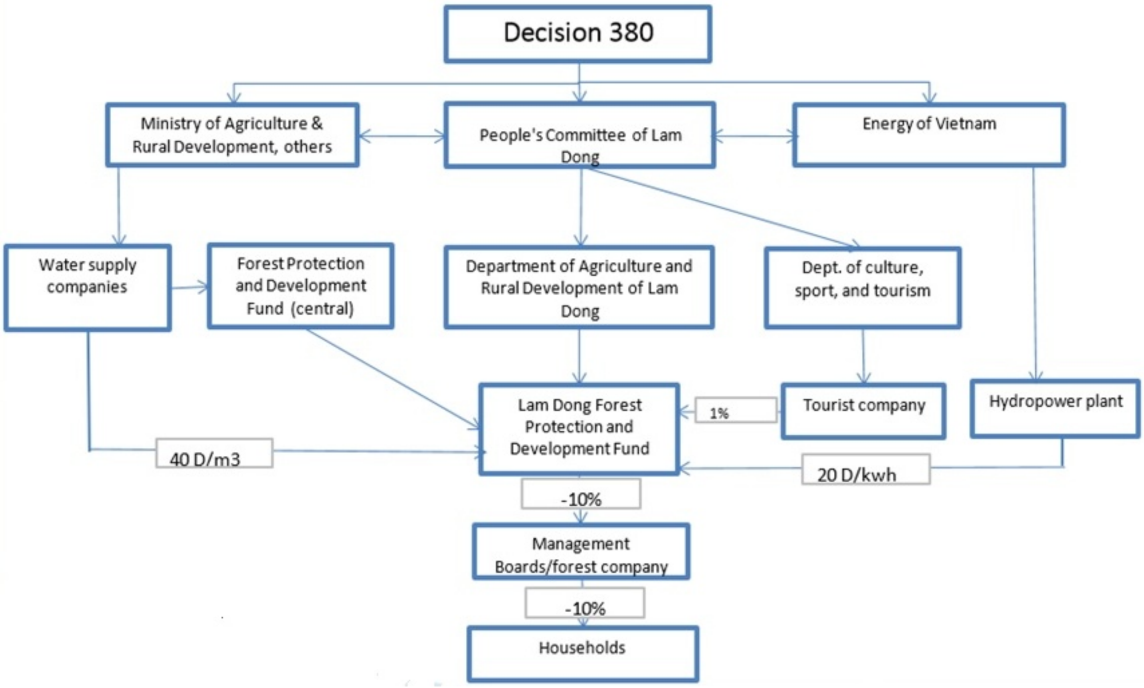
In the first step of implementation, it is essential to build up understanding and awareness of stakeholders involvement in ecosystems' exploitation and compensation. Stakeholders include local communities, civil society organizations, and relevant government and private sector players. Strengthening capacities across all sectors for a solid understanding of and confidence in PES will support the project's success.

Compiling lesson learned, including problems, obstacles, failures and successes, from the field-based PES activities in Mae Sa-Kog Ma would help improve forthcoming projects. Furthermore, at the policy level, this could advise related laws and legislations to support PES.

5.3.4.1.1.1.1 Source: Policy Brief: Field-based PES activities in the Mae Sa-Kog Ma Man and Biosphere Reserve, USAID-ASIA-LEAF November 2012. www.leafasia.org

Case Study 3

This case study concerns piloting of PES in Vietnam.



Decision 380 set an environmental service fee for hydropower plants in Lam Dong province at 20 VND (0.125 cents) per kilowatt hour of electricity produced; for water supply companies the fee was set at 40 VND (0.25 cents) per cubic meter (m3) of water supplied. The team developed a complicated equation to calculate the payment levels, but failed to find a suitable fee to apply to tourist companies benefiting from the landscape beauty of the forest. The team consulted different stakeholders, including tour operators, about their willingness to pay various fee levels and came up with VND 0.5-2% of the companies' gross revenue. Recognizing that the forest had different qualities and ecosystem services, the team calculated payments according to the type of forest service—the status of the forest (rich, average, poor), for example, and whether the forest was natural or planted. A K coefficient was developed to reflect these conditions. Decision 380 also stated that 10% of the total payment derived from environmental service buyers would be retained to cover the administrative costs of the government agency managing the payment, with the remaining 90% to be allocated amongst individuals, households or rural communities – the service providers – receiving forest protection contracts from the relevant state organizations.

6 CLIMATE CHANGE

MODULE 6: CLIMATE CHANGE		
Scope	**Session/Sub-Topic**	**Scope**
Climate change adaptation	**Session 6.1: Climate Change**	
	Overview of Climate Change	Climate change; IPCC scenarios and predictions; governance.
	Climate Change in the Mekong Basin	Predictions, regional and national situations.
	Session 6.2: Climate Change Impacts and Vulnerability	
	Climate Change (CC) & Hydropower	Possible impacts of CC on hydropower: changes in hydrology; increases in extreme events.
	CC Vulnerability Assessment and Adaptation	Introduction to vulnerability assessment approaches, adaptation planning, and design responses.
	CC in the LMB Countries	Regional response, national responses, gap analysis, & country-specific recommendations.

6.1 Climate Change

Key aspects	• The most authoritative projections of climate change are those of the Intergovernmental Panel on Climate Change (IPCC). • Climate change is real; a significant milestone – an atmospheric CO_2 concentration of 400 ppm – has just been passed. • Climate change will have very significant impacts during the present century. • Both mitigation (emission reduction) and adaptation (response to effects) are required. • Regional impacts in SE Asia may include increases in temperature, rainfall, drought and flooding.

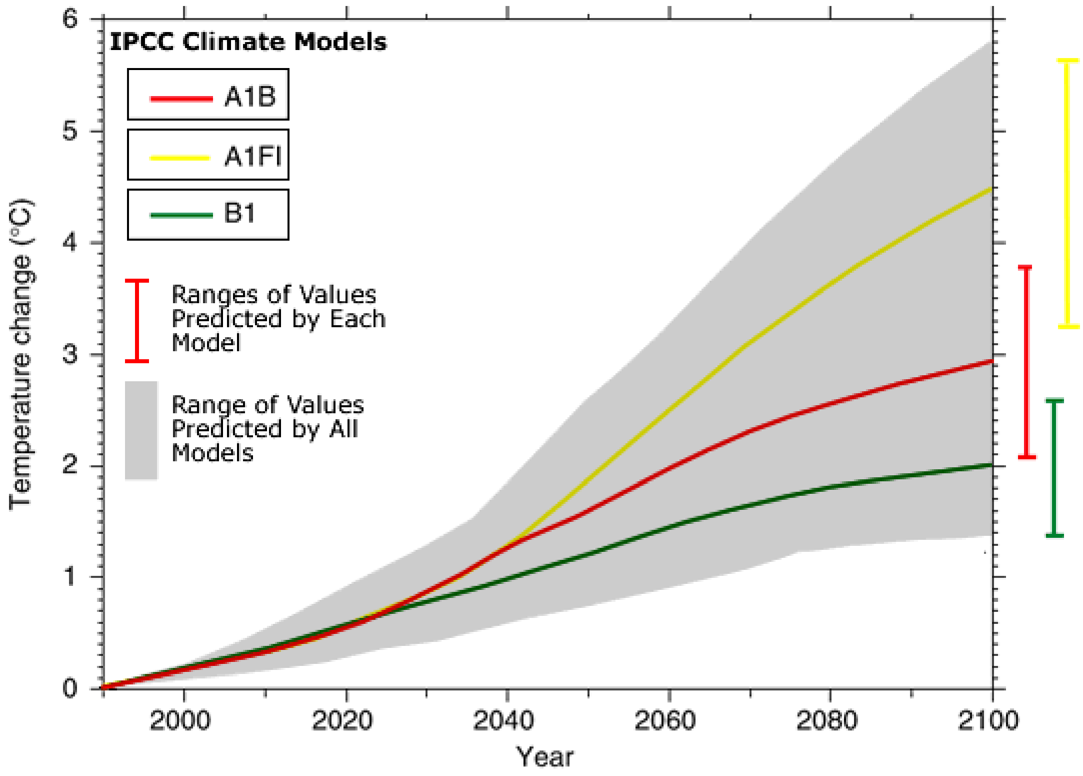
TRAINING AIDS	
Purpose of session	To introduce the global and regional picture with respect to climate change.
Learning objectives	• To understand that climate change is real. • To appreciate the urgent need for both mitigation and adaptation actions.
Key readings	1) Chapter 3, Climate change and its impacts in the near and long term under different scenarios. In: IPCC. 2007. *Climate Change 2007: Synthesis Report*. IPCC 4th Assessment Report. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf 2) LePage, M. 2011. Climate change: What we do know – and what we don't. *New Scientist*, Oct 22-28, 2011

6.1.1 Global Picture

The most authoritative predictions of future climate change are those of the **Intergovernmental Panel on Climate Change** (IPCC). The IPCC is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process to ensure objective and complete assessment of current information.

The IPCC's fourth assessment report (AR4) was published in 2007, and the fifth (AR5) will be completed in 2014 (**Box 6-1**). The IPCC's AR4 projections are shown in **Figure 6-1**.

Figure 6-1: IPCC AR4 Projections



The key conclusions of the IPCC's 4th Assessment's 2007 *Summary for Policymakers* (SPM) were that:

- Warming of the climate system is unequivocal.
- Most observed increases in globally averaged temperatures since the mid-20th century are very likely (>90%) to come to pass, due to the corresponding observed increase in anthropogenic (human) greenhouse gas concentrations.
- Anthropogenic warming and sea level rise will continue for centuries, due to the timescales associated with climate processes and feedbacks. This will continue even if greenhouse gas concentrations were to stabilize, although exact amounts of temperature and sea level rise will vary greatly, depending on the intensity of fossil fuel use during the next century.
- The probability that this is caused by natural climatic processes alone is less than 5%.
- World temperatures could rise by between 1.1 and 6.4 °C during the 21st century.
- Sea levels will probably rise by 18 to 59 cm.
- There is a confidence level >90% that more frequent warm spells, heat waves, and heavy rainfall will occur.

- There is a confidence level >66% that an increase in droughts, tropical cyclones, and extreme high tides will occur.
- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium.
- Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased markedly as a result of human activities since 1750—and now far exceed pre-industrial values over the past 650,000 years.

Box 6-1: IPCC Fifth Assessment Report (AR5) Schedule

The Fifth Assessment Report (AR5) will provide an update of knowledge on the scientific, technical and socio-economic aspects of climate change. It will be composed of three working group reports and a Synthesis Report (SYR). The outline and content can be found in the AR5 reference document and SYR Scoping document. The Working Group (WG) Reports and Synthesis Report will be completed in 2013/2014: WG I: The Physical Science Basis 23-26 September 2013 WG II: Impacts, Adaptation and Vulnerability 25-29 March 2014 WG III: Mitigation of Climate Change 7-11 and 13 April 2014	AR5 Synthesis Report (SYR) 27-31 October 2014 More than 800 authors are involved in writing the reports. Several sets of Lead Author meetings have been held and the expert review of the Working Group contributions has been completed. The IPCC has now begun the government and expert review of the Working Group contributions. For further information on the review process and how to participate please follow this link. For an update on the review process please follow this link. Source: www.ipcc.ch accessed 02 March 2013

In addition to the periodic Assessment Reports, the IPCC prepares Special Reports and Technical Papers on topics such as regional climate change and renewable energy. For example, a Technical Paper on *Climate Change and Water* was published in 2008[113]. A Special Report on *Renewable Energy Sources and Climate Change Mitigation* (SRREN) was agreed and released by the IPCC on May 9th 2009 in Abu Dhabi, assessing existing literature on the future potential of renewable energy for the mitigation of climate change. It covers the six most important renewable energy technologies, as well as their integration into present and future energy systems. It also takes into consideration the environmental and social consequences associated with these technologies, the cost and strategies to overcome technical as well as non-technical obstacles to their application and diffusion (available at http://srren.ipcc-wg3.de/).

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[113] http://www.ipcc.ch/publications_and_data/publications_and_data_technical_papers.shtml#.UZxa15zp_cg).

Important recent climate change findings have been summarised by researchers at the University of New South Wales as a background paper for the 2009 Copenhagen Summit (**Box 6-2**).

Box 6-2: The Most Significant Recent Climate Change Findings (2009)

The most significant recent climate change findings are:

- **Surging greenhouse gas emissions:** Global carbon dioxide emissions from fossil fuels in 2008 were 40% higher than those in 1990. Even if global emission rates are stabilized at present-day levels, just 20 more years of emissions would give a 25% probability that warming exceeds 2°C, even with zero emissions after 2030. Every year of delayed action increases the chances of exceeding 2°C warming.
- **Recent global temperatures demonstrate human-induced warming:** Over the past 25 years temperatures have increased at a rate of 0.19°C per decade, closely correlating with predictions of greenhouse gas increases. Even over the past ten years, despite a decrease in solar forcing, the trend continues to be one of warming. Natural, short-term fluctuations are occurring as usual, but there have been no significant changes in the underlying, increasing, warming trend.
- **Acceleration of melting of ice-sheets, glaciers and ice-caps:** A wide array of satellite and ice measurements now demonstrate, beyond doubt, that both the Greenland and Antarctic ice-sheets are losing mass at an increasing rate. Melting of glaciers and ice-caps in other parts of the world has also accelerated since 1990.
- **Rapid Arctic sea-ice decline:** Summer-time melting of Arctic sea-ice has accelerated far beyond the expectations of climate models.
- **Current sea-level rise underestimated:** Satellites show recent global average sea-level rise (3.4 mm/yr over the past 15 years) to be ~80% above past IPCC predictions. This acceleration in sea-level rise is consistent with a doubling in contribution from melting of glaciers, ice caps, and the Greenland and West-Antarctic ice-sheets.
- **Sea-level predictions revised:** By 2100, global sea-level is likely to rise at least twice as much as projected by Working Group 1 of the IPCC AR4; for unmitigated emissions it may well exceed 1 metre. The upper limit has been estimated as ~ 2 m sea level rise by 2100. Sea level will continue to rise for centuries after global temperatures have been stabilized, and several metres of sea level rise must be expected over the next few centuries.
- **Delay in action risks irreversible damage:** Several vulnerable elements in the climate system (e.g. continental ice-sheets, Amazon rainforest, West African monsoon and others) could be pushed towards abrupt or irreversible change if warming continues in a business-as-usual way throughout this century. The risk of transgressing critical thresholds ("tipping points") increases strongly with ongoing climate change. Thus, waiting for higher levels of scientific certainty could mean that some tipping points will be crossed before they are recognized.
- **The turning point must come soon:** If global warming is to be limited to a maximum of 2 °C above pre-industrial values, global emissions need to peak between 2015 and 2020 and then decline rapidly. To stabilize climate, a decarbonized global society – with near-zero emissions of CO_2 and other long-lived greenhouse gases – needs to be reached well within this century. More specifically, the average annual per-capita emissions will have to shrink to well under 1 metric ton CO_2 by 2050. This is 80-95% below the per-capita emissions in developed nations in 2000.

Source: I. Allison, N.L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J.

Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. *The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science*. The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.

In 2011, the IEA warned that "**We cannot afford to delay further action to tackle climate change if the long-term target of limiting the global average temperature increase to 2°C** …. **Without new policies, we are on an even more dangerous track, for a temperature increase of 6°C or more**." (IEA, 2011).[114]

In May 2013 atmospheric CO_2 readings passed the 400 ppm mark, a significant milestone. The last time the concentration of Earth's main greenhouse gas reached this mark, horses and camels lived in the high Arctic, and seas were at least 10 m higher - a level that today would inundate major cities around the world (Kunzig, 2013)[115].

In summary, human-induced global climate change is happening and will result in dramatic consequences for global civilisation this century. There is essentially no chance of restricting global temperature increases to the 2 ^{o}C agreed by most nations as parties to the UN Framework Convention on Climate Change (UNFCCC). As evidenced by the very limited impact of the UNFCCC's Kyoto Protocol on limiting dangerous human-caused climate change, so far global governance on climate change has failed—yet both mitigation and adaptation actions (mitigation to reduce emissions and eventually decarbonise economies, adaptation to respond to existing and future consequences of climate change) are required urgently. (Note: there is a large and very well funded climate change denial industry, which has had success in confusing the public and preventing climate mitigation actions in some major emitting countries, such as the USA. See, e.g., Goldenberg, 2013[116]).

6.1.2 Regional Climate Change Situation

Regional climate change is predicted by regional climate models (RCMs). Both RCMs and general circulation models (GCMs), which model the global climate, have limitations when predicting regional climate change (Maslin & Austin, 2012).[117] Nevertheless, the consensus is that climate change is expected to result in modifications to weather patterns in the Lower Mekong Basin in terms of temperature, rainfall, and wind—not only in their intensity, but also in terms of the duration and frequency of extreme events. Seasonal water shortages, droughts, and floods may become more common and more severe, as may saltwater intrusion. Such changes are expected to affect natural ecosystems, agriculture and food production, and exacerbate existing problems of supplying increased food to growing populations. The impacts of such changes are likely to be particularly severe, given the strong reliance of LMB communities on natural resources for their livelihoods.

Several studies have attempted to accurately identify the potential future climate situation that could result in the region from global warming. However, most of these studies were

[114] IEA. 2011. *World Energy Outlook 2011, Executive Summary*. International Energy Agency. http://www.worldenergyoutlook.org/media/weowebsite/2011/executive_summary.pdf

[115] Kunzig, R. 2013. *Climate Milestone: Earth's CO_2 Level Passes 400 ppm*. http://news.nationalgeographic.com/news/energy/2013/05/130510-earth-co2-milestone-400-ppm/

[116] Goldenberg, S. 2013. *Secret funding helped build vast network of climate denial thinktanks*. The Guardian, 14 Feb. 2013. http://www.guardian.co.uk/environment/2013/feb/14/funding-climate-change-denial-thinktanks-network

[117] M. Maslin, and P. Austin, "Uncertainty: Climate models at their limit?", *Nature*, vol. 486, pp. 183-184, 2012. http://dx.doi.org/10.1038/486183a

unable to fully quantify the uncertainty around future climate projections. A recent study undertaken for CSIRO (Eastham *et al*., 2008)[118] attempted to redress some of the limitations of earlier studies and, based on the IPCC's Scenario A1B, made the following predictions for the region by 2030:

- A basin wide temperature increase of 0.79˚C, with greater increases for colder catchments in the north of the basin.
- An annual precipitation increase of 0.2 m, equivalent to 15.3%, predominantly from increased wet season precipitation.
- An increase in dry season precipitation in northern catchments and a decrease in dry season precipitation in southern catchments, including most of the LMB.
- An increase in total annual runoff of 21%, which will maintain or improve annual water availability in all catchments. However, pockets of high levels of water stress will remain during the dry season in some areas, such as northeastern Thailand and Tonle Sap (Cambodia).
- An increase in flooding in all parts of the basin, with the greatest impact in downstream catchments on the main stem of the Mekong River.
- Changes to the productivity of capture fisheries, which require further investigation, although it is predicted that the storage volumes and levels of Tonle Sap, a major source of capture fisheries, will increase.
- A possible 3.6% increase in agricultural productivity, but with overall increases in food scarcity, as food production in excess of demand reduces with population growth. Further investigations are required to take into account effects of flooding and crop damage on these predictions.

6.1.3 National Climate Change Situations

Accurate information on the climate change situation at the national level in each of the LMB countries is limited. Available information is often drawn from global or regional level models, with varying degrees of relevance to the national level. Quantitative information is lacking, and most data are presented as broad potential trends.

In Cambodia, it is predicted that there will be an increase in mean annual temperature of between 1.4 and 4.3°C by 2100. Mean annual rainfall is also predicted to increase, with the most significant increase experienced in the wet season. As with the other countries in the LMB, flooding and droughts are expected to increase in terms of frequency, severity and duration. The potential impacts of climate change include changes to rice productivity, with increases in wet season crops in some areas and decreases in others; acceleration of forest degradation, including the loss of wet and dry forest ecosystems; inundation of the coastal zone and higher prevalence of infectious diseases.

In Laos, an increase in mean annual temperature is predicted, together with an increase in the severity, duration and frequency of floods; most probably in floodplain areas adjacent to the Mekong River. The impacts of climate change are predicted to include agricultural and

[118] Eastham, J,, F. Mpelasoka, M. Mainuddin, C. Ticehurst, P. Dyce, G. Hodgson, R. Ali and M Kirby, 2008. *Mekong River Basin water resources assessment: Impacts of climate change*. CSIRO: Water for a Healthy Country National Research Flagship. Canberra. 124p http://www.rfdalliance.com.au/userfiles/file/MekongWaterResourcesAssessment.pdf

infrastructural losses, due to increased storm intensity and frequency; land degradation and soil erosion from increased precipitation, and a higher prevalence of infectious diseases.

In Thailand, an increase in mean annual temperature is predicted, together with an increase in the length of the hot season, with a higher number of days with a temperature greater than 33°C, and a corresponding decrease in the length of the cold season. Higher rainfall intensity is expected in the cold season. Some river basins are expected to face water shortages, and an increase in flood and drought frequency is predicted. The impacts of climate change are expected to include changes in rice productivity, with increases in the wet season crop in some areas and decreases in others, damage to wetland sites from a reduction in water availability, and damage to the coastal zone from changes to coastal erosion and accretion patterns.

In Vietnam, an increase in annual average temperature of 2.5°C by 2070 is predicted with more significant increases probable in highland regions. The average annual maximum and minimum temperatures are also expected to increase. An increased incidence in floods and droughts is predicted, together with changes to seasonal rainfall patterns, and an increased incidence and severity of typhoons. A possible sea level rise of 1.0 m by 2100 has been predicted. It is estimated that there would be direct effects on 10% of population from a 1.0 m sea level rise and losses equivalent to 10% of GDP, due to the inundation of 40,000 km^2 of coastal areas. Salinity intrusion in the Mekong Delta is expected to increase, resulting in changes to cropping patterns and productivity, and negative effects on aquatic and terrestrial ecosystems. A higher prevalence of infectious diseases is also forecast.

TRAINING AIDS	
Discussion topics	1) Should developing countries try to decarbonise their economies, or should they rely on traditional energy supply and use? (The analogy is moving straight to mobile phones without installing landlines). 2) At the national level, what skills will be most needed to plan for and adapt to climate change? Should more resources be put into research? Or into specific disciplines?
Exercises	• Draw problem trees for any of (i) the effects of sea level rise on the Mekong Delta, (ii) hotter and longer dry seasons in the LMB, or (iii) higher rainfall intensities in regional uplands.

Additional reading and resources	1) Website of Intergovernmental Panel on Climate Change (IPCC): www.ipcc.ch 2) Website of Climate Central (a US-based network): www.climatecentral.org 3) Website of IUCN (various pages; example is: http://www.iucn.org/about/work/programmes/species/our_work/climate_change___species/) 4) Stern, N. 2007. *The Economics of Climate Change*. 712pp. Cambridge University Press. http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm 5) World Bank climate change YouTube video: http://www.youtube.com/watch?v=CQbOIl0YQNs&feature=player_detailpage 6) Shukman, D. 2012. *Arctic ice melting at 'amazing' speed, scientists find.* http://www.bbc.co.uk/news/world-europe-19508906

Case Studies

This case study illustrates the impacts of climate change on Mozambique.

Mozambique

Africa is one of the continents most at risk from climate change. Observed temperatures have indicated a warming trend since the 1960s, and IPCC projections suggest that annual temperatures in the region will rise by 3.4 degrees Celsius.

In southern Africa, annual rainfall is likely to decrease, with a higher mean rainfall in the northeast region, while the south and centre are expected to be drier. Only a smaller pocket of the northeast is expected to become wetter – and it is unclear where the geographic division between the 'wetter' northeast and 'dryer' south/central regions will be. The models generally agree on a drying trend for much of the 21st century, and some suggest shorter rainy seasons. Despite the expected drop in overall rainfall for the region, most models agree that what rainfall there is, will fall in a smaller area in the northeast. This suggests that the severity and incidence of heavy precipitation events in the northeast – including Mozambique – is expected to rise.

Mozambique- already more frequently and severely affected by natural disasters than virtually any other country in Africa - is therefore expected to see more precipitation in fewer, more extreme events. The frequency and severity of flooding in Mozambique is expected to increase as a result. In addition, with the expected change in seawater temperatures, the west Indian Ocean tropical cyclones are predicted to be more severe and more frequent in the future – however there is little detailed meteorological modelling on how these storm patterns would evolve.

Mozambique: 2007 floods and cyclone

"*The magnitude of the cyclone and floods (together with drought conditions in the south of the country, which have not been part of the UN humanitarian response) all point to the effects of global warming. These natural disasters are growing more frequent and more severe with time, highlighting* *the importance of national preparedness to reduce the vulnerability of the population to such events and minimize their impact*."

Ironically, damming the Zambezi to control flooding has put more people at risk. The ability to control the annual floods encouraged encroachment on to the lowlands of the lower Zambezi, where the land is very fertile. However, major flood events overwhelm the capacity of the dams, and they are becoming more frequent. The communities currently living in the flood plain are essentially accepting the risk of major floods in return for better harvests and fishing. From a risk reduction perspective, one solution is to encourage permanent resettlement on higher ground, but many do not see this as a viable alternative to the more fertile flood plains. The national disaster management authority estimated that of those evacuated during the 2000, 2001 and 2007 floods, some 40% returned to the flood plains.

Source: UN Office for the Coordination of Humanitarian Affairs (UN OCHA): http://www.unocha.org/what-we-do/advocacy/thematic-campaigns/climate-change/case-study

6.2 Climate Change Impacts, Vulnerability and Adaptation

Key aspects	• Climate change can and will affect hydropower by changing both **power demand** and **power generation**. • Power demand will change due to increases in temperature, increasing the need for cooling as the main user. • Power generation will change due to changes in hydrology – flow volume, timing and quality. • Climate change is already affecting countries with high hydropower dependence. • Vulnerability assessment is the determination of the susceptibility of a system to the adverse effects of climate change. • Climate change adaptation planning requires a systematic approach; methodologies exist. • It is important to address the 'adaptation deficit' first.

TRAINING AIDS	
Purpose of session	To introduce the types of effect which climate change may have on hydropower. To introduce the topics and concepts of vulnerability assessment and adaptation planning.
Learning objectives	• To understand the main types of effect which climate change can and will have on hydropower. • To understand that there is a well-developed technical sector of vulnerability assessment and adaptation planning which can be applied to hydropower systems and individual facilities.
Key readings	1) Blackshear *et al.* 2011. *Hydropower Vulnerability and Climate Change: A Framework for Modelling the Future of Global Hydroelectric Resources*. Available at: http://www.middlebury.edu/media/view/352071/original/ 2) Chapter 2, Background: Climate change vulnerability assessments, in: Hammill *et al.* 2013. *Comparative analysis of climate change vulnerability assessments: Lessons from Tunisia and Indonesia*. IISD for GIZ. http://www.iisd.org/publications/pub.aspx?id=2781 3) Carew-Reid, J., Ketelsen, T., Kingsborough, A., and Porter, S. 2011. *Climate Change Adaptation and Mitigation (CAM) Methodology Brief.* ICEM, Hanoi. http://www.icem.com.au/02_contents/06_materials/06-reports.htm

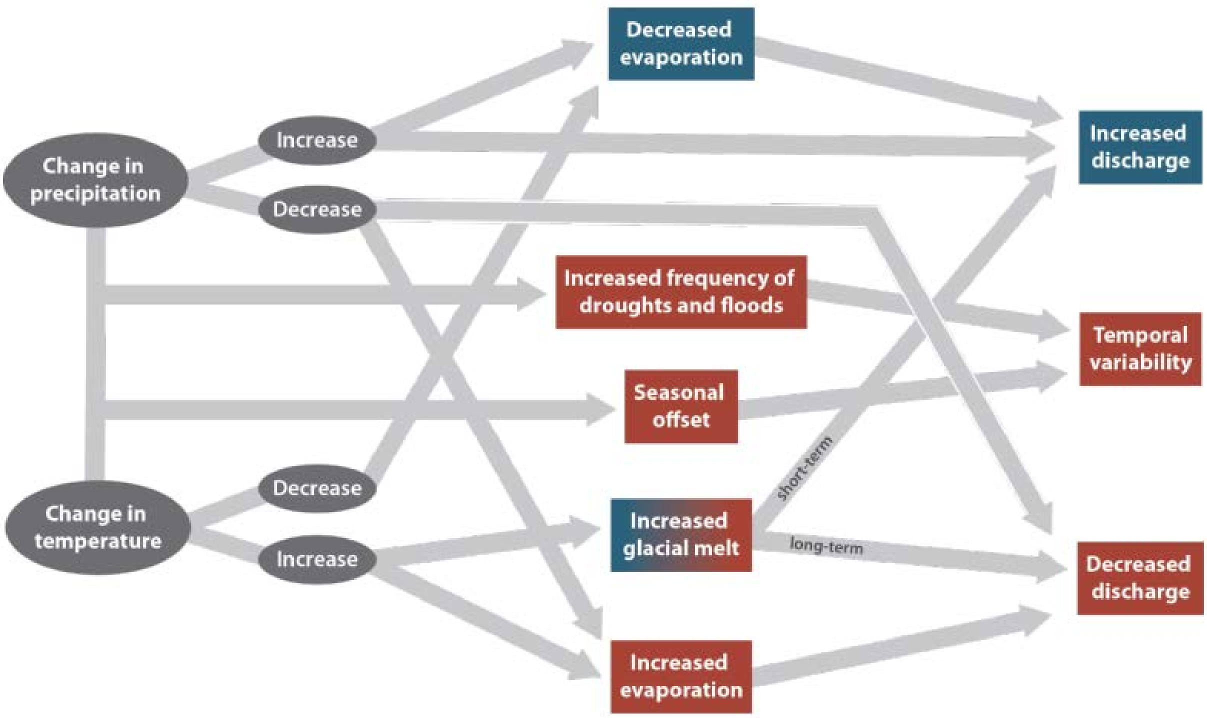
6.2.1 Climate Change and Hydropower

Climate change can affect hydropower by changing the **demand** for electricity, as well as by affecting power generation. The main change in demand is a consequence of higher temperatures and, therefore, increased demands for cooling (air-conditioning). Since these demands often coincide with low-flow periods prior to the seasonal rains, there is, then, a major issue of storage capacity and reservoir operation.

A second major issue is **hydropower dependence**: countries that rely on hydropower, such as Kenya, are now suffering from the consequences of droughts and climate change and seeking to diversify generation towards other renewables, such as geothermal (see, e.g., Burnham & Gronewald, 2010, and the Case Study at the end of this section).[119]

The direct impacts of climate change on hydropower are caused by changes in hydrology and may include reduced or increased annual flows, increased flood runoff (with associated erosion and sedimentation), longer dry seasons and increased variability (uncertainty). Impacts on hydrology resulting from changes in precipitation and temperature are illustrated in **Figure 6-2**.

Figure 6-2: Flow Chart of Climate Change Effects

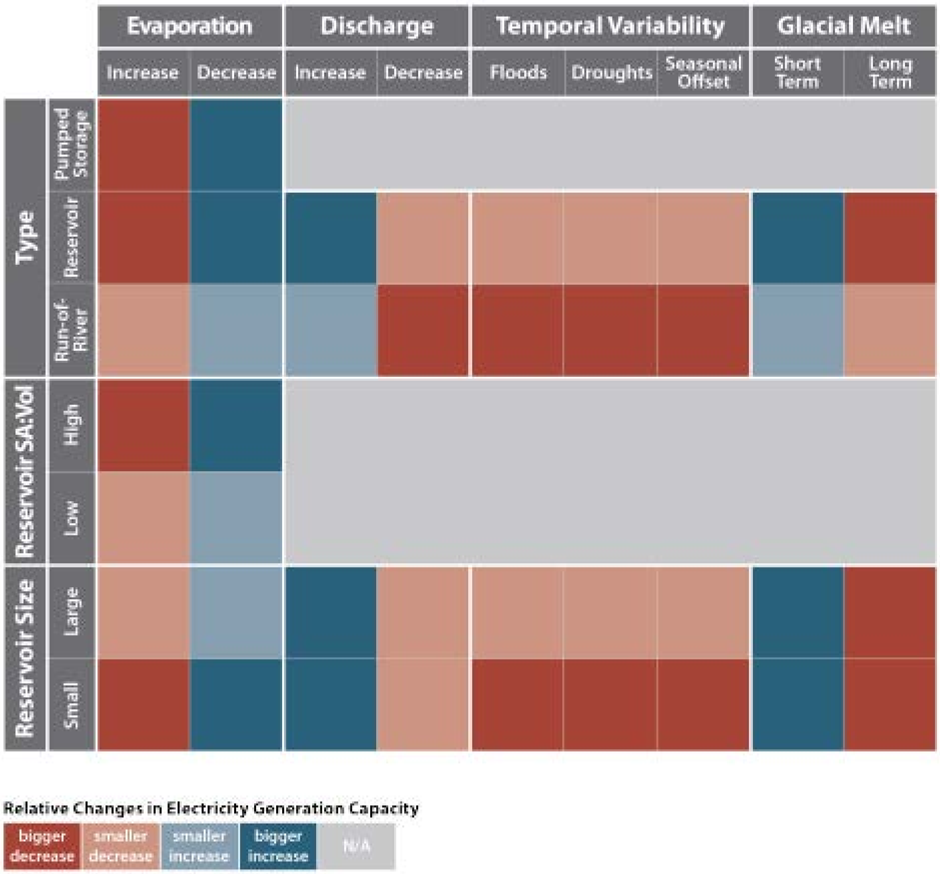


Source: Blackshear *et al.* 2011

A framework of climate change effects on different characteristics of hydropower schemes is shown in **Figure 6-3**.

[119] *Droughts Turn Out the Lights in Hydro-Dependent African Nation*. NY Times, 10 May 2010. http://www.nytimes.com/gwire/2010/05/10/10greenwire-droughts-turn-out-the-lights-in-hydro-dependen-40458.html?pagewanted=all

Figure 6-3: Framework of Climate Change Effects on Characteristics of Hydropower Schemes



Source: Blackshear *et al.*, 2011

Climate change impacts are shown along the x-axis, and hydropower characteristics are shown down the y-axis. Discharge, temporal variability, and glacial melt do not apply to pure pumped storage, which is not connected to a river network. Only evaporation is applicable to reservoir surface area to volume ratio (SA:Vol)

The following notes on the various factors that may change are taken from Blackshear *et al.* (2011)[120]:

Evaporation: increased evaporation will reduce electricity generation for all types of dams, but effects will be most drastic for dams with reservoirs. Due to the direct relationship between the surface area of a body of water and its rate of evaporation, the geometry of reservoirs determines how susceptible they are to evaporation. Reservoirs with higher surface area to volume ratios are more vulnerable to losing capacity from evaporation, which reduces a facility's power production capacity.

Discharge: planned projects should take reservoir shape into consideration in their design in order to reduce evaporation and maximize power potential. Reservoir size is important to evaporation as well, as smaller reservoirs will be more at risk of losing greater proportions of their water volume. This is reflected in the illustrated framework. Though an increase in

[120] Blackshear *et al.* 2011. *Hydropower Vulnerability and Climate Change: A Framework for Modelling the Future of Global Hydroelectric Resources*. Available at: http://www.middlebury.edu/media/view/352071/original/

amount of annual river discharge can sometimes translate simply to an increase in hydropower production, fluctuations in discharge affect different types of facilities differently. Run-of-river dams, for example, may be more vulnerable to decreased amounts of discharge, because they are directly dependent on the river's flow—whereas reservoir dams may be able to compensate better for decreased amounts of water by adapting the management plan for the reservoir volume. In the diagram, discharge is annual and can be directly correlated to changes in precipitation. It does not address other issues such as temporal variability, which is account for in another section.

Temporal variability: climate change will cause increased temporal variability of precipitation events. This will pose significant problems for hydroelectric generation. These impacts will result in more severe and frequent floods and droughts. Seasonal offsets, or the altering timing and magnitude of precipitation for traditional rainy and dry seasons and peak snowmelt, will occur as well.

Flooding: by delivering water supply at varied and unpredictable times, temporal variability negatively impacts hydroelectric production. However, climate change impacts reservoir dams less than run-of-river facilities, because reservoir dams have the capacity to store water, which can help buffer against variations in reservoir volume. Dams can control the flood pulse of a river and help buffer downstream areas from dangerous impacts. Flooding has the potential to increase river flows and hydropower generation as long as the excess river flow level remains within the dam's reservoir capacity. However, in extreme cases, floods can also prove destructive to dams. The large sediment and debris loads carried by floodwaters can block dam spillways, and powerful masses of water can damage important structural components.

Droughts: the extent to which flooding is beneficial or detrimental depends heavily on the size of the dam's reservoir. Droughts may present the most obvious threat to hydroelectric generation, as they reduce the amount of water available to produce electricity. Many regions have experienced droughts in the last several decades, which greatly reduced energy production, reducing up to half of their electrical production capacity in some cases. A 2009 study in the western United States, which modeled the impact of drought scenarios on electricity generation, found that hydroelectric generation would be reduced by 30%. In some scenarios droughts in areas exclusively dependent on hydropower for electricity generation would face blackouts.

Seasonal offset: the seasonality of precipitation causes variability in hydroelectric generation. Regions with distinct seasonal rain cycles and snowmelt seasons typically experience fluctuations in generation, due to precipitation's influence on flow. Munoz and Sailor note: "Under global warming, the existent difference between the generation in fall-winter and spring-summer will increase." Thus power production will indeed increase, relative to current rates, during part of the year; however, this will be counteracted by sharp decreases in other months. The magnitude of climate-change-induced precipitation shifts will vary greatly by season. In some cases precipitation is projected to be reduced twice as much in one season; while in other regions, wet seasons may become drier, and the dry seasons may become wetter.

Glacial melt: glaciated regions of the world act as natural water towers that provide water to downstream areas. As glaciers continue to retreat in response to climate change, runoff to rivers will initially increase in the short-term, due to the large volumes of stored ice melting away. Eventually these stores of ice may disappear entirely, resulting in long-term decreases in annual runoff and stream discharge.

Climate impact assessment requires future climate scenarios to be translated into potential changes on natural and human systems. To assess climate impacts on hydropower production, a number of key steps must be taken:[121]

- A river basin is selected, and its rainfall-runoff processes are modelled and calibrated.
- Climate data, emanating from different GCM or arbitrary climate scenarios, is applied to the model, and the runoff is computed.
- River runoff values are converted into estimates of hydroelectric power production.

6.2.2 Climate Change Vulnerability Assessment and Adaptation Planning

The IPCC defines **vulnerability** as “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity” (IPCC, quoted in Hammill *et al.* 2013).

Vulnerability assessments (VA) are employed to systematically understand how socio-ecological systems may be affected by a source of harm. In climate change adaptation research, vulnerability assessments are used to understand how the effects of climate change may harm a given system, providing a basis for devising measures that will minimise or avoid this harm (Hammill *et al.* 2013). In particular, VAs may be used for:

- **Setting mitigation targets:** Evaluating the impacts of climate change on a given system under different emissions scenarios in order to devise targets and timelines for avoiding “dangerous anthropogenic interference with the climate system” (Article 2 UNFCCC).
- **Allocating resources:** Identifying people, places and sectors that may be most affected by climate change, so that research activities and relevant (financial and technical) assistance can be channelled accordingly. Assessments for this purpose are often comparison and prioritisation exercises;
- **Designing adaptation policies:** Understanding the vulnerability and capacity of socio-ecological systems to function within current and future climate scenarios are key to devising specific strategies to minimise their exposure and sensitivity and/or increase their adaptive capacity.
- **Monitoring adaptation policies:** Evaluating whether or not specified adaptation policy is actually reducing vulnerability. This particular objective is less common, as the development of adaptation policies is nascent, and changes in vulnerability would only actually be observed in the distant future.
- **Raising awareness about climate change:** Highlighting the causes, effects, and ways to address climate change through the identification of people, places, sectors, which it may affect. This is usually a secondary objective in undertaking a VA, often targeted at decision makers with a limited understanding of climate change.

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[121] Harrison *et al.* 1998. *Climate Change Impacts on Hydropower.* http://www.see.ed.ac.uk/~gph/publications/GPH-Upec98.pdf

- **Conducting scientific research:** Understanding vulnerability is about testing and re-fining methodologies, understanding system functioning, developing a better theory of vulnerability, and seeing if this can be applied elsewhere. Similar to the previous point, benefits to the scientific community are more likely to be cited as secondary to the policy objectives.

A typology of VAs is shown in **Table 6-1**. As can be seen from the table, there are many different ways to assess vulnerability. A matrix developed for use in the Asia-Pacific Region is given in **Table 6-2**.

Table 6-1: Typology of Vulnerability Assessments

Approach	What?	Inputs -Typically used data	Inputs - Methods	Inputs - Time and effort required
Quantitative, model-based approaches	Modeling the system in view of climate change	Meteorological/ climate data, biophysical	Climate/bio-physical Modeling	Usually high
Impact chain approaches	Deriving a qualita-tive model of the system	Can go potentially without data, or subsequent mod-eling	Expert judgement, or quantitative modeling	From low to high
Indicator-based approaches	Representing a system based on proxy-indicators	Socio-economic, biophysical, meteorological/ climate data	Literature review; statistical analysis	From medium to high
Bottom-up approaches	Describing the broader develop-ment context/ stressors on liveli-hood, climate only one of them	Historical data of weather & hazard impacts, livelihood data	Participative, qualitative (e.g. consultations, focus groups)	From low to high

Table 6-2: Determining Vulnerability

		Impact				
Adaptive Capacity		***Very Low*** *Inconvenience (days)*	***Low*** *Short disruption to system function (weeks)*	***Medium*** *Medium term disruption to system function (months)*	***High*** *Long term dam-age to system property or func-tion (years)*	***Very High*** *Loss of life, livelihood or system integrity*
	Very Low *Very limited institutional capacity and no access to technical or financial resources*	***Medium***	***Medium***	***High***	***Very High***	***Very High***
	Low *Limited institutional capacity and*	***Low***	***Medium***	***Medium***	***High***	***Very High***

	limited access to technical and financial resources					
	Medium *Growing institutional capacity and access to technical or financial resources*	***Low***	***Medium***	***Medium***	***High***	***Very High***
	High *Sound institutional capacity and good access to technical and financial resources*	***Low***	***Low***	***Medium***	***Medium***	***High***
	Very High *Exceptional institutional capacity and abundant access to technical and financial resources*	***Very Low***	***Low***	***Low***	***Medium***	***High***

Source: Carew-Reid *et al.* 2011 (see Key Readings)

Climate change **adaptation** refers to actions that minimise the adverse effects of existing or predicted climate change on vulnerable systems – whether ecosystems, social systems, or economic infrastructure. Note that climate change **mitigation** refers specifically to measures, which reduce the drivers of climate change – specifically, anything that can be done, directly or indirectly, to reduce greenhouse gas emissions.

The aim of **climate change adaptation assessment and planning** is to reduce the vulnerability of natural, social, economic, built and institutional systems to the risks of climate change. As an example, readers should refer to a methodology specifically developed for use in the Asia-Pacific region (Carew-Reid, *et al.*, 2011). The following notes and diagrams are taken from the same source and describe ICEM's *Climate Change and Adaptation Planning Methodology* (CAM).

Guiding Principles of Adaptation Planning: to ensure an integrated approach to climate change mitigation and adaptation, climate change planning and actions should:

- **Recognise the fundamental role of natural systems in maintaining and enhancing resilience:** Recognise that healthy natural systems are a foundation for the development and wellbeing of socio-economic systems and are essential in building resilience in communities, economic sector and areas. Mitigation and adaptation actions should always contribute to ecological sustainability and social equity, as well as reduce climate change vulnerability or emissions. The corollary to this principle is to ensure that adaptation and mitigation actions do not contribute to environmental and biodiversity degradation.
- **Recognise the cyclical and iterative nature of adaptation and mitigation:** There is no permanent "fix" to climate vulnerability. Adaptation responses need to be regularly adjusted, based on experience and new information. It is not necessary or possible to do everything at once; priorities need to be set, with less urgent measures left to later development cycles. Adaptation is best achieved in phases.

- **Maximize co-benefits:** Pursue synergies and opportunities to integrate adaptation and mitigation. This is not always possible, but all adaptation and mitigation actions should be assessed for their impact on resilience and reducing climate change and their potential to reinforce each other.
- **Use spatial planning as the foundation for adaptation:** Adaptation is best planned and achieved on an 'area wide' basis, which allows for important integration across sectors and levels of government. The opportunities for adaptation and integration become clearer when considered on a spatial basis. Even adaptation planning for organisations such as line ministries must consider how their mandate and responses to climate change play out on the ground.
- **Integrate with development planning:** Recognise adaptation and mitigation actions as part of development planning cycles, so they become an integral part of sector socio-economic plans, budget allocation and staffing commitments. Climate change impact, vulnerability, and adaptation assessments need to lock into sector and area planning steps. Separate adaptation and mitigation plans are important to build capacity and focus attention; however, they should be progressively woven into existing development plans and structures.

In undertaking adaptation planning, it is important to first address the **adaptation deficit** (**Box 6-3**) – what some refer to as the "no regrets" options. Addressing many day-to-day environmental, development and maintenance challenges can enhance resilience to climate change. Most importantly, it brings climate change to the immediate agenda and budgets of local planners in ways they appreciate and understand.

Box 6-3: The Adaptation Deficit

The Adaptation Deficit

An important part of the approach to developing adaptation priorities through a vulnerability assessment is addressing the adaptation deficit. The adaptation deficit refers to things, which need to be done to address current development problems, such as rehabilitation and maintenance of water drainage systems, forest loss and soil erosion, flooding from poor development control, land use, and coastal protection.

Many actions to address current development problems will build resilience—even if not specifically targeting—climate change. The importance of addressing the adaptation deficit in the early stages of building resilience to climate changes is illustrated in **Figure 6-4**.

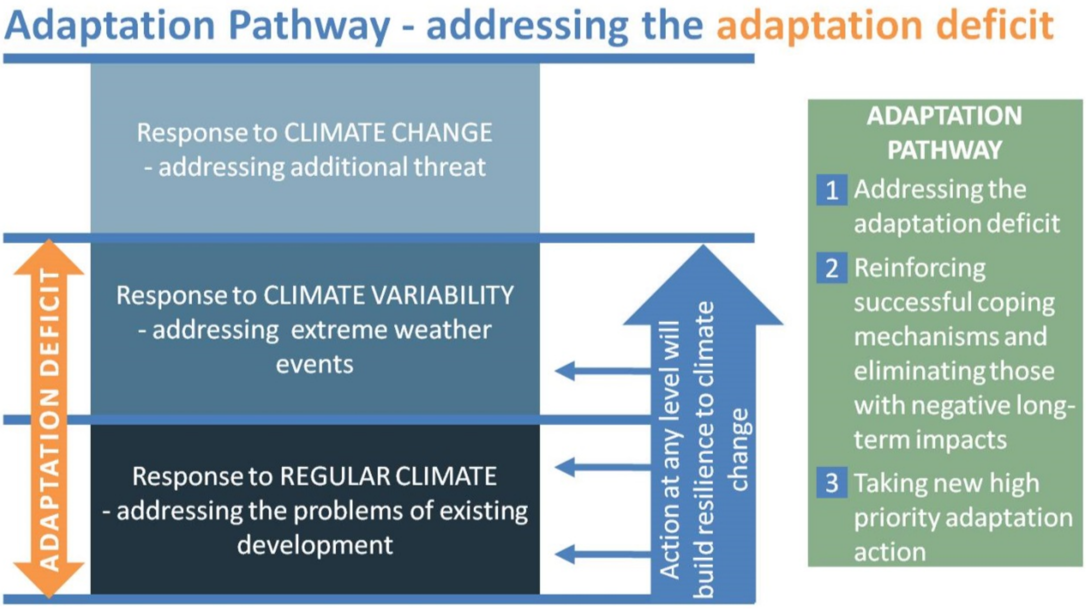
Build on understanding and documenting past extremes and trends, based on stakeholder experience, official records and expert judgment. Integrate modelling results and projections as solid scientific evidence becomes available. In many cases available information and capacities do not allow for useful science-based projections.

Emphasise adaptation action, despite scientific uncertainty. High levels of uncertainty and variability in scenarios, models and interpretation of future threats exist; this does not mean we cannot identify trends and directions of change. We live and plan with uncertainty in every facet of human activity, and climate change is no different. We need to take action in the face of scientific uncertainty.

Focus on integration across sectors and geographic areas: Adaptation action is best implemented by integrating actions across systems, sectors and geographic areas. Adaptation in one area or sector can have unwanted impacts on the resilience of others.

Adapt in phases. Seek to stage adaptation measures so that lessons can be learned and adjustments made if required.

Figure 6-4: The Adaptation Pathway - Addressing the Adaptation Deficit

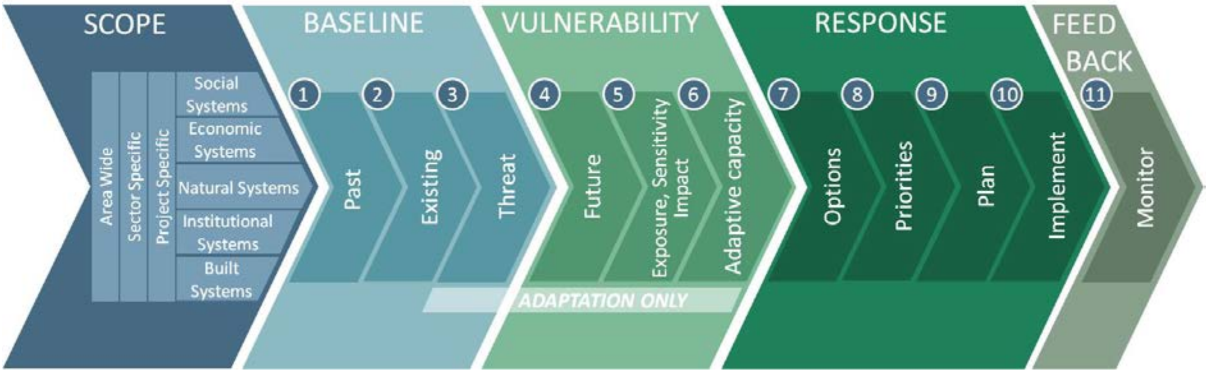


The CAM process, illustrated in **Figure 6-5**, includes five primary steps for adaptation planning including:

- **Determine the scope**, by identifying the geographic and sectoral focus of the assessment and the systems (natural, social, economic, institutional and built), which will be impacted.
- **Conduct a baseline assessment** to describe the past and existing situation, as well as trends and drivers across each of the identified systems, projecting any changes, which will occur irrespective of climate change.
- **Determine climate change threats** through an analysis of past extreme events and trends and through climate modelling and downscaling of future climate and hydrology against various scenarios.
- **Conduct an impact and vulnerability assessment**, which includes analysis of the projected climatic threats to the target systems for defined time slices. The impact assessment combines the level of exposure of key system components and assets and their relative sensitivity to threats. Vulnerability is a measure, which considers the impact and the of the component or asset to adapt.
- **Define adaptation responses:** this step includes developing a range of options for integrated adaptation interventions and then working with stakeholders to determine priorities. With limited resources, it is not possible or necessary to do everything at once.

- **Provide feedback on the adaptation implementation**. Monitoring implementation and making adjustments and additions, based on experience and new information, is critical to taking a phased and systematic approach to adaptation.

Figure 6-5: The ICEM CAM Methodology



In this approach climate change **impacts** are a function of **exposure** of the system or asset to climate threats, and the **sensitivity** of the system or asset (Table 6-3).

Table 6-3: Climate Change Impacts Matrix for Climate Change Threats to a System

		Exposure of system to climate threat				
Sensitivity of system to climate threat		***Very Low***	***Low***	***Medium***	***High***	***Very High***
	Very High	*Medium*	*Medium*	*High*	*Very High*	*Very High*
	High	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Medium	*Low*	*Medium*	*Medium*	*High*	*Very High*
	Low	*Low*	*Low*	*Medium*	*Medium*	*High*
	Very Low	*Very Low*	*Low*	*Low*	*Medium*	*High*

The **vulnerability** of the system or asset can be judged as a function of the impact (from the able above) and the system or asset's **adaptive capacity** (see **Table 6-2**).

Adaptation response: the next phase of the process involves: (i) identifying adaptation options to address the vulnerabilities of strategic assets and systems, (ii) choosing between these, and (iii) drawing up adaptation plans and projects (Figure 6-6).

Adaptation builds climate change resilience in communities, sectors and areas. Opportunities for increasing resilience (i.e. for reducing vulnerability) through adaptation can be found in natural, built, social, economic and institutional systems, for example:

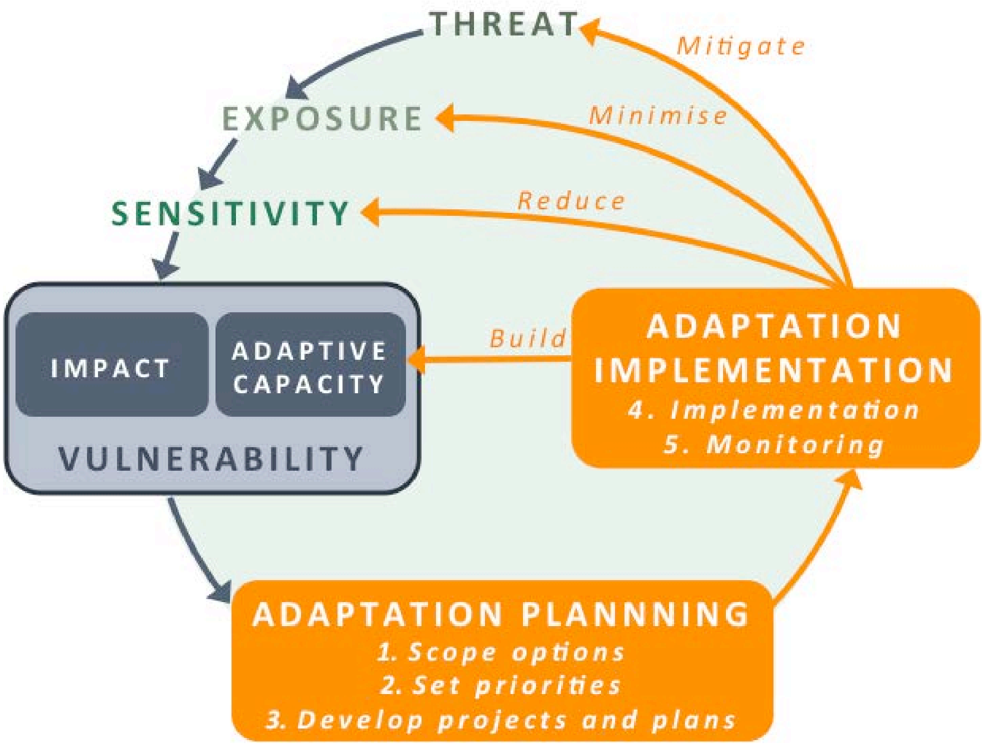
- Engineering options (e.g. flood protection dykes, sea walls and effective drainage systems)

- Traditional local strategies (e.g. terracing and selection of crops)
- Social responses (e.g. resettlement and migration)
- Land use planning (e.g. zoning and development controls)
- Economic instruments (e.g. subsidies and tax incentives)
- Natural systems management (e.g. rehabilitation, conservation, watershed management)
- Sector-specific adaptation practices (e.g. agriculture - species, cropping patterns)
- Institutional options: associated policy, institutional and administrative innovations

In most cases, an effective response requires an integrated set of adaptation actions across all fields of management so that they reinforce each other. Also, it is desirable to analyse how the action will modify vulnerability – either by minimising exposure, reducing sensitivity, or building adaptive capacity, as illustrated in Figure 6-6.

Listing adaptation options requires the involvement of a cross-sectoral group of specialists, as well as other affected stakeholders; often, it is a matter of identifying what has worked in the past, as well as learning from international experience.

Figure 6-6: Adaptation Responses and Feedback



6.2.3 Climate Change in the LMB Countries

6.2.3.1 Regional Response

The LMB covers an area of approximately 606,000 km^2 within the countries of Cambodia, Laos, Thailand, and Vietnam. Based on the outcomes of recent national and regional studies, there is growing concern about the potential effects of climate change on the socio-economic characteristics and natural resources of the LMB region. A need for a more informed understanding of the potential impacts from climate change has been identified.

In response, the Mekong River Commission has launched the regional Climate Change and Adaptation Initiative (CCAI). The CCAI is a collaborative regional initiative designed to address the shared climate change adaptation challenges of LMB countries. A Regional Synthesis Report (RSR) has been prepared as part of the initial phase of the CCAI to provide a snapshot of current knowledge and activities related to climate change in the LMB countries. The specific objectives of the RSR are:

- To inform a wide audience of the current state of knowledge of climate change issues in LMB countries and across the region.
- To provide up to date information on regional and national adaptation activities and policy, and institutional responses in relation to climate change.
- To present the results of a climate change 'gap analysis', identifying information deficiencies and shortcomings in planned activities, as well as policy and institutional responses.
- To present a series of recommendations for future climate change related actions in the LMB.

6.2.3.2 National Responses to Climate Change

National responses to climate change include policy, institutional and adaptation responses. All LMB countries have ratified the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Each country has a primary policy document, which outlines its strategy and responses to climate change. In Cambodia and Laos, this takes the form of a National Adaptation Program of Action to Climate Change (NAPA). Thailand has prepared the 'Action Plan on National Climate Change as the Five Year Strategy on Climate Change 2008 to 2012', and Vietnam has prepared the 'National Target Plan to Respond to Climate Change'. In general, climate change issues are not well integrated into the broader policy frameworks of national governments.

Each of the LMB countries has nominated a national focal point for climate change issues. Within Cambodia, the Ministry of Environment plays this role, within Laos, the Water Resources and Environment Administration, and within Thailand and Vietnam the respective Ministries of Natural Resources and Environment. All countries have established a high level governmental body with responsibility for the development of climate change policy and strategies. Cambodia has established the National Climate Change Committee, Laos has established the National Steering Committee on Climate Change, Thailand has established the National Board on Climate Change Policy and Vietnam has established the National Climate Change Committee.

All LMB countries have a history of implementation of adaptation activities, although most activities implemented to date have focused on natural disaster response management rather than climate change. The NAPAs of Cambodia and Laos contain information on proposed adaptation projects, including 39 activities planned for Cambodia and 45 for Laos. Thailand's 'Action Plan on National Climate Change, as the Five Year Strategy on Climate Change 2008 to 2012', contains strategic directions for development of detailed action plans for future adaptation activities. The Vietnamese 'National Target Plan (NTP) to Respond to Climate Change' establishes directions for the development of sectoral and geographic adaptation action plans; to date, an action plan has been completed for the agricultural and rural development sectors.

A large number of international organisations are working on climate change issues in partnerships with national governments. Across the LMB, more than 300 projects are being implemented or are planned, including:

- The MRC has recently launched the CCAI and has been involved in other related climate change activities as part of its various sector programmes since 2000.
- The UN Development Programme (UNDP) is mainstreaming climate change activities into development programmes through the Poverty and Environment Initiative (PEI).
- The Asian Development Bank (ADB) has a range of climate change activities in the preparatory phase as part of its Greater Mekong Sub-region Core Environment Program.
- The 'Study on Climate Change Impact Adaptation and Mitigation in Asian Coastal Mega Cities' is being carried out with support from the ADB, World Bank and the Japan Bank for International Cooperation, and is investigating climate change issues in Bangkok and Ho Chi Minh City.

6.2.3.3 Gap Analysis and Country Recommendations

A gap analysis, prepared by the National Expert Teams (NETs) and the Regional Synthesis Report (RSR) study team, identified a large degree of commonality in perceived shortcomings in climate change knowledge, activities and responses at both the national and regional level. The gap analysis reflects the key concerns and priority aspects as expressed by national and regional experts.

A large number of recommendations for future actions in climate change activities have been developed by the NETs and the RSR study team. These are presented below in terms of recommendations for each of the LMB countries, followed by a series of regional level recommendations.

Table 6-4: Climate Change: Gap Analysis Recommendations for LMB Countries and the Region

Cambodia
C1 - Support for implementation of NAPA priority activities.
C2 - Development and implementation of climate change awareness raising campaigns.
C3 - Mainstreaming of climate change adaptation into development programmes.
C4 - Institutionalisation of an inter-organisational climate change coordination mechanism.
C5 - Integration of climate change adaptation into the national budgetary process.
C6 - Formulation of climate change adaptation and climate change proofing legislation/policies.
C7 - Strengthening of climate change research.
Laos
L1 - Development and implementation of capacity building programmes.
L2 - Development and dissemination of modelling and assessment tools.
L3 - Support to policy frameworks and improved regulatory and institutional frameworks.
L4 - Pilot study of climate change impacts in selected provinces.
L5 - Development and implementation of a national monitoring and reporting system.
L6 - Investigations into the appropriate use of forest resources as sink sources for carbon dioxide.
L7 - Research to strengthen health systems and services to better anticipate and address potential health challenges.
L8 - Development of a strategy for the multipurpose use of the water for national development activities.
Thailand
T1 - Improved development and assessment of adaptation strategies.
T2 - Development and implementation of capacity building programmes.
T3 - Development and implementation of awareness raising programmes.
T4 - Mainstreaming adaptation to climate change in national policy development processes.
T5 - Mechanisms to increase funds for adaptation to climate change.
T6 - Investigations into linkages between poverty and climate change.
T7 - Development and dissemination of improved modelling tools.
T8 - Increased scientific research.
Vietnam
V1 - Identification of funding sources for NTP activities and adaptation measures.
V2 - Further research on climate change impacts.
V3 - Improved information sharing networks and mechanisms.
V4 - Institutional coordination at a national level.
V5 - Guidance on adaptation planning for national agencies.
V6 - Communication of scientific results through translation of key findings.

Regional Recommendations
R1 - Development of regional institutional structures to address climate change issues.
R2 - Climate change predictions and integrated basin wide assessment of climate change impacts.
R3 - Provisions for sustainability of climate change policy planning.
R4 - Development and implementation of stakeholder awareness raising campaigns.
R5 - Riparian country cooperation to address transboundary issues related to adaptation activities.
R6 - Development of regional information sharing networks and mechanisms.

TRAINING AIDS	
Discussion topics	Is climate change factored into hydropower planning in your country? If not, why not?
Exercises	• For a single hydropower project or cascade of projects, develop a climate change scenario, including increased power demand in the dry season, longer dry seasons, higher flood peaks, and increased variability in precipitation and river flows. Identify the organisation responsible for advance planning for such a scenario. If no such organisation exists, design a better institutional framework for the sector.
Additional reading and resources	1) World Bank video on climate change: http://www.youtube.com/watch?v=CQbOIl0YQNs&feature=player_detailpage 2) Harrison *et al.* 1998. *Climate Change Impacts on Hydropower*. http://www.see.ed.ac.uk/~gph/publications/GPH-Upec98.pdf 3) G. P. Harrison, H. W. Whittington and A. R. Wallace. 2006. Sensitivity of hydropower performance to climate change. *International Journal of Power and Energy Systems*, **26** (1), 2006 4) International Rivers. 2012. *Climate Change & Hydro: Mutually Damming.* http://www.internationalrivers.org/resources/climate-change-hydro-mutually-damming-769 5) Predicted water shortages in USA: see http://www.global-warming-forecasts.com/water-supply-shortage-water-scarcity-climate.php 6) Hammill *et al.* 2013. *Comparative analysis of climate change vulnerability assessments: Lessons from Tunisia and Indonesia*. IISD for GIZ. http://www.iisd.org/publications/pub.aspx?id=2781

Case Studies

Case Study 1

This case study concerns Brazil's dependence on hydropower and the consequences of drought.

Brazil's reliance on hydropower: an opportunity and liability

The connection between water and energy production is not always appreciated. Areas, which lack diverse energy sources can expose themselves to risks if water supplies are unreliable. Brazil has the western hemisphere's third-largest electricity sector—and subsequently reveals the risks inherent with water unreliability.

Hydropower accounts for over 90% of Brazil's electricity; this abundant hydroelectric power is a mixed blessing.

On the positive side, hydroelectric power reduces Brazil's overall generation costs, and compared with the majority of thermal generation, hydropower is also more environmentally sustainable. However, this dependence exposes Brazil to supply shortages in years with low precipitation, especially given sustained and increasing consumer and industrial demand.

See also: *Hydropower in Europe: Lowest Hydro Reserve Levels in More Than a Decade*

Consider what happened in 2000 and 2001, when Brazil faced severe drought. In order to prevent blackouts, the government imposed energy quotas that aimed to reduce consumption by 10% to 35%, according to a report by environmental advocacy group Ceres. Many industries in Brazil's southeastern region – which accounts for almost 60% of the country's GDP – were negatively impacted by reductions in operational capacity, production delays, and increased production costs.

Overall, the drought is estimated to have reduced the country's GDP by 2%, or roughly $20 billion (US) – proving that, especially in countries that depend on hydroelectric power, the impact of water management touches every part of the economy and can force real drawbacks when resources are unexpectedly diminished.

Source: http://growingblue.com/case-studies/brazils-reliance-on-hydropower/

Case Study 2

This case study describes a rapid climate threat and vulnerability assessment of a thermal power plant in Vietnam.

O Mon IV Rapid Climate Change Threat and Vulnerability Assessment

ICEM undertook a rapid assessment of potential climate change threats to the O Mon IV combined cycle gas-fired power plant and of the vulnerability of plant design, infrastructure and operations to these threats for the ADB and Can Tho Power Company. The project tested new modelling and vulnerability analysis methods for CC assessment of large infrastructure.

The ICEM approach included climate downscaling, hydrological and hydrodynamic modelling, plant performance simulation, and hydro-economic and life-cycle analyses to assess the impact of climate change on the structural integrity, performance, legal compliance and maintenance scheduling of the plant and provide recommendations on priority adaptation options. The science-based approach was necessary to convince power station owners and achieve uptake.

The study found that climate change would not result in significant damage to plant assets, but that the performance and efficiency would be reduced over the economic design life. Increasing air temperature would reduce the efficiency of the gas turbines, while increasing river water temperature would reduce the efficiency of the cooling water cycle and steam turbine.

Source: Carew-Reid, J., Ketelsen, T., Kingsborough, A., and Porter, S. 2011. *Climate Change Adaptation and Mitigation (CAM) Methodology Brief.* ICEM, Hanoi. http://www.icem.com.au/02_contents/06_materials/06-reports.htm

Case Study 3

This case study illustrates the incorporation of climate change adaptation measures into the design of major transport infrastructure facilities.

Mekong Delta Bridges Rapid Climate Change Threat and Vulnerability Assessment

ICEM's assessment for the ADB of potential climate change impacts to the Cao Lanh and Vam Cong Bridges and connecting road is the first climate change assessment in the Mekong region to be undertaken concurrent with the detailed design phase of major infrastructure – allowing recommended adaptation options to be integrated into the project life-cycle at the outset.

The study utilizes climate data from six Global Circulation Models (GCMs), downscaled using statistical techniques to quantify the changes in 14 hydro-physical parameters, which have been identified as critical for the project site context. A review of the bridge and road design identified 11 main infrastructure components as being sensitive to climate change, and the CAM vulnerability assessment framework was applied to quantify the impact of climate change on each component.

Central to the study was the use of Cost-Benefit analysis and Cost-Effectiveness analysis as economic tools to quantify the cost of climate change and the benefits of adaptation over the design life (100 years). Based on this quantification of impact, the study supported the ADB to source funding to cover the cost of adaptation from available funding streams.

Source: Carew-Reid, J., Ketelsen, T., Kingsborough, A., and Porter, S. 2011. *Climate Change Adaptation and Mitigation (CAM) Methodology Brief.* ICEM, Hanoi. http://www.icem.com.au/02_contents/06_materials/06-reports.htm

7 MITIGATION AND COMPENSATION

MODULE 7: MITIGATION AND COMPENSATION		
Scope	**Session/Sub-Topic**	**Scope**
Mitigation and Compensation measures (environmental, focused on hydrology)	**Session 7.1: Introduction**	
	Principles of Mitigation	Review of principles of mitigation (avoidance, minimisation, mitigation, compensation) in relation to water infrastructure development; examples in relation to specific impacts of dams on ecosystems (changed hydrology, barrier effect, etc.).
	Multipurpose Dams	Review of the multipurpose concept; trade-offs; institutional and economic factors in operational decision-making.
	Session 7.2: Environmental Flows	
	Environmental Flows	Environmental flows: basic approaches; managed flood releases: theory and practice; case studies.
	Environmental Flow Determination	Review of types of models; introduction to some instream flow requirement (IFR) models; examples of use (e.g. South Africa).
	Session 7.3: Other Mitigation Topics	
	Reservoir Water Quality	Mitigation options: design, operation; removal of vegetation; cleaning; stratification; oxygenation; adjustment of intakes.
	Protected Areas	Identification; management; as offsets.

7.1 Introduction

Key aspects	• The best mitigation measure is avoidance. • Where significant negative impacts will occur, these should be minimised by changes to project location, design or operation. • Significant negative impacts that cannot be avoided or minimised by design should be mitigated. • Unavoidable losses in ecological values can sometimes be compensated by improving ecological conditions elsewhere. • Where there is uncertainty as to potential adverse effects of a project, with significantly irreversible impacts, the precautionary principle should be applied. • Mitigation measures should be written into the EMP, fully budgeted, and strictly enforced. • Multi-purpose dams are complex to optimise, due to conflicting demands of different users.

TRAINING AIDS	
Purpose of session	To introduce the principles of mitigation and the concept of multipurpose dams.
Learning objectives	• To understand the hierarchy of the mitigation approach – avoid, minimise, mitigate, compensate. • To be aware of the complexities of optimising multipurpose projects.
Key readings	1) Goodwin, P., K. Jorde, C. Meier & O. Parra. 2006. Minimizing environmental impacts of hydropower development: transferring lessons from past projects to a proposed strategy for Chile. *J. Hydroinformatics* 8:4, 253-270. 2) Trussart *et al.* 2002. Hydropower projects: a review of most effective mitigation measures. *Energy Policy* 30:14, 1251-1259.

7.1.1 Principles of Mitigation

7.1.1.1 Definition

Mitigation measures are actions intended to avoid, minimise or compensate for negative impacts the project would otherwise cause.

7.1.1.2 The Objectives of Mitigation Measures

Mitigation measures are formulated within legal and social systems and are guided by policy. In order of priority, they are:

- **Avoid:** avoid activities that could result in adverse impacts (e.g. by avoiding certain types of resources or areas considered to be environmentally sensitive). This approach is most effective when applied in the earliest stages of project planning and is often associated with application of the **precautionary principle** (see 7.1.1.3).
- **Minimise:** make the project's negative effects as small as possible, limiting their degree, extent, magnitude and duration. This can be achieved by scaling down, relocating, or redesigning elements of a project, or by changing operating procedures.
- **Mitigate:** when negative impacts are unavoidable and - despite efforts to minimise them by design - are significant, they require mitigation. For example, if construction will inevitably cause sediment mobilisation from earthworks, then sediment traps can be installed.
- **Compensation:** if, despite all measures, some ecological 'value' will still be significantly affected or lost, then this can be 'compensated' offsite, by restoring or creating similar habitats or resources (e.g. fisheries) elsewhere.

Other objectives that may be found in mitigation literature include[122]:

- **Prevention:** measures aimed at preventing the occurrence of negative environmental impacts and/or preventing such an occurrence having harmful environmental and social impacts.
- **Preservation:** preventing any future actions that might adversely affect an environmental resource. This is typically achieved by extending legal protection to selected resources beyond the immediate needs of the project.
- **Rehabilitation:** repairing or enhancing affected resources, such as natural habitats or water sources, particularly when previous development has resulted in significant resource degradation.
- **Restoration:** restoring affected resources to an earlier (and possibly more stable and productive) state, typically a ‘pristine’ condition.

7.1.1.3 The Precautionary Principle

To maintain a river’s health and the associated ecosystem services, it is important to apply the **precautionary principle**.

The precautionary principle holds that, when scientific investigation has found a plausible risk of serious or irreversible environmental and social damage, decision makers have a responsibility to protect the public and environment from possible harm. That protection can be relaxed only if further scientific findings emerge, which provide sound evidence that no harm will result or that effective mitigation is possible.

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[122] South African Department of Water Affairs and Forestry. May 2002 *Guidelines for Standardised Environmental Management Plans*. http://www.dwaf.gov.za/documents.asp.

The application of the precautionary principle and the need to take precautionary measures are triggered under two conditions:

(i) a threat of serious or irreversible environmental and social damage, and

(ii) scientific uncertainty as to the exact nature and extent of that damage (ICEM, 2010)[123].

The threat of serious or irreversible damage must be adequately supported by scientifically plausible evidence. The more significant and more uncertain the threat, the greater the degree of precaution required. Use of the precautionary principle often results in *avoidance* of impacts that would otherwise require mitigation. There are many projects where this principle has not been applied, with adverse consequences. In SE Asia, the most obvious example is the Xayaburi Dam, in relation to its probable impact on fisheries.

7.1.1.4 General

The costs and benefits of large projects accrue in and well beyond the boundaries of the project—and indeed for large dams into the general national economy, even across national borders. However, negative impacts are generally confined to the project area or downstream. Mitigation measures are actions intended to avoid, minimize or compensate for negative impacts that would occur in the absence of the measure. They may also include measures to restore damaged resources, such as wetlands and other sources of livelihoods. Negative impacts may be avoided by design changes; however, this is not always possible, and other forms of mitigation become necessary. Mitigation measures should not be compromised by envisaged future phases of the project (e.g. resettlement on land that needed later).

The core socio-economic purpose of mitigation (and compensation) is to prevent individuals or communities from bearing costs that are in excess of the benefits that will accrue to them from the project. The "development approach" to mitigation has arisen as a result of, first, the global failure of resettlement programmes based on the goal livelihood restoration to achieve their objectives (The goal has to be set higher to achieve mere restoration.); second, the increasing importance of social justice, good governance and human rights for economic development; and third, because alternatives (traditional models of infrastructure project implementation) tend to result in social unrest, project delays, and reputational risks.

Ultimately mitigation is about the transfer of cost and benefits between all stakeholders—geographically, inter-generationally, inter-culturally, and otherwise.

Like impacts, mitigation options must be assessed from social, economic, financial, environmental, technical and political viewpoints. Stakeholder participation is essential to ensure that mitigation measures are feasible and socially acceptable. Communities must take informed decisions; therefore, capacity building initiatives are essential.

Mitigation measures may be broadly classed as **structural** or **non-structural**. Structural measures include changes to a project's location and to the design of engineered components (for example, dam height or the incorporation of a fish pass). Non-structural measures encompass initiatives such as adjustments to reservoir operating rules, changes to the legal

[123] ICEM. 2010. SEA of Hydropower on the Mekong Mainstream, Final Report. MRC.

and institutional framework (for example, creation of a basin management authority), power and water demand management, public awareness, and training. Some mitigation measures incorporate both aspects (for example, sediment control in headwaters (structural), combined with improved land use management (non-structural)).

Mitigation measures may be needed before and during construction, as well as during operation (and, eventually, for decommissioning). These may deal with direct impacts (such as land take) and with indirect, induced or cumulative effects (such as project-induced immigration and over-exploitation of natural resources).

For any particular project, the identification of impacts, the level of risk and possible mitigation measures are part of the EIA process that precedes preparation of an Environmental and Social Management Plan (ESMP). Specifying the mitigation measure for each impact is conventionally included in the environmental approval. Ensuring that the approved mitigation measures are implemented is at the conceptual heart of project social and environmental management and, as such, is at the core of environmental management plans.

To be successfully implemented, mitigation measures must:

- Have been written into the EMP;
- Have been carefully formulated to avoid misinterpretation;
- Be linked to measurable indicators of performance;
- Have had responsibility for their execution and management assigned to specific functionaries; and
- Have been budgeted and programmed in the project.

Box 7-1: Mitigation of development risk of mainstream dams - Considerations / Options

If dam construction is not avoidable, mitigation options are needed. This is mainly related to the regional distribution of adverse impacts and related transboundary impacts, such as:

1. **Sequence LMB mainstream dam development to reduce, minimize and defer potentially significant livelihood impacts,** in view of the consensus that livelihood impacts are highest for lower schemes, especially in terms of capture fisheries and sediment, sediment-nutrient impacts.
2. **Ensure effective institutional arrangements for coordinated operation of reservoirs forming cascades** (e.g. operation in low flows periods, flood management, sediment flow, emergency preparedness measures, etc.).
3. **Ensure consistent project design, mitigation and enhancement approaches**. This is especially important for the upper 6 dam cascade (e.g. navigation lock dimensions, spillway PMFs, consistent with MRC Preliminary Design Guidance and relevant BDP, MRC Programme and PNPCA guidance).
4. **Provide greater transparency around LMB hydropower status,** starting with updating the proposed implementation schedule for LMB schemes by MRC review of the status of mainstream and tributary MOUs and LMB / GMS bilateral power trade agreements.
5. **Ensure transparent compliance and enforcement mechanisms for mitigation measures** on LMB mainstream projects that all LMB countries accept and can monitor (e.g. transparent M&E mechanisms for environmental / social mitigation and management

involving LMB countries, especially for transboundary impacts and related development risks).

6. **Identify and strengthen opportunities for co-management of fisheries** as river-flood plain fish will come under pressure. This is also linked to impacts of tributary dam fisheries (e.g. consistent protection of fishing practices in each country).

Box 7-2: Nam Theun 2 Hydropower Project (NT2)

Some Environmental and Social Impact Assessment of NT2

Hydrological Impacts

- Negative hydrological impacts will be mitigated through operational management of the project; specifically, the operation of the regulating dam. To prevent additional flooding caused by the project, outflow from the regulating dam will be restricted when flows in the Xe Bang Fai approach 1,970 m^3/s, and outflow will cease before the natural flow reaches 2,270 m^3/s (the point at which flooding currently occurs in Xe Bang Fai). The regulating dam will limit the rate of increased discharge into the Xe Bang Fai to a maximum of 20 m^3/s/hour.
- The hydrological changes caused by the project provide significant opportunities to enhance the economies and livelihoods of downstream Xe Bang Fai populations. Higher dry season flows will provide an increased and guaranteed water resource for irrigation and reduced irrigation water pumping costs; these benefits are discussed further in Section V.D.5.
    - o

Environmental Impacts Associated with Resettlement Sites

- Necessary measures will include a range of infrastructure services and management controls in the resettlement villages, such as proper waste treatment facilities and disposal, prohibiting shifting cultivation in the resettlement area, protection of susceptible soil surfaces with seeding and/or mulch, clearance of unexploded ordinance, and sustainable management of 100 km^2 of the resettlement area by the Nakai Plateau Forest Association.

Impacts on Social Environment (Na Kai Plateau)

- The proposed resettlement area is situated on the southwest shore of the Nakai reservoir as shown in Figure 6 above. Efforts have been made to select resettlement sites, within existing traditional and spiritual territories, and ensure cultural continuity and familiarity. Of the 17 villages to be moved, 10 will be relocated 3.5 km or less from their existing site. One settlement will move 4.8 km away, while four villages will move 10–15 km away. Two villages will remain at their present location. In Ban Oudomsouk, only a third of the houses will be relocated, while in Phonphanpek, only agricultural land (no houses) will be affected. The plateau resettlement sites comply with village desires to be near the future reservoir, an all-weather road, their present locations, the forest, and land that can be used to grow rice. Approximately 650 ha of land will be converted to sustainable, irrigated agricultural land. The Tai resettlers from Sop Hia and Nam Nian will relocate from the plateau back to their original village (Nam Pan) in Bolikhamxay province. Consultation with the host village of Nam Pan is ongoing. The Vietic people from Sop Hia prefer to remain on the plateau. The ways in which project-affected people have influenced the resettlement process through consultation and participation are indicated in Chapter 4 of the SDP.

Source: Lao People's Democratic Republic. 2004. Summary Environmental and Social Impact Assessment. 80 pp.

Box 7-3: Lom Pangar Hydropower Project

Measures for Management of Environmental and Social Impacts of the Lom Pangar Hydropower Project

Environmental

- Creation of Deng Deng national park to ensure survival of large primates, based on a biodiversity conservation programme, carried out in collaboration with neighbouring villages, including eco-guards.
- Filling of the reservoir to limit methane emissions from the decomposition of forest vegetation, including possible exploitation of timber (subject of detailed study).
- Limitations on hunting for bush meat.
- Forest management plan to compensate for loss of on-timber forest products in future reservoir area.
- Monitoring of water quality, upstream and downstream of the dam, including re-oxygenation.
- Inventory and monitoring of aquatic biodiversity; monitoring of invasive species.
- Environmental flows: proposals for maintaining satisfactory hydrological conditions in the River Sanaga downstream of the dam.
- Environmental management of construction works/site, including waste management, pollution control, landand scaping.

Social

- Inventory (fichier nominatif) of persons to be displaced by the project.
- Resettlement action plan (RAP) to be drawn up, including compensation for displacement and replacement of agricultural and pastoral areas with technical support, as well as loss of hunting grounds.
- Support to development initiatives (e.g. agriculture) for displaced persons.
- Construction of a bridge for crossing the widened River Lom at Touraké, including for pastoralists.
- Development of a programme for sustainable fisheries in the reservoir of the dam.
- Compensation for loss/displacement of cultural sites (graves and other sacred places).
- Labour, health and safety conditions for construction workers and local people; opportunities for local workers; improvement of local water and sanitation access; measures to reduce vectors of malaria and other illnesses.
- Dam safety measures (e.g. emergency response).

Source: GoC 2010: measures listed in draft final report of Environmental and Social Management Plan, July 2010, p. 41-46, in Newborne (2010: see Additional Readings)

7.1.2 Multipurpose Dams

About 70% of large dams worldwide are single purpose[124]. According to ICOLD[125], the latest version of the World Register of Dams lists 48% of single-purpose dams as for irrigation, 17% for hydropower, 13% for water, 10% for flood control, 5% for recreation, and less than 1% for navigation and fish farming.

Large multi-purpose dams typically combine hydropower generation with water storage for irrigation or water supply, or, in flood-prone areas, with flood-control. Because of the often-conflicting demands of different users, multi-purpose dams are far more complex to plan, fund, and implement than single-purpose dams. For example, flood control requires reservoir levels to be kept low in order to create volume for floodwater storage, but hydropower managers may want higher levels to provide more power or to ensure over-year water availability for power generation in the dry season. Similarly, electricity managers in Central Asia need power in the winter and therefore release waters from storage in the cold months, but irrigation managers want this water in the hot summer months, the usual period of high flow.

Climate change is likely to increase the demand for water storage in order to safeguard against increasing uncertainties in supply. There will also be an increased need for flood control, although whether this is best done by hard strategies, such as storage and flood defences, or by soft strategies such as watershed management and land use planning, is an ongoing debate.

Some of the advantages and disadvantages of multi-purpose dams are listed in **Table 7-1**.

Multipurpose projects require optimisation through multi-criteria decision-making methods. This is a specialised field, with its own technical journals. In general terms, multi-criteria analysis (MCA) describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. In MCA, desirable objectives are specified, and corresponding attributes or indicators are identified. The actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Different environmental and social indicators may be developed side by side with economic costs and benefits. Explicit recognition is given to the fact that a variety of both monetary and nonmonetary objectives may influence policy decisions. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indictors are used. MCA includes a range of related techniques[126].

Table 7-1: Advantages and Disadvantages of Multipurpose Dams

Advantages

- From a macroeconomic perspective, multi-purpose dams provide multiple benefits from a single investment.
- While not as economically appealing to investors (see below), multi-purpose projects are often

[124] http://agriwaterpedia.info/wiki/Multi-purpose_dams

[125] ICOLD: International Commission on Large Dams. http://www.icold-cigb.net/GB/Dams/Role_of_Dams.asp

[126] http://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/multicriteria_analysis__mca_pdf.pdf

more attractive to international financial assistance.

- Multi-purpose dam projects may fit well into regional development programmes (e.g. to improve food production, electricity supply, and the general physical and social infrastructure in rural areas).
- Multi-purpose dams can complement strategies for climate change adaptation; for example, if hydropower generation is combined with increased water storage or flood regulation.

Challenges

- Most multi-purpose dams are funded by governments, with possible international donor support. Attracting private investors to finance more multi-purpose projects is desirable but difficult, due to the inherent complexity. Conflicts of interest among the individual uses (e.g. hydropower, requiring maximum storage levels, and irrigation, causing drawdown), result in complex and potentially vulnerable contract structures. Often promoting a single purpose dam, such as hydropower, is more economically attractive as it promises secure returns on investment.
- Regulatory demands are more complex for multi-purpose dams, compared to projects serving only a single function. Water rights and allocation quotas have to be distributed among the users, with potentially competing demands and impacts usually spread over a large portion of the river basin. As a consequence, inter- and cross-sectoral coordination demands are much higher, requiring relatively strong institutional capacities.
- The impacts of climate change may further intensify competition among the different users as overall water availability decreases.

Source: http://agriwaterpedia.info/wiki/Multi-purpose_dams

Additional example from the **Environmental management Plan for Ngam Ngum 2 Hydroelectric Power Project (NN2 HPP):**

NN2 HPP is a power project of Lao PDR, located approximately 90 km north of the capital, Vientiane. It is a concrete-faced rock fill dam (CRFD), with a crest length of 485 meters, a dam height of 181 meters, and a reservoir storage capacity of 6,774 MCM. This 615 MW hydroelectric power plant can generate 2,218 GWh annually.

NN2 HPP is a multi-purpose dam for electricity generation, irrigation, domestic consumption, and flood control. Electricity generation is for domestic use and for export to Thailand. In accordance with the project’s concession agreement with the Government of Lao PDR, the Environmental and Social Management Plan (ESMP) was conducted in order to minimize social and the environmental impacts in the related area of project vicinity. This ESMP, arranged by the South East Asia Energy Limited (SEAN), as a key shareholder in Nam Ngum 2 Power Company Limited (NN2PC), included an Environmental Management Plan (EMP), Resettlement Action Plan (RAP), Social Development Plan (SDP) and Ethnic Minorities Development Plan (EMDP).

EMP were implemented in the NN2 reservoir, downstream area, and part of the watershed; while RAP, SDP and EMDP were focused in the resettlement area at Muang Fuang, host communities, and related vicinity. The activities of each plan are as follows.

*1. Setting up and Operating the Resettlement and Environmental Management and Monitoring Unit (REMMU)***.** Actions included setting up the working system of REMMU, assisting the Public Consultation Program, formulating the Compensation Entitlement and Asset Valuation Policy, and assisting and facilitating the compensation payment and grievance

process.
2. Environmental Management Plan (EMP). This dealt with supervising and following up work progress of reservoir clearing, supervising water quality monitoring during the construction and commissioning phase, and following up on the watershed management program.
3. Resettlement Action Plan (RAP). This consisted of several tasks: (1) assisting and facilitating land acquisition for resettlement development, (2) identifying and surveying additional sites, (3) developing an alternative physical planning, layout, and development scheme, (4) consultation and finalization of resettlement sites and development plans with Project Affected Persons (PAPs), and (5) supervising the detailed design and construction of infrastructure and public facilities.
4. Social Development Plan (SDP). This included a Community Development Program, Livelihood Restoration Program, and Occupational Training Program.
5. Ethnic Minority Development Plan (EMDP). This included a Traditional and Cultural Re-Adjustment Program, and Ethnic Community and Livelihood Development.
Source: Implementation of EMP, RAP, SDP and EMDP for Nam Ngum 2 Hydroelectric Power Project, Lao PDR . TEAM Consulting Engineering and Management Co., Ltd. The Consulting Engineers of Thailand. www.ceat.or.th/.../391-implementation-of-emp-rap-sd. assessed on September 7, 2013.

TRAINING AIDS	
Discussion topics	When should analysis of impacts and mitigation start? At the feasibility stage? At the pre-feasibility stage? Is it reasonable to compensate for unavoidable loss of ecological habitat by improving habitat elsewhere – or should other habitat be improved anyway?
Exercises	• Consider a proposal to dam a major fish-bearing stream and alter flows so that downstream wetlands used by international migratory birds are no longer seasonally flooded. The project will also create improved access (roads) to the forested watershed. Develop a list of the range of measures that might be required to mitigate the probable negative impacts on ecological values.
Additional reading and resources	1) ACTEW Water. 2012. *Cotter Dam enlargement threatened fish protection case study: saving of fish habitat while building a new dam.* ACTEW Water, Australian Capital Territory. 2) Sale G. F., *et al.* 1991. *Environmental Mitigation at Hydroelectric Projects. Volume 1. Current Practices for Instream Flow Needs, Dissolved Oxygen, and Fish Passage*. Oak Ridge National Laboratory & Idaho National Engineering Laboratory. http://www1.eere.energy.gov/water/pdfs/doewater-10360-vol.1.pdf 3) Vovk-Korže, A. *et al.* Undated. Review of best practic-

	es/guidelines for compensation measures for hydropower generation facilities. CH_2OICE. http://www.ch2oice.eu/download/public/CH2OICE_D2-2.pdf 4) *General Mitigation Measures (Best Management Practices) for Low-Head Hydropower Facilities*. Tribal Energy and Environmental Information Clearinghouse. http://teeic.anl.gov/er/lhhydro/mitigation/index.cfm 5) Newborne, P. 2010. *Decision-making and dialogue relating to large dams and hydraulic infrastructures: Diversity of approaches; evolution of policies and practices applying to project preparation and implementation; case studies from Cameroon and Senegal*. Report for IUCN. 6) Ananda, J., & G. Herath. 2009. A critical review of multi-criteria decision making methods with special reference to forest management and planning. *Ecological Economics* 68, 2535-2548 7) Foote, K. E. & P. Norlund. 2010. *An Introductory Overview to Multi Criteria Evaluation*. Available at: www.colorado.edu/geography/foote/.../Methodology_Norlund_final.ppt

Case Study

This case study concerns the replacement fish spawning habitat when raising a dam to enlarge storage capacity.

Cotter Dam

To improve water security, ACTEW is enlarging the Cotter Reservoir from 4 gigalitres to 78 gigalitres, raising the dam level 50 meters, and increasing the shoreline from 10 km to 25 km. To provide alternative shelter habitats for fish species, including the endangered Macquarie Perch, as reed beds are inundated, seven kilometres of carefully researched, trialed, and strategically placed artificial rock reefs are being constructed. In addition, revegetation has been incorporated, including the use of locally collected native seeds, shrubs, grasses, and trees, particularly Xanthorrhoea trees. ACTEW worked closely with university experts and key environment stakeholders to develop the plan to comply with the requirements of the ACT's Nature Conservation Act and the Federal Government's Environment Protection and Biodiversity Conservation legislation.

Establishing artificial fish habitats

When the enlarged Cotter Dam is complete, and the reservoir begins to fill, the macrophyte reed beds that Macquarie Perch currently use as shelter will be inundated. As part of a comprehensive fish management program, involving ACTEW Corporation and the University of Canberra, Australian National University, and the University of Sydney; ACTEW completed a trial of artificial fish habitats for the endangered Macquarie Perch population in the Cotter Reservoir. Results showed that in the absence of reed beds Macquarie Perch prefer artificial rock reefs over other forms of artificial habitat that were trialed.

Following the submission of a Development Application to the ACT Planning and Land Authority in early 2011, work began on constructing artificial rock reef habitats at carefully selected sites around the Cotter Reservoir for the Macquarie Perch. The habitats will provide new shelter for the fish species, when the enlarged reservoir begins to fill, and the macrophyte reed beds that they currently shelter in are inundated. Rocks of the right size and quality have been sourced to create the habitats and it is expected construction of them will be complete before the water level starts to rise in the enlarged Cotter Reservoir.

Source: ACTEW Water. 2012. *Cotter Dam enlargement threatened fish protection case study: saving of fish habitat while building a new dam*. ACTEW Water, Australian Capital Territory.

7.2 Environmental Flows

Key aspects	• Environmental flows maintain ecosystem services at a level determined by the decision-making process. • E-flows are trade-offs between competing interests. • Determination of e-flows requires the establishment of objectives for river health and other water uses (e.g. sediment transport and channel maintenance, wetlands, fisheries). • There are four basic categories of environmental flow assessment methods: hydrologic, hydraulic, habitat simulation, and holistic; these have increasing requirements for data and time. • E-flow determinations rely on multidisciplinary, multi-stakeholder approaches. • E-flow agreements are meaningless unless monitored and effective compliance mechanisms are in place.

TRAINING AIDS	
Purpose of session	To introduce the concept of environmental flows.
Learning objectives	• To understand that e-flow determination is a complex social, as well as scientific, process. • To understand that a range of method are available.
Key readings	1) Arthington A.H., R.E. Tharme, S.O. Brizga, B.J. Pusey & M.J. Kennard. 2003. *Environmental Flow Assessment with Emphasis on Holistic Methodologies*. http://www.fao.org/docrep/007/ad526e/ad526e07.htm 2) Key Messages, in Dyson, M., G. Bergkamp & J. Scanlon (eds). 2003. *Flow: The Essentials of Environmental Flows*. IUCN, Gland. Available at: http://moderncms.ecosystemmarketplace.com/repository/moderncms_documents/iucn_the-essentials-of-environmental-flows.pdf

7.2.1 Principles

IUCN's description of an environmental flow is "the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits, where there are competing water uses and where flows are regulated" (Dyson *et al.* 2003; see Key Readings). Another definition is environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater ecosystems and the human livelihoods and well-being that depend on these ecosystems" (Brisbane Declaration, 2007, 10th International River Symposium and Environmental Flows Conference).

Environmental flows are also termed in-stream flow requirements (a use sometimes applied specifically to flows in stretches of rivers dewatered by hydropower schemes), environmental water requirements, and ecological flows.

To maintain a desired suite of goods and services, a corresponding level of ecosystem condition must be maintained. The ecosystem condition is determined by flow pattern, water quality, and river structure.

An environmental flow is not the amount of water needed to maintain an ecosystem in close-to-pristine condition; instead, it is the flow allocated, following a process of environmental, social, and economic assessment. The flow will maintain the ecosystem or river in a less than pristine condition—but still acceptable to the decision-making process. This is a societal judgement that will vary from country to country and region to region.

Environmental flows are an essential ingredient in integrated water resources management (IWRM) and are now mandated by the water legislation in many countries, such as Tanzania.

As stated in the IUCN guide to environmental flows (see Key Readings), intuitively, it might seem that all of the natural flow, in its natural pattern of high and low flows, would be needed to maintain a near-pristine ecosystem. Many ecologists believe, however, that a small portion of flow could be removed without measurable degradation of the ecosystem. How much could be removed in this way is difficult to assess, with estimates ranging between about 65% and 95% of natural flow having to remain, with the natural patter of flow also retained. Once flow manipulations move past this, then river ecologists can advise on patterns and volumes of flows that will result in a range of different river conditions. This information can then be used to choose a condition that allows an acceptable balance between a desired ecosystem condition and other social and economic needs for water. The flows allocated to achieve the chosen condition are the environmental flow.

Further, since establishing environmental flows is a question of values, so the setting of river objectives is largely a socio-political process. A successful process therefore needs to include representatives of different interest groups as well as scientists and experts. All involved need to have a basic understanding of what environmental flow setting and management entails.

Environmental flows to maintain ecological values focus on the following purposes[127]:

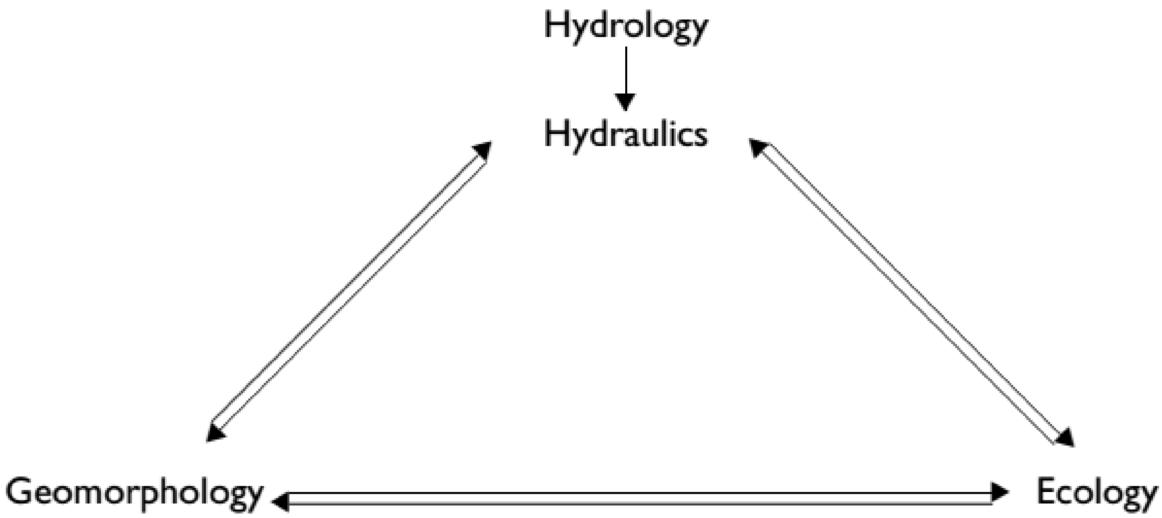
- **Geomorphology:** geomorphology is a critical factor in all aspects of river functioning (**Figure 7-1**). As stated by Brizga (in Arthington & Zalucki, 1998), by altering the downstream hydrological regime, water resource development affects sediment entrainment, transport and deposition processes, as these are all partly determined by flow. Reductions in the frequency or duration of flows competent to transport tributary sediment inputs further downstream have implications for sedimentology and channel morphology, as sediment bars will develop or become enlarged near tributary junctions. Changes in hydrological regime resulting from flow management and flow

[127] Arthington & Zalucki (eds). 1998. *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Methods.* Land and Water Resources Research and Development Corporation.

augmentation may increase the frequency and duration of competent flows, resulting in accelerated erosion.

- **Wetland, riparian and floodplain vegetation:** as stated by McCosker (in Arthington & Zalucki, 1998), water availability is the key factor influencing the structure and floristic composition of vegetation communities in wetland, riparian and floodplain ecosystems. Typically these communities are dependent on regularly varying annual flows, with seasonal floods. The resulting wetlands are often highly biodiverse and biologically productive; for example, the Kafue Flats in Zambia are noted for both their wildlife and for their importance for seasonal grazing and flood recession agriculture. (Note: wetlands are distinct from riparian and floodplain communities in that standing water is the primary force that determines plant assemblages. While flooding plays an important role in the ecology of riparian and floodplain plant communities, water drains off land occupied by these communities soon after the recession of floodwaters. Wetlands can be considered water storage systems, while riparian zones and floodplains act as conduits for water transmission (McCosker, in Arthington & Zalucki, 1998)).
- **Freshwater fisheries:** the importance of adequate flows for fisheries downstream of dams cannot be overstated. Flow volume, timing, velocity, and quality are all critical for maintaining different aspects of fish life cycles.
- **Coastal fisheries:** as stated by Bunn *et al.* (in Arthington & Zalucki, 1998), there are many linkages between river discharge and the dynamics of coastal ecosystem. For example, seasonal or inter-annual variation in discharge can determine whether the mouth of an estuary is open or closed, and whether marine species are able to recruit into them. Flow-driven changes in salinity and turbidity are important factors influencing the distribution and abundance of fish and crustaceans. Furthermore, nutrients exported from rivers to coastal areas may stimulate the production of microalgae, which are thought to be important primary sources of energy to coastal food webs.

Figure 7-1: Relationship between Hydrology, Ecology and Geomorphology in a River



Source: Brizga, S. in: Arthington & Zalucki (eds), 1998 (see Additional Readings)

7.2.2 Environmental Flow Determination

Environment flow assessment (EFA) is concerned with balancing the use (or development) of water from aquatic ecosystems for various, direct human needs, such as hydropower, industry, irrigation, and public water; whilst protecting (or managing) aquatic ecosystems, so that they can continue to be used by present and future generations. Seven **key concepts** are important[128]:

- Complexity and variability are vital to ecosystem health;
- River systems can be maintained at different levels of health;
- Different flows play different roles in maintaining river systems;
- Ecological and social consequences of flow manipulations can be predicted;
- River condition is a societal choice;
- Dams can be more river-friendly if designed and operated appropriately;
- Uncertainty is a reality; adaptive management is crucial.

Environmental flow assessment methods have evolved significantly over the years, and there are now many methods (

Figure 7-2); Tharme (2003) identified more than 200. The advantages and disadvantages of some of the most popular approaches are summarised in

Table 7-2 and Table 7-3.

[128] IUCN. 2003. *Building Capacity to Implement an Environmental Flow Determination Programme in Tanzania.* Report of a Training Workshop.

Figure 7-2: Evolution of EFA Approaches and Methods

1960s: Desktop methods, based on flow records (hydrological methods).	**IUCN 2003**	**Methods** (hydrological, BB, habitat); **approaches** (expert, stakeholder); **frameworks** (In-stream incremental methodology (IFIM), Downstream Response to Imposed Flow Transformation (DRIFT).
1970s: Field measurements of channel and flow characteristics (hydraulic ratings methods).	**WB 2003**	Prescriptive (HI, HR, EP) and interactive methods (IFIM, DRIFT).
1980s: Hydraulic measurements linked to single species flow requirements (habitat simulation methods)		
1990s: All aspects of the river ecosystem considered (holistic approaches).		

Source: presentation at GIZ Training Workshop, Hoa Binh, Vietnam, 2013.

Table 7-2: Advantages and Disadvantages of Various EFA Approaches

Method	**Advantages**	**Disadvantages**
Hydrological Index (½ month)	• Low cost, rapid to use Look-up tables, Desktop analysis	• Not site specific, ecological links assumed
Hydraulic rating (2-4 months)	• Low cost, site specific: Wetted perimeter	• Ecological links assumed
Habitat simulation (6-18 months)	• Ecological links included: in-stream incremental methodology, PHABSIM – physical habitat simulation	• Extensive data collection and use of experts, high cost

Holistic (12-36 months)	• Covers most aspects (Building Block Method, Downstream Response to Imposed Flow Transformation, Expert panels)	• Requires very large scientific expertise, very high cost

Source: presentation at GIZ Training Workshop, Hoa Binh, Vietnam, 2013.

The four principal categories of methods are (according to Tharme, 2003 and de Freitas, 2008):

- **Hydrologic:** Tennant, Q_{90}

  These primarily use hydrological data (historical monthly or daily flow records) for making e-flow recommendations to maintain river health at a designated level.

- **Hydraulic rating:** Wetted Perimeter Method

  These use changes in simple hydraulic variables (e.g. wetted perimeter) across single river cross-sections as surrogates for habitat factors, which are limiting to target biota.

- **Habitat simulation:** IFIM, PHABSIM

  These assess e-flows on the basis of modelling of the quantity and suitability of physical habitat available to target species under different flow regimes (integrated hydrological, hydraulic and biological response data).

- **Holistic methods:** Building Bocks Methodology (BBM)

  This method identifies important flow events for all major components of the river; models relationships between flows and ecological, geomorphological, and social responses; and uses an interdisciplinary team approach to establish recommended e-flow regime/implications of flow scenarios (bottom-up or top-down).

Table 7-3: Strengths and Deficiencies of Various EFA Approaches

Strengths and Deficiencies		
Hydrological Methods	**Habitat Simulation Methods**	**Holistic Methods**
Simple, rapid, inexpensive desktop approaches Low data needs, primarily flow data Suitable for water resource planning purposes Potential to regionalize different river ecotypes Simplistic, inflexible, low resolution output	High resolution habitat-flow relationships for target species Generate alternative e-flow scenarios for different species Advanced technical support Focus on target species, not whole ecosystem Not applicable for some ecosystem components Limited links with characteristics	Whole-ecosystem focus Generates alternative environmental flow scenarios for different ecological and social conditions Use of interdisciplinary expert judgement in a structured, consistent process Usable in both data-rich and data-poor contexts

Direct ecological links absent or limited (although recent advances made to improve ecological relevance of flow indices and to set flow targets) Dynamic nature of flow regime seldom addressed Suitable for low controversy situations	of flow regime Output restricted to flow-hydraulic habitat relationships Resource intensive relative to output Poor links with biological responses to flow change	Explicit links with characteristics of low regime and with biological and social responses to flow change Reliant on expert judgement Difficulties in reconciling opinions of different experts
Source: de Freitas (2008)		

Details of the various methods can be found in specialised publications. A diagram of a holistic approach is given in **Figure 7-3**, and six steps in the practical application of this approach are listed in **Table 7-4**.

Table 7-4: 6 Steps in Practical Application of Holistic EFA Approach

1. Estimate ecosystem flow requirements.

- Gather historical hydrological flow data series (hydrological desk top analysis).
- Characterise the natural flow regime (hydrological and hydraulic analysis).
- Identify critical flow events.
- Develop simulation models to assess how biodiversity is related to the natural flow regime (habitat modelling ex. PHABSIM).

2. Determine influence of human activities.

- How much is human presence influencing the natural flow regime and critical flow events?
- Hydrological models (e.g. water budget analysis)
- Water withdrawals, evaporation, transpiration, amount of rainfall, etc.

3. Identify areas of potential incompatibility.

- Hydrological alteration analysis (e.g. IHA software)
- Range of variability approach (RVA)
- Flow recommendations workshop / multidisciplinary teams
- Understand the natural and altered flow regimes.
- How are biodiversity and socio-economics affected?
- Scenario analysis and hydrograph prescriptions (spatial and temporal analysis)

4. Foster collaborative dialogue to search for solutions.

- Participatory meetings and workshops to assess scenarios and flow recommendations
- Search for the accomplishment of distinct objectives
- Trade off analysis, engaging decision makers, users, local communities, etc.
- Discuss “win-win” solutions.

5. Conduct water management experiments to resolve uncertainty.

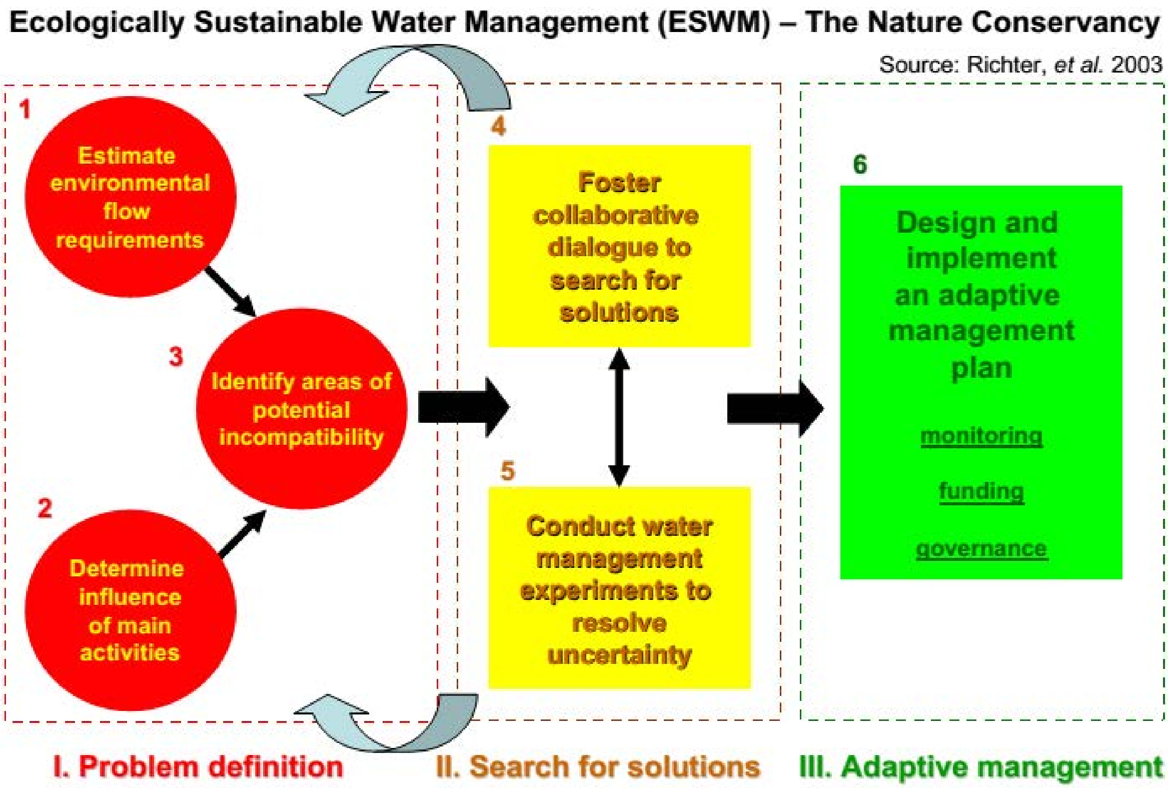
- Experimental implementation of the best scenario(s) (“win-win” situations)

6. Design and implement an adaptive management plan to promote ecologically sound water

management, including monitoring, funding and governance.

Source: de Freitas, 2008 (see Additional Reading)

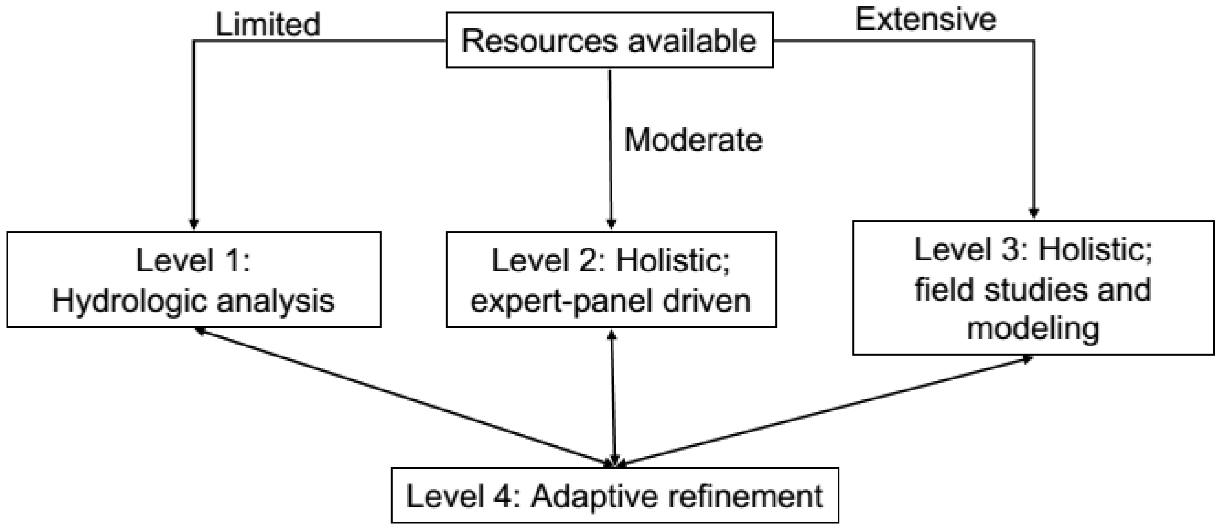
Figure 7-3: Example of Holistic EFA Method Application



Source: de Freitas, 2008 (see Additional Readings).

The final figure in this section illustrates how to choose the most appropriate EFA approach (**Figure 7-4**).

Figure 7-4: EFA: Choosing the Right Method



Source: de Freitas, 2008 (see Additional Reading)

TRAINING AIDS	
Discussion topics	Should sediment transport be included in e-flow determination? Or only fisheries? What about floods and wetlands? How can the release of environmental flows be enforced?
Exercises	• Consider a river that you know; what sorts of data, and what skills, would be needed to undertake an effective EFA?
Additional reading and resources	1) Tharme, R.E. 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 2) Arthington & Zalucki (eds). 1998. *Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Methods.* Land and Water Resources Research and Devel-opment Corporation. 3) Tharme, R. (1996). *Review of the International Methodologies for the Quantification of the Instream Flow Requirements of Riv-ers*. Water Law Review Final Report for Policy Development, for the Department of Water Affairs and Forestry, Pretoria, 4) Anantha, L., & P. Dandekar. 2012. *Towards Restoring Flows into the Earth's Arteries: A Primer on Environmental Flows*. 5) Davis, R. & R. Hirji (eds). 2003. *Environmental Flows: Con-cepts and Methods*. Water Resources and Environmental

	Technical Note C. 1. World Bank, Washington DC. 6) Davis, R. & R. Hirji (eds). 2003. *Environmental Flows: Case Studies*. Water Resources and Environmental Technical Note C. 2. World Bank, Washington DC. 7) de Freitas, G.K. 2008. *Methods and Tools for Defining Environmental Flows.* Presentation at GEF IW:LEARN Regional Workshop on Application of Environmental Flows in River Basin Management, February 11-15 2008. The Nature Conservancy. http://iwlearn.net/publications/ll/methods-and-tools-for-defining-environmental-flows-de-freitas

Case Studies

Case study 1

This case study concerns early use of the Instream Flow Incremental Methodology to agree appropriate environmental flow releases from a planned hydropower plant affecting significant fish and wildlife resources.

The Terror Lake Hydropower Project

The Terror River, on Kodiak Island in Alaska, lies within the Kodiak National Wildlife Refuge. It supports commercially important runs of several species of Pacific Salmon. These fish are a vital food source for the Kodiak brown bear; the bear's protection is the main purpose of the Refuge.

The river is also a prime resource for generating hydropower. Between 1964 and 1981, negotiations took place between the Kodiak Electric Association (KEA) and a range of government institutions and other interested parties . KEA wished to establish a hydropower plant on the river to meet the entire electrical demand of the city of Kodiak,. The project became the first hydropower project for which a license was held up, due to concern over environmental flows. KEA initially used a rule-of-thumb approach to assess flows for fish maintenance. The licensing agency, FERC, felt this method was inappropriate outside its area of development and was also too coarse to assess the impacts of a range of potential changes in flow.

This led to a pioneering application of the Instream Flow Incremental Methodology (IFIM), which allowed the impacts of hydropower releases to be predicted and trade-offs to be considered. IFIM has two major features. First, it describes the changes in hydraulic conditions within the river with changing flows. Second, it evaluates these changing conditions in terms of suitable fish habitat. The IFIM assessment described how proposed flow changes could impact fish migration, salmon spawning, egg incubation, and rearing of juveniles. Because these activities took place at different times and required different kinds of flows, a key issue in the negotiations was the scheduling (timing) and volume of flow in the river at any time of the year.

Major factors leading to a successful agreement were the early agreement to use IFIM, and the receptiveness of all interested parties to its outputs once they knew what the methodology could do and were regularly updated on emerging results. Using IFIM, minimum stream flows to be released from the project were specified, and the parties agreed to an Instream Flow Mitigation Plan. In June 1981, a compromise agreement incorporating these and other concerns was signed by KEA, the U.S. Department of the Interior, the State of Alaska, the Sierra Club, the National Audubon Society, and the National Wildlife Federation. FERC issued the license to proceed with the project in October 1981, which included specifications for monitoring the fisheries for 9 years.

Source: Davis, R. & R. Hirji (eds). 2003. *Environmental Flows: Case Studies*. Water Resources and Environmental Technical Note C. 2. World Bank, Washington DC.

Case study 2

E-flows Project in the Nam Songkhram River Basin

The E-flows project in the Nam Songkhram River Basin was initially implemented during 2006 – 2007. The Nam Songkhram River Basin is situated in northeastern Thailand. The prime objective of the project was to link ecosystems, livelihoods, and flows. A combination of field assessment and multi-stakeholder dialogues were employed throughout the study.

The Nam Songkhram River is 495 km long with a basin area of 13,126 km^2. It incorporates part of 4 provinces, namely Thani, Sakhon Nakhon, Nong Khai and Nakhon Phanom, with a population of 1.45 million.

The lower reaches of the Nam Songkhram River is still a serviceable floodplain system with a wide range of aquatic and terrestrial habitats, as well as spacious diversity of aquatic fauna.

A unique feature of this floodplain riverine system is prolonged annual flooding and full connection with the Mekong mainstream. No dam construction currently exists on the Nam Songkhram River), allowing for the precious conservative ecosystem value.

As this study is the first E-Flow exercise, definitive answers, such as minimum flow levels, precise instructions, or blueprints for basin management might not be explicit. More importantly, the participatory approach by stakeholder dialogues is a meaningful tool to increase knowledge and understand the river floodplain system, as well as the effects of hydrological flows. This is a key output of the E-Flows process.

Source: David J.H. Blake et. al 2008. *E-Flows in the Nam Songkhram River Basin.* International Union for the Conservation of Nature (IUCN), International Water Management Institute (IWMI), Mekong River Commission (MRC), Water and Development Research Group at Helsinki University of Technology (TKK), Government of Thailand's Department of Water Resources.

7.3 Other Mitigation Topics

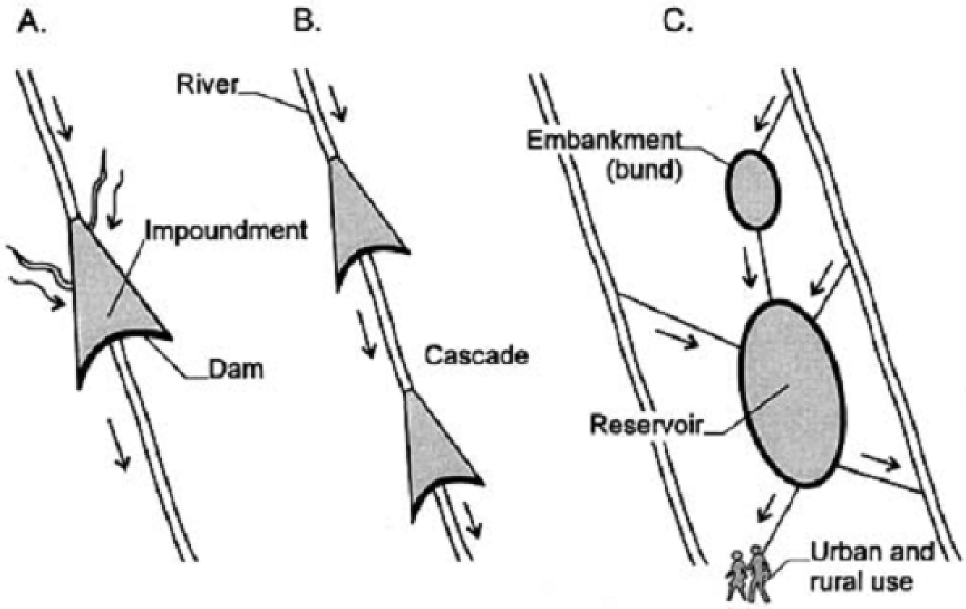
Key aspects	• Reservoir water quality is an important issue and requires both design and operational management. • Reservoir water quality affects both reservoir and downstream ecology. • Reservoir water quality issues may be physical, chemical or biological. • Water quality management is often overlooked but is a technical issue requiring significant skills and resources to avoid potentially very expensive problems. • Protected areas are a major tool for biodiversity conservation, the maintenance of ecosystem services, and, in some cases, livelihoods. • Protected area establishment and management requires multi-stakeholder agreement and continuing budgets. • Protected areas may be funded through payment for ecosystem services arrangements.

TRAINING AIDS	
Purpose of session	To introduce trainees to (i) the issues involved in reservoir water quality management, and (ii) the concepts and principles of protected areas as mitigation for hydropower projects.
Learning objectives	• To understand that water quality is an important topic requiring skilled technical attention in hydropower planning and operations. • To understand that protected areas are an important component of hydropower mitigation strategies, and require careful planning.
Key readings	1) Dortch, M.S. 1984. *Water Quality Considerations in Reservoir Management*. http://ucowr.org/files/Achieved_Journal_Issues/V108_A3Flood%20Control%20Operations.pdf 2) Chapter 1, Building Comprehensive Protected Area Networks, in Langhammer *et al.* 2007. *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. World Commission on Protected Areas, Best Practice Protected Area Guidelines Series No. 15. Gland, Switzerland: IUCN.

7.3.1 Reservoir Water Quality

Hydropower reservoirs (impoundments) are generally on-stream, although in some circumstances, such as pumped storage, they may be off-stream (Figure 7-5). As stated by Thornton *et al.* (1996), unlike natural lakes, reservoirs create environmental impacts and suffer from impacts caused by human activity. By modifying the flow regime of natural watercourses (in some cases completely diverting river flows from one watershed to another), reservoirs can alter species compositions both upstream and downstream, change thermal regimes, and also modify the chemical content of waters. In addition, changes in the quality and quantity of reservoir discharges, arising from changes in operational regime, into rivers and downstream lakes can affect the water quality of the receiving water body (**Table 7-5**).

Figure 7-5; Types of Reservoir



Source: Thornton *et al.* 1996.

The water quality parameters of most interest are, usually, temperature and dissolved oxygen (DO), since temperature regulates growth rates, chemical processes, is fundamental to thermal stratification, and oxygen is necessary to sustain aquatic life. Other parameters affecting or affected by water quality include, for example, nutrient status, pH, turbidity, total dissolved solids (TDS), and total suspended solids (TSS), contaminants, levels of iron, manganese and sulphides, and pathogens, such bacteria, viruses and protozoa.

For hydropower, water quality in terms of turning the turbines is not usually an issue except in relation to (i) acidity or corrosiveness and (ii) abrasion due to suspended sediment. The main challenge is often maintaining minimum water quality standards downstream. In this case, it can be particularly difficult to meet DO requirements. Substantial efforts have been focused on methods to increase DO in hydropower releases, for example, at the Tennessee Valley Authority (TVA) dams. Also, low DO in releases are a major concern for dams under consideration for hydropower retrofit, where existing releases are well aerated (Dortch, 1984). Pumped-storage hydropower projects also draw considerable interest in water quality, since the influx of return water can significantly alter in-pool and release water quality.

Reservoirs are, essentially, managed water bodies; therefore, a particular need exists for managers to understand their physics, chemistry and biology. This knowledge is acquired through assessment of water quality data gathered during well-planned monitoring programmes. In turn, the management operations, themselves, can affect the water quality characteristics and behaviour of the reservoir.

Table 7-5: Changes in Water Quality Characteristics due to Impoundment

Characteristics of river stretch	Not impounded	Minor impoundment	Major impoundment/chain of impoundments
Flow velocity at mean low water discharge	20 cm s^{-1}	5-10 cm s^{-1}	5 cm s^{-1}
Residence time in the area of impoundment	na	1-5 days	> 5 days
Mean depth of water	1.5 m	2-5 m	5 m
Physical O_2 input per unit of volume	xxx	xx	x
Day/night fluctuations of O_2 concentration; tendency to O_2 supersaturation	x	xx	xxx
Self-purification of organic pollution[1]	x	xx	xxx
Ammonia oxidation	xxx	xx	xx
Fine sediment deposition at low discharges	-	x	xxx
Resuspension of fine sediment at high discharges	xxx	xx	x
O_2 depletion in sediment	-	x	xxx
Turbidity due to suspended sediment	xxx	xx	x
Secondary pollution, algal growth and turbidity due to algae	x	xx	xxx
Development of higher aquatic plants	x	xx	xxx

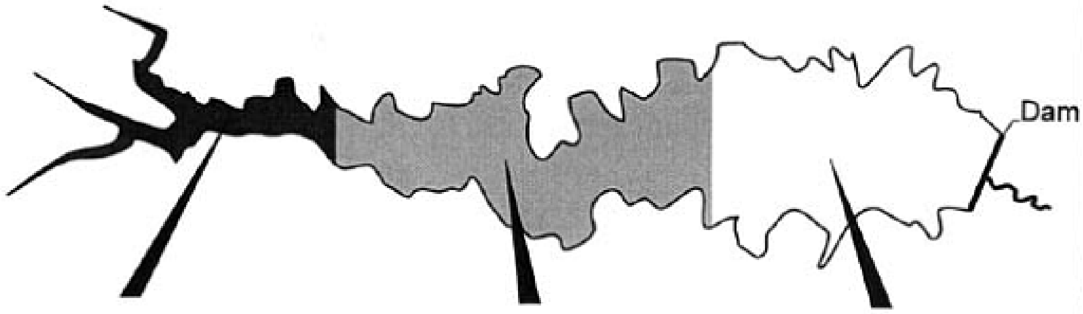
Source: Thornton *et al.* 1996.

Reservoirs and their associated water quality can benefit from correct siting and construction, within the limitations of topography, for their best operational advantage. The water quality of established reservoirs can be managed by altering operating regimes, changing water uses, and blending waters of varying quality. In water-poor climates, the development of elaborate inter-basin transfer schemes provides additional opportunities to ensure safe and reliable supplies of water throughout countries and regions. Such schemes, however, can increase the likelihood of the transfer of undesirable species and habitat destruction.

Reservoirs may have several different water quality zones along their length, depending on the topography of the valley where they are built (**Figure 7-6**).

Water quality changes in reservoirs may be physical, chemical or biological. These, in turn, affect the qualty of waters released downstream (**Figure 7-7**).

Figure 7-6: Longitudinal Variation in Reservoir Water Quality Zones

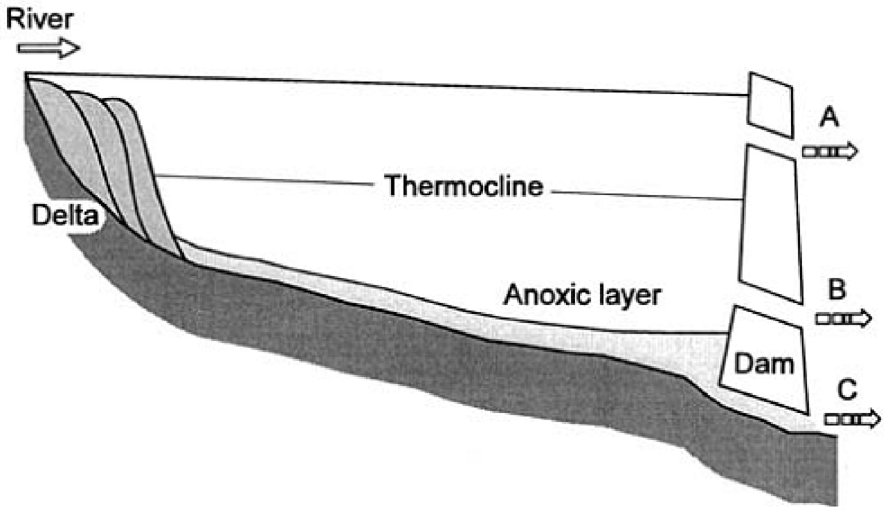


Riverine zone	Transitional zone	Lacustrine zone
Narrow, channelised basin	Broader, deeper basin	Broad, deep, lake-like basin
Relatively high flow rates	Reduced flow rates	Low flow rates
High suspended solids; low light availability at depth	Reduced suspended solids; light availability at depth	Relatively clear; high light availability at depth
Nutrient supply by advection; relatively high nutrient levels	Advective nutrient supply reduced	Nutrient supply by internal recycling; relatively low nutrient levels
Light-limited primary productivity	Primary productivity relatively high	Nutrient-limited primary productivity
Cell losses primarily by sedimentation	Cell losses by grazing and sedimentation	Cell losses primarily by grazing
Organic matter supply primarily allochthonous	Intermediate	Organic matter supply primarily autochthonous
More eutrophic	Intermediate	More oligotrophic

Source: Thornton *et al.* 1996.

Figure 7-7: Quality of Water Released from Reservoir Depending on Vertical Location of Outlet

Figure 8.8 The quality of water withdrawn from a reservoir determined by the depth and location of water withdrawal points (A, B, C) in relation to the thermocline: A Oxygenated epilimnetic water; B Anoxic hypolimnetic water; C Anoxic, sediment-laden water (After Cole and Hannan, 1990)



Source: Fig. 8.8 in Thornton *et al.* 1996.

The fundamental change in physical characteristics is **thermal stratification**. This occurs in all large bodies of water due to the density variation between warmer and colder water, but the degeree and duration of startification depend on mixing caused by wind, incoming waters, varying depth due to reservoir offtake, etc. Shallow trpoical reservoirs tend to stratify less thancoller deeper reservoirs in temperate zone valleys.

In reservoirs subject to thermal stratification the suppression of vertical transport processes at the thermocline (the transition between warmer and cooler water layers) normally allows an oxygen gradient to occur. This can cause **anoxic conditions** to develop in the hypolimnion (the cooler, denser bottom layer of water). Under these conditions iron and manganese tend to move into the water column from sediments with the possible eventual formation of large quantities of hydrogen sulphide (H_2S). Any water released downstream from such a layer can cause significant problems downstream, for example fish kills. At the Kariba Dam, passage of anaerobic water through the turbines damaged them so badly that they had to be replaced (Balon & Coche, 1974)[129]. Hypolimnetic de-oxygenation is more common in tropical and sub-tropical reservoirs than in temperate areas, due to higher temperatures, and is a particular problem at the first inundation of tropical impoundments. This is due to the oxygen demand of the decaying, submerged carbonaceous materials exceeding the available oxygen supply (until a more stable aquatic regime is established) (Thornton *et al.* 1996).

The opposite problem—oxygen supersaturation or 'dissolved gas supersaturation' (DGS)—is a problem often associated with hydropower facilities. Tailrace waters can become supersaturated, resulting in gas bubble trauma (GBT) in fish. This is a common problem in, for example, British Columbia in Canada[130]. In the USA, the Environmental Protection Agency published DGS water quality guidelines, which recommend a maximum total gas pressure (TGP) of 110% of local atmospheric pressure.

Reservoir managers have various options for water quality treatment, both in the reservoir itself and during release (**Table 7-6**). Thermal stratification may be prevented by **thermal stratification control.** Complete destratification can create higher levels of dissolved oxygen concentrations from the surface to the sediments. Maintenance of an oxidised microzone at the sediment surface is also quite possible. This prevents the interchange of many noxious or undesirable substances between water and sediments, either directly or because they remain bound to the iron complexes formed in aerobic conditions.

An alternative approach to destratification is to re-aerate the hypolimnetic waters by the direct supply of oxygen without disrupting the thermal profile. By this means, the cool hypolimnetic water is maintained as a water supply or fisheries resource even through the warm months of the year. Such management actions (usually in the pursuit of adequate drinking water quality) completely alter the chemical characteristics of a reservoir from its more natural conditions.

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[129] Balon, E.K. and Coche, A.G. 1974 Lake Kariba: A Man-made Tropical Ecosystem in Central Africa. *Monographiae Biologicae* 24, Dr W. Junk, The Hague.

[130] Fidler, L.E. & S.B. Miller. 1994. British Columbia Water Quality Guidelines for Dissolved Gas Supersaturation. BC Ministry of Environment, Canada DFO. http://www.env.gov.bc.ca/wat/wq/BCguidelines/tgp/index.html#TopOfPage

Selective withdrawal of water requires both known thermal stratification and appropriate multi-level intake structures.

Table 7-6: In-Reservoir Treatment Techniques

In-Reservoir Treatment Techniques
• Destratification
• Hypolimnetic aeration/oxygenation, underwater dam
• Pool drawdown
• Dilution
• Phosphorus inactivation
• Sediment removal
• Harvesting
• Biological controls
• Herbicides and algicides
Release Treatment Techniques
• Turbine venting
• Reaeration of release flows by, e.g., reaeration weirs
• Localised mixing
• Selective withdrawal
Source: Dortch (1984).

Other interventions such as re-impoundments, chemical modification of water quality within smaller reservoirs (e.g. addition of a coagulant such as alum or an inhibitor such as copper sulphate) and sediment manipulation, can all significantly alter the chemical characteristics of a reservoir. Similarly, the transfer of water between basins can result in a reservoir having a very different ionic composition to that which would occur naturally in the receiving basin (Thornton *et al.* 1996).

Eutrophication: many reservoirs mimic natural lakes in their transition from an aquatic environment to a terrestrial environment over time – but in a much shorter time period. Reservoirs are susceptible to cultural eutrophication (an increased rate of ageing) caused by human settlement and activities in the watershed. To some extent the effects of high nutrient inputs to reservoirs are offset by relatively high flushing rates in reservoirs (compared to natural lakes). Control of nitrogen (N) and phosphorus (P) inputs to lakes may require land use modification upstream, control of fertilizer use, or (in industrialised watersheds) the removal of P from laundry soap.

Hydropower reservoirs are often associated with very significant **public health issues**—some associated with water quality, especially blooms of toxic algae and other micro-organisms (cyanobacteria), and some due to the creation of habitats favourable for disease vectors such as Simulid flies. Management issues are required to deal with these problems, preferably during the design stage of the project.

Management of reservoir water quality requires detailed knowledge of the changing conditions and cannot be undertaken without comprehensive **water quality monitoring**. Awareness of the effects of the location and depth of water withdrawal points on the water quality characteristics and behaviour within the reservoir is essential to their management to achieve the optimum water quality for intended uses. In addition, in order that managers may make the maximum use of physical and water quality data gathered from reservoirs, it is necessary to determine and understand the effects of inflows and outflows, retention time, in-basin facilities and actions, and morphometry and location of the reservoir within its watershed. Since monitoring is resource-intensive, it needs to be very specific; some monitoring strategies for different uses of reservoir water are listed in **Table 7-7**. Usually the highest use of reservoir water (e.g. for drinking water supply) should be used to develop the strategy. For hydropower reservoirs the highest uses are fisheries, both in the reservoir and downstream.

Table 7-7: Some Monitoring Strategies for Various Uses of Reservoir Waters

Principal water use	Main sample site location	Sampling frequency[1]	Hydrodynamic considerations	Physical and chemical measurements	Biological methods
Potable water supply	At outlet to supply	Continuous, daily to weekly	Thermal stratification, short-circuit flows	Temperature, diss. oxygen, colour, turbidity, suspended solids, odour, pH, organic compounds, metals, nitrate	Coliforms, pathogens, phytoplankton species, chlorophyll a
Industrial water supply[2]	At outlet to supply	Continuous, daily to weekly	Thermal stratification	Temperature, pH, hardness, dissolved and suspended solids, major ions	Pathogens[2]
Power generation	Close to outlet	Daily to weekly	Thermal stratification, internal water currents	Conductivity, dissolved and suspended solids, major ions, dissolved oxygen	
Irrigation supply	Representative open water site(s) and/or outlet(s)	Weekly to monthly		pH, total dissolved solids, sodium, chloride, magnesium	Faecal conforms
Fisheries and recreation	Representative open water site(s)[3]	Weekly to monthly	Thermal stratification	Suspended solids, dissolved oxygen, BOD, ammonia	Phytoplankton species, chlorophyll a, fish biomass
Aquaculture	At inlet and open water site(s)	Daily to weekly	Thermal stratification	Temperature, suspended solids, dissolved oxygen, ammonia, pesticides	Chlorophyll a
Flood control	Inflow(s) and outflow(s)	Monthly to annual		Suspended solids, turbidity	

Source: Thornton *et al.* 1996.

Reservoir assessment requires knowledge of basic reservoir conditions, such as bathymetry. For most reservoirs this is easily established from pre-existing topographic surveys. Change can then be monitored by relatively simple repeat surveys of sedimentation. Thermal stratification is more complex to survey, because it may vary significantly with season, reservoir depth, the volume and velocity of incoming water and any drawdowns.

7.3.2 Protected Areas

Protected areas (**Box 7-5**) remain one of the cornerstones for promoting biodiversity, ecosystem services and human well-being. Today protected areas cover 12.7% of the world's terrestrial area and 1.6% of the global ocean area. They store 15% of the global terrestrial carbon stock, assist in reducing deforestation, habitat and species loss, and support the livelihoods of over one billion people.[131]

Box 7-4: IUCN Definition of 'Protected Area'

A protected area is: **"A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".**

In applying the categories system, the first step is to determine whether or not the site meets this definition and the second step is to decide on the most suitable category.

Source: Dudley, N. (ed), 2008

[131] Bertzky *et al.* 2013 (see Additional Reading).

Figure 7-8: Percentage of World's Ecoregions Meeting CBD Protection Targets

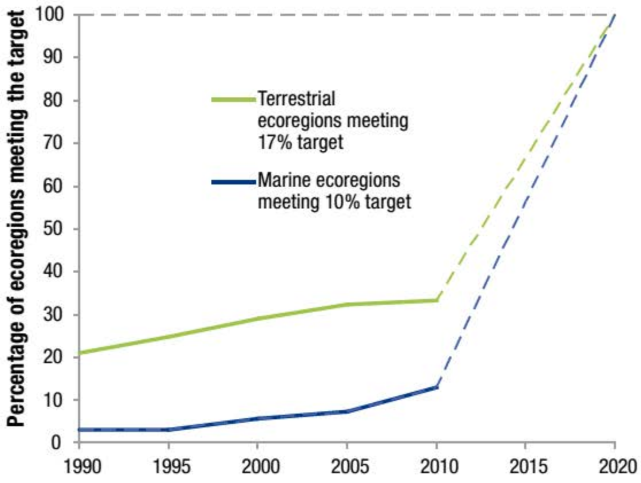


Figure 3.1.4 Percentage of the world's ecoregions that meet the 17% terrestrial protection target and 10% marine protection target of the CBD (solid line; marine ecoregions out to 200 nautical miles) and hypothetical progress required to meet the targets in all ecoregions (dashed line). Source: WDPA 2011 based on terrestrial ecoregions from Olson *et al.* 2001 and marine ecoregions from Spalding *et al.* 2007

Source: Fig. 3.14 in Bertzky *et al.* 2013 (see Additional Reading).

Protected areas are classified by IUCN into six functional categories, according to their objectives and purpose (

Box 7-6). These widely-used categories are supplemented by formal designations under international laws and agreements such as UNESCO's World Heritage Convention (World Heritage Sites) and Man and the Biosphere Programme (Biosphere Reserves); by national and sub-national legal systems (national parks, provincial parks, nature reserves, etc.); by designations based on strict biodiversity criteria (e.g. International Bird Areas, IBA); and by informal designations by local residents for economic, spriritual or cultural reasons (protected forests, sacred mountains, etc.).

Protected area establishment or management may feature as a mitigation measure for a hydropower scheme in a variety of ways: upstream, to conserve existing biodiversity, typically associated with watershed protection; downstream, where habitats may be affected by hydrological changes and required enhanced management; at the project site itself, for example when reservoirs themselves become biological assets and can be managed for their ecological values; and off-site, when protected areas elsewhere are set up or managed better, as a compensation or off-set measure.

Box 7-5: IUCN Protected Area Categories

Ia	**Strict nature reserve**
Ib	**Wilderness area**
II	**National park**
III	**Natural monument or feature**
IV	**Habitat/species management area**
V	**Protected landscape/seascape**
VI	**Protected area with sustainable use of natural resources**

Source: Dudley, N. (ed), 2008

Protected area management is a large and complex topic. There is a great deal of literature on its many aspects. For example, major steps in setting up a protected area network are described by Ardron (2010)[132] as:

- Identify and involve stakeholders and others.
- Compile ecological and socio-economic data.
- Set network objectives for each bioregion.
- Set specific conservation targets and apply design principles.
- Review existing areas and existing proposed area, and perform gap analysis.
- Identify jurisdictions to identify priority areas.
- Undertake site-specific planning and implementation.
- Manage and monitor the protected area network.

One of the most useful sources of guidance is the *Best Practice Protected Area Guidelines* series available from IUCN (see www.iucn.org/themes/wcpa/pubs/guidelines.htm).

Box 7-6. Cambodian Ministry of Environment protected area zoning regulations

The following are the protected area definitions from the draft Ministry of Environment Law on Protected Areas (2007) in Cambodia:

Core zone: management area(s) of high conservation value, containing threatened and critically endangered species and fragile ecosystems. Access to the zone is prohibited—except by Nature Conservation and Protection Administration's officials and researchers who, with prior permission from the Ministry of Environment, conduct research for the purpose of preservation and protection of biological resources and the natural environment. National security and defence sectors are also exempted.

Conservation zone: management area(s) of high conservation value containing natural resources, ecosystems, watershed areas, and natural landscapes adjacent to a *core zone*. Access to the conservation zone is allowed only with the prior consent of the Nature Conservation and Protection Administration (national security and defence personnel exempted). Small-scale community uses of non-timber forest products (NTFPs) to support local ethnic minorities' livelihoods may be allowed under strict control, provided they do not result in serious adverse impacts on biodiversity within the zone.

Sustainable use zone: management area(s) of high economic value for the national economy, local community, or the livelihoods of indigenous ethnic minorities', development, and management. After consulting with relevant ministries and institutions, local authorities, and local communities, the Royal Government of Cambodia, in accordance with relevant laws and procedures, may permit development and investment activities in this zone on request by the Ministry of Environment.

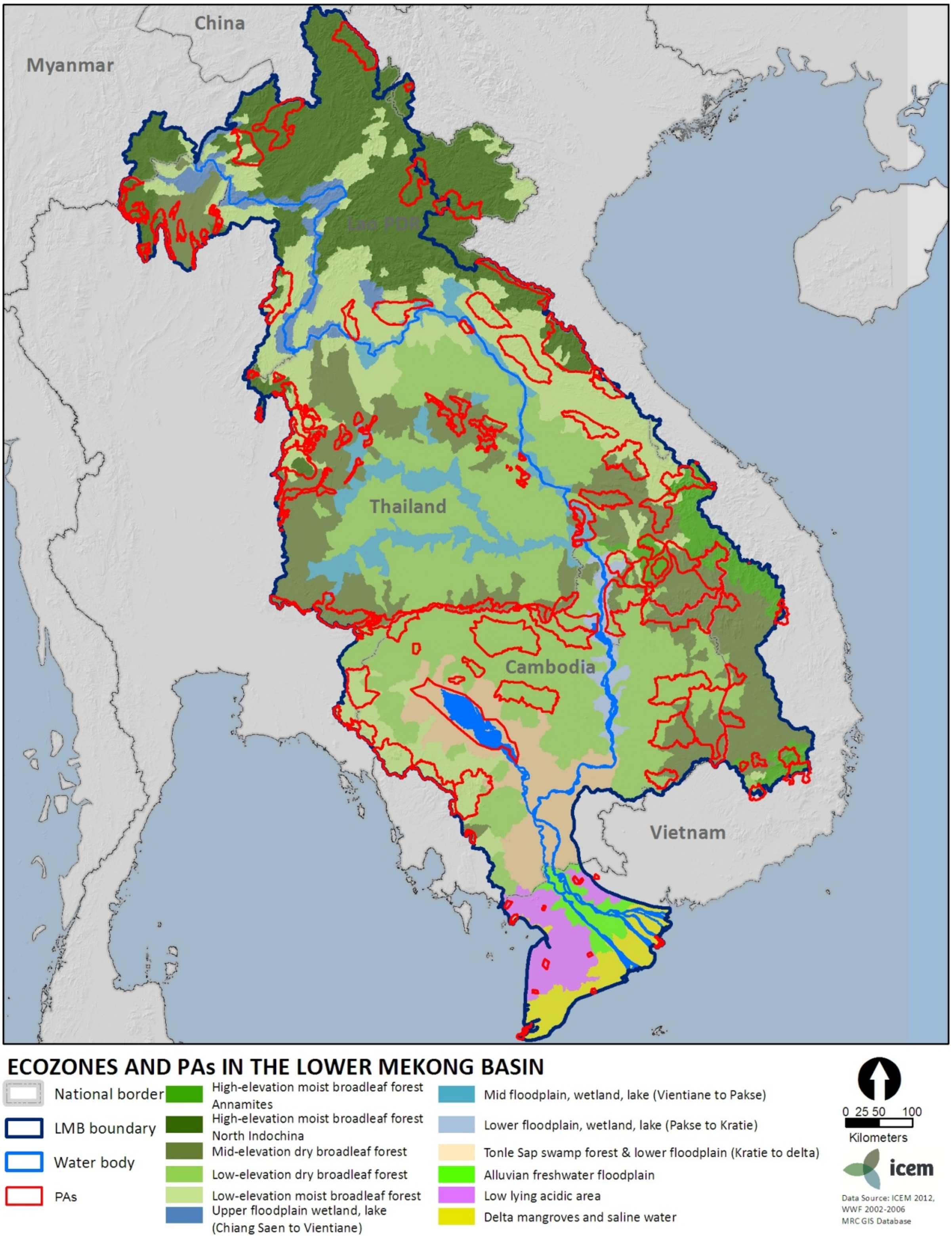
Community zone: management area(s) for socio-economic development of local communities and indigenous ethnic minorities; these may contain existing residential lands, paddy field and field gardens or swidden (*chamkar*). Issuing land titles or permission to use the land in this zone is subject to prior agreement from the MoE in accordance with the Land Law. This management area does not cover the Apsara authorities and other authorities designated and management area(s) to which the Royal Government has allocated the tasks.

[132] Ardron, J. 2010. *Key Planning Approaches - How They Fit Together; Planning Tools; Marxan/Marxan Zones*. Presentation at: "Decision Support Tools for Conservation Planning in Settled Landscapes" Workshop, Toronto, 15 December 2010.

Source: MoE (2008) Protected Law in Cambodia

Protected Areas (PAs) in the Lower Mekong Basin are important assets for the region ecosystem. The four counties have identified and established 115 P As across 9,821,395 ha, covering up to 16% of the LMB and most of its remaining forests and upper watersheds. The Protected Areas are designed to protect specific natural features, species and communities. They are also the most importance strategy for national and international biodiversity conservation.

Figure 7-9 Eco-zones and Protected Areas in Lower Mekong Basin



The LMB has diverse ecosystems, which support a wide range of flora and fauna. PAs[133] in the basin cover areas of rich and distinct biological diversity. With over 60 million people

[133] ICEM (2013) Protected Areas Vulnerability Assessment and Adaptation Planning, a thematic baseline prepared for Mekong ARCC Task 2: Climate Change Vulnerability Assessment. USAID, Bangkok.

living in the LMB and persistent poverty within communities living in and around PAs, these areas are under escalating threats from unsustainable and illegal logging, wildlife trading, rapid industrialization, shifting cultivation, development infrastructure, unsustainable tourism, etc. Despite efforts to protect biodiversity diversion and habitats, PAs conditions are depleting. Some large species, such as tigers and elephants, are endangered to the point of disappearance from previously abundant habitats—and, possibly, total extinction. Many fish species are also endangered, partly as a result of the spread of invasive species.

ICEM (2013) has summarized the balance of conservation and development around PAs, with key actions for zoning management. These include:

- **Establishment of a Core Zone of significant ecosystems or habitat**. This zone is the central area of the PA and the focus of strong protection measures. Defining the core zone's resources, as well as agreed control and safeguards therein, are important activities. In the context of climate change, this zone may need to be expanded or relocated to provide appropriate protection for significant habitat or species;
- **Buffer zone**; this zone is an extension of a PA that surrounds the core zone. The intensity of human activities is greater than that allowed in the core zone. This zone creates a buffer wherein NTFP collection, tourism, and other uses may occur; the existence of this area provides communities with an alternative to exploiting forest resources in the core zone and thereby protects the latter. Once again, it may be necessary to expand or relocate the buffer zone to increase resilience of the core zone to climate change.
- **Transition area;** this zone is similar to the buffer zone, except that even more intense development, such as agriculture, is permitted.

Community-based participation and a flexible approach to management zones are crucial to their success as a policy tool. Climate change represents a major regime change and, therefore, must be integrated into ongoing planning.

TRAINING AIDS	
Discussion topics	1) Why is water quality often a 'forgotten topic' when the terms of reference for dam design studies are prepared? 2) Is water quality a problem in reservoirs used for daily peaking operation? 3) Is it better - or more practical - to control pollution at its source, rather than at the receptor? 4) Is there always a case for protecting watersheds above hydro reservoirs? 5) Should hydropower dams be built in degraded landscapes to provide more resources for better landscape management – or in healthy landscapes, which would result in much higher impacts on ecosystem services, but much lower impacts on dam operation and reservoir?
Exercises	• Design a water quality monitoring programme for a major hydropower reservoir, which has issues concerning thermal stratification, eutrophication, and dissolved oxygen levels.

	• Consider a proposal to build a new hydropower dam in a forested watershed. Design a multi-stakeholder process to a) identify conservation needs, b) agree a plan of action, c) prevent contractors hired to log the reservoir from logging the watershed.
Additional reading and resources	1) Thornton *et al.* 1996. *Reservoirs*. Chapter 8 in: Chapman, D. (ed). 1996. Water Quality Assessments – A Guide to Use of Biota, Sediments and Water in Environmental Monitoring. 2nd ed. UNESCO/WHO/UNEP. 2) Dortch, M.S. 1984. *Water Quality Considerations in Reservoir Management*. http://ucowr.org/files/Achieved_Journal_Issues/V108_A3Flood%20Control%20Operations.pdf 3) Langhammer *et al.* 2007. *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. World Commission on Protected Areas, Best Practice Protected Area Guidelines Series No. 15. Gland, Switzerland: IUCN. 4) Dudley, N. (ed). 2008. *Guidelines for Applying Protected Area Management Categories.* IUCN. 86p. http://data.iucn.org/dbtw-wpd/edocs/paps-016.pdf 5) Bertzky *et al.* 2013. *Protected Planet Report 2012: Tracking progress towards global targets for protected areas.* IUCN, Gland and UNEP-WCMC, Cambridge. 6) Dudley *et al.* 2010. *Natural Solutions: Protected areas helping people cope with climate change.* IUCN-WCPA, TNC, UNDP, WCS, The World Bank and WWF. 130p 7) World Database on Protected Areas: http://www.wdpa.org/

Case Studies

Case study 1

The case study concerns the Nam Theun 2 hydropower project in central Lao PDR; it explains some potential impacts of the project on aquatic habitats, as well as suggested mitigation steps.

POTENTIAL IMPACTS ON AQUATIC HABITATS

Below are the main potential impacts and mitigation measures, identified by Kottelat, and which are referred to in the EAMP, separated into two main categories as follows: (i) impacts related to construction and, (ii) impacts related to the permanent changes to the various aquatic habitats. The impacts are listed only where they relate specifically to the Xe Bang Fai river basin, and include the reviewer's own comments on each.

(a) Construction Related Impacts

Work in the Riverbed & Infrastructure Construction

Impacts: Identifies construction of the Downstream Channel as an activity "*that could potentially increase sediment load*" in the streams and rivers, and that this could affect fish populations downstream both directly and indirectly. Presumably the worst affected areas will be the Nam Kathang, Nam Gnom and other small streams in the Gnommalat plain closest to the surface disturbance and the Nam Phit floodplain and its tributaries, down into the middle Xe Bang Fai around Mahaxai.

Suggested Mitigation: A short section reads: "*The HC [Head Contractor] will adhere to the erosion plans set down in HCCEMMP's [Head Construction Contractor's Environmental Management and Monitoring Plan] to help limit sedimentation resulting from construction of the downstream channel. In the Xe Bang Fai, some species are adapted to high levels of suspended solids, to which they are currently subjected in the wet season*". A few paragraphs later in the section (p. 88, Chapter 3) it reads: "*All infrastructure, including temporary constructions, will be stabilised and bridges will be built to respect the existing stream/river bed and bank morphology*".

Limestone Extraction in Karstic Formations

Impacts: The EAMP (p.89) warns that the quarrying of limestone for construction material may threaten biodiversity (often specialised and highly endemic fauna, found in underground streams and water bodies) "*either directly by destruction of the habitat or indirectly by pollution*."

Mitigation: "*The sites where limestone will be quarried and the location where the downstream channel passes through karst* [i.e. in Gnommalat and Mahaxai Districts] *will be surveyed for possible presence of caves and springs. As this is part of a very extensive karstic area, it is very unlikely that limestone extraction will threaten any endemic species. If any caves are present, the opportunity to explore them scientifically should be taken. Particular attention will be given to avoid all types of pollution in karstic areas, as in such places contamination may spread faster and over greater distances than in any other soil types*".

Source: David J.H. Blake. 2005. A Review of the Nam Theun 2 Environmental Assessments and Management Plan (EAMP) As It Pertains to Impacts on Xe Bang Fai Fisheries. Report Prepared for International Rivers Network, Berkeley, California. 23 pp.

Case study 2

This case study concerns a hydropower project in Central America, which reports a net gain for habitat protection as a result of various conservation initiatives.

Project snapshot: Hydroelectric project takes unprecedented measures to protect habitat

Reventazón hydroelectric project, Costa Rica

Hydroelectric projects produce renewable energy, but they can also have serious environmental and social impacts. Dams block free-flowing river ecosystems and prevent fish migrations, and the reservoirs they create may block the movement of terrestrial species.

Latin America is in the midst of a boom in hydropower construction, making it all the more urgent to protect habitat in a project's entire area of biological influence - terrestrial as well as aquatic. Achieving this goal is a major challenge confronting the region's power utilities.

With this in mind, Costa Rica's national power company (the Instituto Costarricense de Electricidad, ICE), the IDB, and an international conservation organization are turning a major hydroelectric project on the Reventazón River from a potential environmental liability into a net gain for habitat protection. In addition to meeting 10% of the nation's electricity needs, the project will:

- Lead to the protection in perpetuity of a free-flowing river system with largely intact ecosystems
- Safeguard critical habitat that will support a program to ensure the survival of the Americas' most emblematic and enigmatic carnivore: the jaguar.

The Reventazón, which flows from the country's central highlands to the Caribbean Sea, already has three hydropower plants in its middle and upstream sections. The Reventazón Hydroelectric Project, financed with the help of an IDB loan for US$200 million, will be located downstream of the existing dams, where the central highlands give way to the coastal banana-growing region.

Corridor for big cats. One concern in designing the project was loss of habitat connectivity caused by its reservoir, which is 8 km long and covers 6.9 km^2. This new barrier would cut through the Barbilla Destierro Biological Subcorridor (SBBD) - a critical pathway for jaguars along Costa Rica's Volcanica Central Talamanca Biological Corridor and for the Mesoamerican Biological Corridor as a whole.

Although the SBBD is far from pristine forest, its patchwork of pastures, farms, tree plantations, communities, and blocks of forest have been designated as part of the Path of the Jaguar by the international nongovernmental organization Panthera. According to Panthera, such human landscapes are fully usable by jaguars, which only need a place where they can pass through unharmed in search of prey and mates.

Under the IDB's policy on environmental safeguards, the SBBD's designation as a critical natural habitat requires that ICE restore habitat to preserve the subcorridor's role in safeguarding the movement of jaguars and their genetic flow. ICE will meet these requirements by taking measures to protect land along the southern, eastern, and western portions of the reservoir at higher and more permanent levels than at present. The project will also help restore degraded lands and improve local understanding of the need to maintain this key biological corridor. In addition, the project will set protection goals and measure compliance by carrying out an initial Rapid Ecological and Social Assessment, establishing monitoring indicators, and undertaking regular third-party monitoring.

The project's win-win protection measures have won general support from the SBBD's residents. Included will be payments to forest owners for environmental services as well as support for environmental education, restoration of degraded lands, agroforestry, and technical support. For example, farmers will learn how to raise pigs in enclosures rather than letting them run free. In this way, the pigs' waste can be converted to fertilizer and gas and will not affect water quality in the reservoir. At the same time, the animals will be less exposed to jaguar predation, reducing the potential for conflicts between farmers and conservationists.

Region's first river offset. The new hydropower project, in conjunction with the other projects upstream, will substantially reduce the ability of the Reventazón River to support three migratory fish species. The IDB requires an offset for the river's loss of capacity to support these species.

ICE will take the unprecedented step of protecting migratory routes for these fish species in perpetuity in the ecologically similar Parismina River, which joins with the Reventazón on the coastal plain. The offset agreement guarantees that artificial modifications, including dams that would block migrations, will be prohibited and that the Parismina's natural flow pattern and its biological integrity will be preserved or restored where required.

Throughout the Parismina and Reventazón watersheds, ICE will work with landowners to reduce erosion, sedimentation, and pesticide runoff into the rivers. Other measures may result in net habitat improvement in the Parismina watershed. For example, restoring riverbank vegetation could create additional jaguar habitat and connectivity extending from Tortuguero National Park on the coast up into the central mountain range. The effectiveness of the protection measures will be verified through a permanent program to monitor water quality, biodiversity, and key habitats.

Need for new capacity. In the new project, ICE's legal responsibilities for environmental protection will extend far beyond protecting the Reventazón's water resources. The company must now safeguard biological connectivity over large terrestrial areas and throughout entire river systems. ICE will meet this new responsibility by working in partnership with the many actors in watershed management, including local municipalities, farmers, conservation organizations, and national agencies. This multistakeholder approach to regional watershed management is a critical element of sustainable hydropower.

With the IDB's support, ICE will strengthen its environmental capacity as well as contract with outside experts to support corridor design, river offsets, biodiversity assessment, data compilation and analysis, and management of some of the target species. An existing law that supports ICE's efforts to conserve the Reventazón watershed is being expanded to include the entire Reventazón-Parismina basin.

The project will set a new standard for habitat protection not only for hydroelectric projects in the region but for large-scale infrastructure works in general. In some respects, however, the Reventazón project is unusual. In most cases, different companies - generally private firms - exploit resources in a given area, making it difficult to determine which company should take responsibility for environmental mitigation. But ICE operates all the hydroelectric projects on the Reventazón. Moreover, its status as a public-private company helps to ensure close working relationships with its government agency counterparts and permanent protection for the watershed and the biological corridor.

Source: IADB website:

http://www.iadb.org/en/topics/sustainability/project-snapshot-hydroelectric-project-takes-unprecedented-measures-to-protect-habitat,7998.html

8 INTRODUCTION TO EIA

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<tr><td>Introduction</td><td>Review of background (history), and purpose of EIA.</td></tr>
<tr><td>Types of Impact Assessment</td><td>Introduction to SIA, ESIA, BIA, HIA, SEA, CIA, etc.</td></tr>
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</table>

8.1 Background and Purpose of EIA

Key aspects	• EIA is a process intended to anticipate the effects of projects in order to improve decision-making and impact management. • EIA emerged from environmental concerns in the USA and rapidly spread around the world. • Dams were among the earliest types of projects to trigger impact assessment, due to their significant social and environmental impacts. • Impact assessment processes should be purposive, rigorous, practical, cost-effective, efficient, focused, adaptive, participative, interdisciplinary, credible, integrated, transparent, systematic and objective. • However, EIAs are seldom politically neutral, since they are set in a wider social, political and cultural context. • Decision-making after completion of an EIA process is often political act rather than an act driven by sound scientific principles. • Impact assessment (IA) includes social as well as environmental issues and both positive and negative impacts. Social impact assessment is known as SIA. “EIA” is often used as an umbrella term for all impact assessment at project level. • Impact assessment has developed many branches, including in addition to EIA, social impact assessment, health impact assessment, biodiversity impact assessment, cultural heritage assessment, and others. • Strategic Environmental Assessment (SEA) is a “second generation” process, which incorporates environmental and social issues into higher levels of decision-making, and facilitates early consideration of alternatives well in advance of project level EIA.

TRAINING AIDS	
Purpose of session	To provide trainees with an overview of the history, purpose and types of EIA.
Learning objectives	By the end of this session, the trainee will: • Understand the purpose and principles of impact assessment. • Understand the range of types of impact assessment processes and the range of resources available as guidance.

Key readings	1) IAIA. *Impact Assessment.* Fastips No. 1, April 2012.

8.1.1 Introduction

Environmental impact assessment (EIA) is a tool for anticipating the environmental effects of proposed projects, enabling the incorporation of management or control measures into project design. Simply defined, impact assessment "… is the process of identifying the future consequences of current or proposed actions…." [134], or as defined in UNEP's 2002 EIA Training Resource Manual:

> "*EIA is a systematic process to identify, predict and evaluate the environmental effects of proposed actions and projects. This process is applied prior to major decisions and commitments being made. A broad definition of environment is adopted. Whenever necessary, social, cultural and health effects are considered as an integral part of EIA. Particular attention is given in EIA practice to preventing, mitigating and offsetting the significant adverse effects of proposed undertakings.*"[135]

The purposes of EIA are to:

- Provide information for decision-making on the environmental consequences of proposed actions.
- Promote environmentally sound and sustainable development through the identification of appropriate enhancement and mitigation measures.

EIA has been accepted very widely as an important tool to assist decision-making. For example, Principle 17 of the 1992 UNCED Rio Declaration states:

> *"Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority."*

Initiation of EIA: the modern impact assessment movement can be traced back to the precedent-setting US National Environmental Policy Act (NEPA, 1969), which, for the first time, mandated the use of EIA. A number of factors led to the introduction of EIA in the USA, including public concern about the quality of the environment and the increasing effects of new technologies and ever-larger development schemes. In addition, the economic appraisal techniques then available, such as cost-benefit analysis, did not account for the environmental and social impacts of major projects.

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[134] Vanclay, F. *Summary of workshop on International Guidelines and Principles for Social Impact Assessment*, report to the closing session of the meeting of the International Association of Impact Assessment, Glasgow. 1999

[135] UNEP. 2002. *EIA Training Resource Manual (2nd ed.).* http://www.unep.ch/etu/publications/EIAman_2edition_toc.htm

The subsequent evolution of EIA can be divided into four overlapping phases: [136]

1) *Introduction and early development (1970-1975).* During this time, EIA's mandate and foundations were established in the USA; adopted by a few other countries (e.g. Australia, Canada, New Zealand); but retained their basic concept, procedure and methodology.
2) *Increasing scope and sophistication (mid '70s to early '80s).* More advanced techniques (e.g. risk assessment) were developed, along with guidance on process implementation (e.g. screening and scoping); social impacts were considered; and public inquiries and reviews helped drive innovations in leading countries. The current take up of EIA is still limited but includes developing countries (e.g. China, Thailand and the Philippines).
3) *Process strengthening and integration (early '80's to early '90s).* Review of EIA practice and experience occurred; scientific and institutional frameworks of EIA updated; coordination of EIA with other processes (e.g. project appraisal, land use planning) took place; ecosystem-level changes and cumulative effects began to be addressed; and attention was given to monitoring and other follow-up mechanisms. Many more countries adopt EIA during this time; the European Community and the World Bank respectively establish supra-national and international lending requirements.
4) *Strategic and sustainability orientation (early '90s to present).* EIA aspects enshrined in international agreements; marked increase in international training, capacity building and networking activities; development of strategic environmental assessment (SEA) of policies and plans; inclusion of sustainability concepts and criteria in EIA and SEA practice; EIA applied in all OECD countries and large number of developing and transitional countries.

The architects of NEPA intended the environmental impact statement to be an 'action-forcing' mechanism, which would change the way government decisions were made. However, they probably did not foresee the extent to which EIA would be adopted internationally, culminating in Principle 17 of the Rio Declaration on Environment and Development. Today, EIA is applied in more than 100 countries, by all development banks, and most international aid agencies. The diffusion of impact assessment has been driven and accompanied by innovations in law, procedures and methods. In comparison to its early phase, EIA today is now multi-dimensional in purpose, scope and approach.

Impact assessment is now a mature methodology, with qualified practitioners and national and international networks of professionals (who can be found through the International Association for Impact Assessment, IAIA: www.iaia.org). However, whether or not impact assessment is sufficiently effective within particular sectors remains up for debate (see, for example, *World Rivers Review* March 2013)[137].

Principles**:** the fundamental requirement for all impact assessment exercises is that they should be conducted with integrity and objectivity **(see Box 8-1, Box 8-2, and Box 8-2: EIA – Selected Principles**

[136] Source: updated and amended from Sadler, B. 1996. *Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance*. Final Report of the International Study of the Effectiveness of Environmental Assessment. Canadian Environmental Assessment Agency and IAIA, Ottawa, Canada.

[137] Available at: www.internationalrivers.org/world-rivers-review

Table 8-1). In addition, although objective, the process of impact assessment is generally considered to be a vehicle for promoting certain universal values, such as good governance, and a voice for those would not otherwise be heard **(Table 8-2).**

- **Be objective**
- **Be transparent**
- **Respect citizens' rights to be consulted**
- **Just "ticking the boxes" is *not* good practice!**

Box 8-1: EIA – Core Values

- **Integrity: the process must in-depth and objective (not biased)**
- **Utility: the process must be useful (for decision making)**
- **Sustainability: the goal (better projects)**

Box 8-2: EIA – Selected Principles

- **Be objective**
- **Be transparent**
- **Respect citizens' rights to be consulted**
- **Just "ticking the boxes" is *not* good practice!**

Table 8-1: EIA: Five Important Things to Know

Five Important Things to Know

1. The social contract between impact assessment professionals and civil society and decision-makers is that (a) impact assessments will be conducted with integrity and will be free from mis-representation or deliberate bias, and (b) impact assessments will respect citizen rights to participate in decisions that affect them.
2. An IA priority is the assessment of alternative development options to ensure more sustainable and low environmental and social risk solutions are given full consideration.
3. The aim of IA is to optimize positive and minimize residual negative effects. Mitigation measures to reduce the magnitude of negative impacts must be adopted where it is not possible to avoid impacts through appropriate design.
4. It is not professional to produce an IA report solely to meet a legal requirement when an impact assessment must be submitted. Ticking boxes is not good practice. A genuine effort must be made to evaluate and properly describe a range of development options.
5. It is desirable to integrate the environmental, social and economic dimensions of impact assessment unless the jurisdiction for which the assessment is being prepared constrains IA to an analysis of specific types of impacts.

Source: IAIA. *Impact assessment*. Fastips No. 1. 2012.

Table 8-2: EIA: Five Important Things to Do

Five Important Things to Do

1. Promote IA to address and incorporate into strategic and project development decision-making important challenges such as climate change, biodiversity loss, a growing population and urbanization, and conflicts over increasingly scarce resources and inequities.
2. Ensure that IA makes a positive contribution to the environment and the well-being of the people living in it, by suggesting ways to avoid, or reduce, risks and enhance benefits of actions.
3. Promote transparency, participation, and the full engagement of all relevant stakeholders, including the public, in decision-making.
4. Ensure good quality information in IA and evaluation of the IA process and its outcomes, to enhance IA effectiveness.
5. Shift IA thinking away from the licensing stage and closer to the key decisions on future development options to increase IA influence on concept and design.

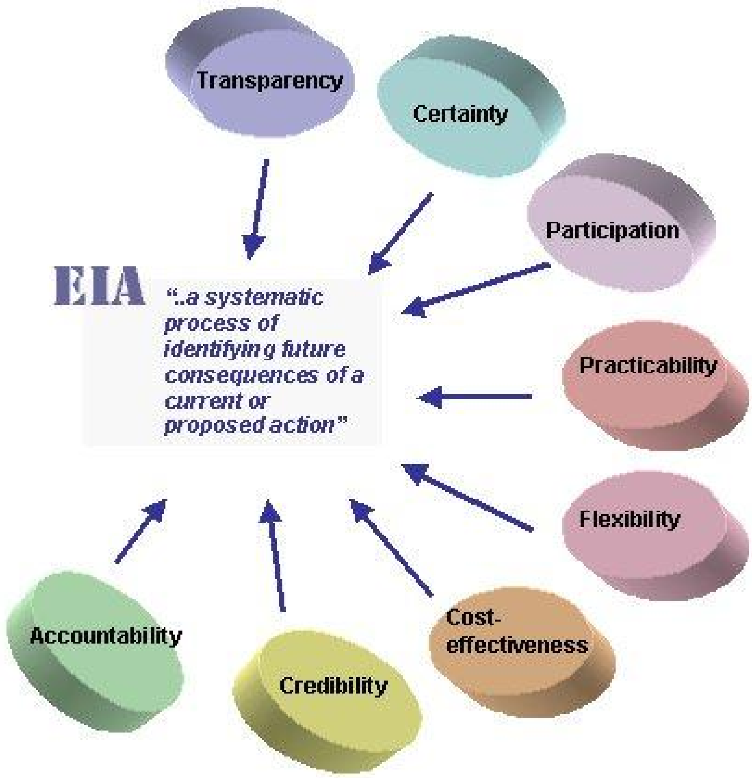
Source: IAIA. *Impact assessment*. Fastips No. 1. 2012.

Eight principles of good EIA practice are illustrated in

Figure 8-1 and summarised below:

- **Participation:** An appropriate and timely access to the process for all interested parties.
- **Transparency:** All assessment decisions and their basis should be open and accessible.
- **Certainty:** The process and timing of the assessment should be agreed in advance and followed by all participants.
- **Accountability:** The decision-makers are responsible to all parties for their action and decisions under the assessment process.
- **Credibility:** Assessment is undertaken with professionalism and objectivity.
- **Cost-effectiveness:** The assessment process and its outcomes will ensure environmental protection at the least cost to the society.
- **Flexibility:** The assessment process should be able to adapt to deal efficiently with any proposal and decision making situation.
- **Practicality:** The information and outputs provided by the assessment process are readily usable in decision making and planning.

Figure 8-1: Eight Principles of Good EIA Practice



Source: UNESCAP: http://www.unescap.org/drpad/vc/orientation/m8_1.htm

The EIA process should be implemented:

- As early as possible in decision making and throughout the life cycle of the proposed activity;
- To all development proposals that may cause potentially significant effects;
- To biophysical impacts and relevant socio-economic factors, including health, culture, gender, lifestyle, age, and cumulative effects consistent with the concept and principles of sustainable development;
- To provide for the involvement and input of communities and industries affected by a proposal, as well as the interested public; and
- In accordance with the law and policy of the jurisdiction concerned.

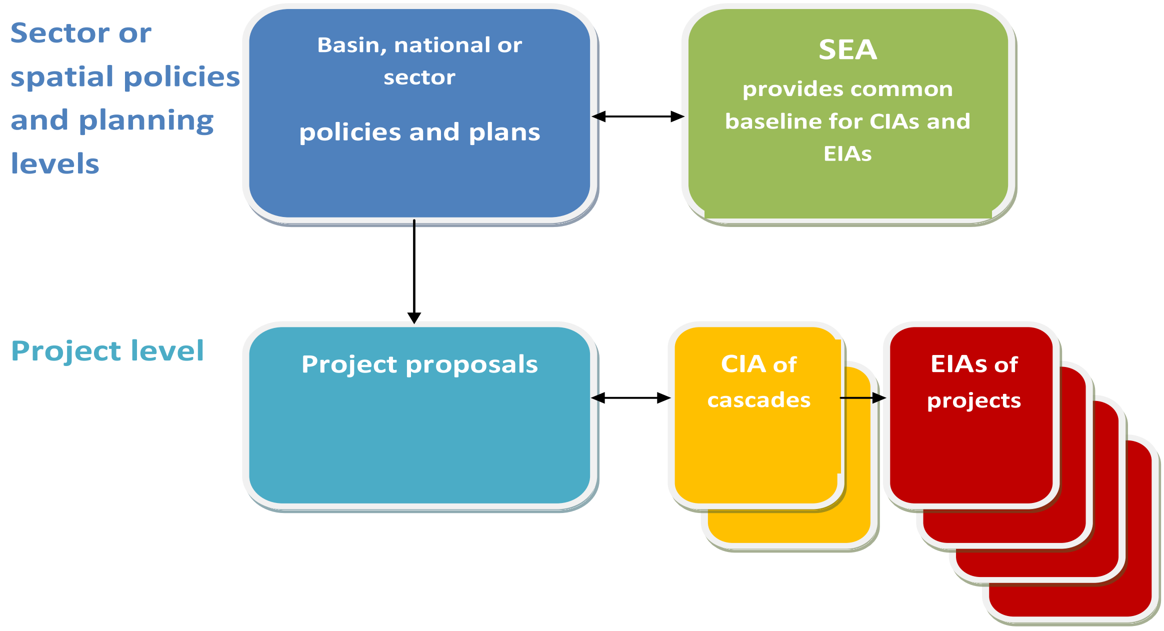
8.1.2 Types of Impact Assessment

Since its introduction in the 1969 NEAP in the United States, IA has evolved as a family of instruments, some of which are formalized through regulatory procedures. These include **environmental impact assessment** (EIA), **social impact assessment** (SIA), **health impact assessment** (HIA), **biodiversity impact assessment**, **cultural heritage assessment**, **cumulative effects assessment**, and **strategic environmental assessment** (SEA). Other non-formalized instruments of the IA family include sustainability assessment, technology assessment and risk assessment, which tend to be separate disciplines with their own specialised terminology.

The relationships between some of these sub-types of impact assessment are illustrated in **Figure 8-2**. An illustrative list of environmental and social issues potentially requiring investigation on a project is given in

Table 8-3. The following notes very briefly introduce some of the different sub-types of impact assessment now in use.

Figure 8-2: EIA, CIA and SEA



Source: ICEM, 2012. *Ensuring Sustainability of GMS Regional Power Development*. ADB RETA 7764

- **Social impact assessment** (SIA) is "… the process of analysing (predicting, evaluating and reflecting) and managing the intended and unintended consequences on the human environment of interventions (policies, plans, programs, projects and other social activities) and social change processes so as to create a more sustainable biophysical and human environment". On most large hydropower projects SIA is carried out in parallel with and integrated into the overall EIA, hence the commonly used term **environmental and social impact assessment** (ESIA).
- **Health Impact Assessment (HIA)** focuses on the potential public health impacts of projects, but also includes occupational health and safety issues (very important in large construction projects such as dams)[138].
- **Biodiversity Impact Assessment**, is a response to, *inter alia*, the Convention on Biological Diversity[139] (see **Box 8-3** for an example of typical biodiversity-related questions in relation to project planning).

[138] http://www.who.int/hia/en/

[139] (http://www.cbd.int/)

Table 8-3: Illustrative List of Social and Environmental Issues

Illustrative List of Potential Social and Environmental Topics and Issues
• Assessment of the baseline social and environmental conditions; • Consideration of feasible environmentally and socially preferable alternatives; • Requirements under host country laws and regulations, applicable international treaties and agreements; • Protection of human rights and community health, safety and security (including risks, impacts and management of project's use of security personnel); • Protection of cultural property and heritage; • Protection and conservation of biodiversity, including endangered species and sensitive ecosystems in modified, natural and critical habitats, and identification of legally protected areas; • Sustainable management and use of renewable natural resources (including sustainable resource management through appropriate independent certification systems); • Use and management of dangerous substances; • Major hazards assessment and management; • Labour issues (including the four core labour standards), and occupational health and safety; • Fire prevention and life safety; • Socio-economic impacts; • Land acquisition and involuntary resettlement; • Impacts on affected communities, and disadvantaged or vulnerable groups; • Impacts on indigenous peoples, and their unique cultural systems and values; • Cumulative impacts of existing projects, the proposed project, and anticipated future projects; • Consultation and participation of affected parties in the design, review and implementation of the project; • Efficient production, delivery and use of energy; and • Pollution prevention and waste minimisation, pollution controls (liquid effluents and air emissions) and solid and chemical waste management. Note: The above list is for illustrative purposes only. The Environmental and Social Assessment process of each project may or may not identify all issues noted above, or be relevant to every project.
Source: Exhibit II to *The Equator Principles*. July 2006. On http://www.equator-principles.com/index.shtml

- **Cultural Heritage Assessment** is specialised topic focusing on cultural heritage potentially affected by projects, typically all forms of tangible (physical) cultural heritage, some of which may be artefacts (e.g. buildings) or natural (e.g. sacred sites such as springs or groves of trees). Intangible cultural heritage—language, poetry, music, dance, intellectual knowledge—may also be included (but is not covered by the World Bank's Physical Cultural Resources Safeguard Policy Guidebook).

- **Cumulative Effects (or Impacts) Assessment** investigates the results of multiple interventions in a particular area, as opposed to a single project. Cumulative effects assessment is often ignored or downplayed since a serious investigation might result in findings, which would adversely affect the proponent's interests.

Box 8-3: Biodiversity Questions during Project Planning

The World Bank provides some questions related to biodiversity. (It is worth noting these should be asked of any project.).

- Does the project address issues concerning integrity of natural habitats and ecosystems and maintenance of their functions?
- Do the project boundaries encompass the relevant natural habitats and ecosystems within the limitations of political and administrative boundaries? Have adequate steps been taken to deal with issues affecting the project boundaries?
- Have local communities dependent upon the affected area(s) been included in the preparation and implementation of the project? Are arrangements agreed on compensation and/or concessions to groups adversely affected by the project?
- Is the project design flexible enough to manage the predicted changes? Does the project draw adequately upon scientific and local knowledge to inform adaptive management of the natural environment?
- Does the project involve all the relevant sectors and disciplines? Are there adequate mechanisms for coordination and collaboration among sectoral agencies? Are the roles and responsibilities of government, the private sector, and non-governmental organizations clearly defined?

Source: The World Bank. 1997. *Biodiversity and Environmental Assessment*. Environmental Assessment Sourcebook Update No. 20.

- **Strategic Environmental Assessment (**SEA) analyses proposed policies, programmes and plans, and can be carried out in large geographical areas, such as a river basin (see also **Error! Not a valid bookmark self-reference.**). Project-level EIA is considered a "first generation" process, limited in its capability to examine alternatives and options by the relatively late stage of decision-making to which it is applied. By comparison, Strategic Environmental Assessment is a "second generation" process, which incorporates the environment into higher levels of decision-making (see **Table 8-5**).

Table 8-4: Strategic Environmental Assessment

Strategic Environmental Assessment
"The purpose of SEA, broadly stated, is to ensure that environmental considerations inform and are integrated into strategic decision-making in support of environmentally sound and sustainable development. In particular, the SEA process assists authorities responsible for plans and programmes, as well as decision-makers, to take into account:

- Key environmental trends, potentials and constraints that may affect or may be affected by the plan or programme
- Environmental objectives and indicators that are relevant to the plan or programme
- Likely significant environmental effects of proposed options and the implementation of the plan or programme
- Measures to avoid, reduce or mitigate adverse effects and to enhance positive effects
- Views and information from relevant authorities, the public and – as and when relevant – potentially affected States.

SEA has evolved largely as an extension of project-level environmental impact assessment (EIA) principles, process and procedure".

Source: UNECE: Pamphlet: *Applying the Protocol on SEA*. www.unece.org/env/sea

Table 8-5: EIA and SEA: a Comparison

SEA: Definition	*"[A] process of anticipating and addressing the potential environmental consequences of proposed initiatives at higher levels of decision-making. It aims at integrating environmental considerations into the earliest phase of policy, plan or programme development, on a par with economic and social considerations" (Sadler, 1995).*	
Comparison	**EIA**	**SEA**
	Is reactive to a development proposal.	Is pro-active and informs development proposals.
	Assesses the effect of a proposed development on the environment.	Assesses the effect of the environment on development needs and opportunities.
	Addresses a specific project.	Addresses areas, regions or sectors of development.
	Has a well-defined beginning and end.	Is a continuing process, aimed at providing information at the right time.
	Assesses direct impacts and benefits.	Assesses cumulative impacts and identifies implications and issues for sustainable development.
	Focused on the mitigation of impacts.	Focused on maintaining a chosen level of environmental quality.
	Narrow perspective and high level of detail.	Wide perspective and a low level of detail to provide vision and overall framework

	Focus on project-specific impacts.	Creates a framework, against which impacts and benefits can be measured.
Conceptual Hierarchy	SEA	Higher level such as regions or sectors
	Project EIA	Development proposals & projects
	Environmental Management Systems	Construction & operation of projects
	Monitoring & Data Collection	Feedback to higher levels
Source: CSIR (South Africa) 1996. *Strategic Environmental Assessment - A Primer*. ENV/S-RR 96001		

The final table, **Table 8-6**, is a simple framework for matching impact assessment tools to purpose.

Table 8-6: EIA Toolbox: Matching Purpose to Tools

EIA Toolbox	
Purpose	**Examples of available tools**
Internalising the environment in policy and planning	SEA, technology assessment, comparative risk assessment
Planning and designing environmentally sound projects	EIA, SIA, risk assessment, environmental benefit-cost assessment
Environmental management of the impacts of an operating facility or business enterprise	EMS (ISO 14000 series), total quality environmental management (TQEM), industrial codes of practice
Eco-design of processes and products	Environmental design, life cycle assessment, cleaner production
Monitoring, audit, and evaluation of performance	Effects and compliance monitoring, site, energy, waste, health and safety audits, benchmarking performance
Source: UNEP, 2002. *Environmental Impact Assessment Training Resource Manual* - Second Edition. Topic 11, p 411	

TRAINING AIDS	
Discussion topics	1) Should cumulative effects assessment be included in all EIA studies, or only in strategic assessments (SEAs)? 2) How can scoping be made more effective—so that ESIA studies obtain adequate resources for all issues requiring analysis? 3) Many EIA studies are administrative formalities with no significant effect on project design—let alone influencing a go / no-go decision on the project itself. How can EIAs be made more effective decision-making tools for sustainability? 4) Should the EIA process be phased to match the project cycle (e.g. an IEE at pre-feasibility stage, an EIA at feasibility stage, and a detailed EMP at design stage)? If not, why not? 5) How can you obtain all the resources needed for effective EIA (money, time, skills, authority)? 6) How can the independence and objectivity of the EIA process be assured? 7) Should EIA practitioners be trained in ethics?
Exercises	• Divide into groups. First, develop a hydropower project scenario involving a large dam on a river with important fisheries and a large catchment with some forest and wildlife and an increasing number of poor indigenous people. Second, imagine the potential significant issues that might require study. Third, list all the disciplines that should, in theory, be involved in the study. Fourth, compare this idealised list with what you know happens in reality.
Additional reading and resources	1) Special issue of Impact Assessment and Project Appraisal (journal): *The State of the Art of Impact Assessment.* IAPA Vol. 30, No.1, March 2012. 2) R.K. Morgan. 2012. *Environmental impact assessment: the state of the art.* IAPA Vol. 30, No. 1, March 2012, 5-14 http://dx.doi.org/10.1080/14615517.2012.661557 3) Fisher, P. 2013. Why Environmental Impact Assessments Fail to Protect Rivers. *World Rivers Review* March 2013. 4) International Rivers. 2013. Talking to the Experts: Can We Improve the ESIA Process? *World Rivers Review*, March 2013. www.internationalrivers.org/world-rivers-review 5) World Bank. *Environmental Assessment Sourcebook*. World Bank, Washington, DC. http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTENVASS/ 0,,contentMDK:20282864~pagePK:148956~piPK:216618~theSitePK:407988,00.html 6) World Bank. Environmental Assessment Sourcebook *Updates*. World

	Bank, Washington, DC. Same website as above. 7) World Health Organisation. 1999. *Health Impact Assessment: Human Health and Dams.* http://www.who.int/hia/examples/energy/whohia052/en/index.html 8) IFC. 2009. *Introduction to Health Impact Assessment.* IFC. http://www1.ifc.org/wps/wcm/connect/a0f1120048855a5a85dcd76a6515bb18/HealthImpact.pdf?OD=AJPERES&CACHEID=a0f1120048855a5a85dcd76a6515bb18 9) The Cumulative Effects Assessment Working Group (Hegmann, G., C. Cocklin, R. Creasey, S. Dupuis, A. Kennedy, L. Kingsley, W. Ross, H. Spaling and D. Stalker) and AXYS Environmental Consulting Ltd. 2009. *Cumulative Effects Assessment Practitioners' Guide*. Prepared for: Canadian Environmental Assessment Agency. http://www.ceaa-acee.gc.ca/default.asp?lang=En&n=43952694-1 10) Walker *et al*. 1999. Guidelines for the Assessment of Indirect and Cumulative Impacts as well as Impact Interactions. European Commission DG XI: Environment, Nuclear Safety & Civil Protection. 172p. http://ec.europa.eu/environment/eia/eia-studies-and-reports/guidel.pdf 11) Abaza, H., R. Bisset & B. Sadler. 2004. *Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach.* UNEP. http://www.unep.ch/etu/publications/textONUbr.pdf

Case Studies

Case Study 1

This example below introduces a detailed case study carried out for the World Commission on Dams of the controversial Pak Mun Dam in Thailand.

Pak Mun Dam – EIA Predictions vs. Reality

The Pak Mun report is one of 8 case studies undertaken world-wide with a common methodology and approach that sought to inform the Commission on the performance and the development effectiveness of large dams. This case study concerns the Pak Mun Hydropower project, a run-of-the-river dam, located near the confluence of the Mun and the Mekong River in Northeast Thailand.

The report attempts to compare the planned intended outcomes and the actual results. The case study would provide an analysis of the performance and the manner in which decision-making processes have responded to an evolving social, economic and political context since project completion. The lessons learned from the planning and decision-making process will directly inform the Commission's findings and recommendations. Six central questions have been identified that are key to the World Commission on Dams (WCD) work programme and methodology. These questions serve to structure the information collection, discussion and assessment of the topics of performance and development effectiveness. The Pak Mun case study sought to address these questions:

1) What were the projected vs. actual benefits, costs and impacts?

2) What were the unexpected benefits, costs and impacts?
3) What was the distribution of costs and benefits, who gained and who lost?
4) How were decisions made?
5) Did the project comply with the criteria and guidelines of the day?
6) How would this project be viewed in today's context?

The Pak Mun Project: Description

The Pak Mun Dam is built on the Mun River, 5.5km upstream from its confluence with the Mekong, in the province of Ubon Ratchathani, in Northeast Thailand. The dam type is roller-compacted concrete, with a maximum height of 17m and total length of 300. The reservoir has a surface area of 60 square km at normal, high water level of 108 metres above the mean sea level (MSL), and a capacity of 225 million cubic metres. The Electricity Generating Authority of Thailand (EGAT) built and operates the dam as a run-of-the-river hydropower plant. Its operating rules are designed to ensure that the water level does not rise above 106mMSL during the dry season; from January to May water level remains at a maximum level of 108m MSL for the rest of the year. The storage capacity of the dam's reservoir is essentially that of the pre-existing river channel.

When the Environmental Impact Studies conducted in 1982, the report indicated that approximately 4000 households would be displaced if the reservoir was impounded to a level of 113 MSL; therefore, an alternative design with a normal water level of 108 MSL was agreed upon in 1985. The relocation of the dam site significantly minimised the extent of displacement to an estimated 248 households. The original project design was further modified by relocating the dam 1.5km upstream to avoid the submergence of Kaeng Tana rapids, an important environmental and tourist site. EGAT also decided to lower the reservoir to 106 MSL during dry season from January to May and to adjust the dam's operating regime to uncover the upstream Kaeng Saphue rapids. However a new environmental impact assessment (EIA), which may have identified and anticipated some of the new environmental impacts arising from the new location, was not conducted at this stage.

How would this project be viewed in today's context?

The economic premise on which the project was justified can be questioned. The planners confused a switching value analysis, also called Equalising Discount Rate analysis, with a traditional economic benefit analysis. The former analysis should be performed to choose the best of two project implementation solutions that have already proven to be both economically viable. When applied to power projects, the switching value analysis should be done on projects that have the same dependable capacity. This was not done in case of Pak Mun.

Since the Pak Mun project was, in reality, conceived and operated as part of EGAT's power development plan to respond to long-term national load forecasts, its claim as a multipurpose project is misleading.

In the present context, the absence of assessment and lack of consideration of the project impact on fish and fisheries in Mun River in the initial planning and decision-making stages would be considered a critical lapse. This is more so given the fact that this World Bank funded project was approved and implemented in the early 1990s. The absence of comprehensive assessment of the households whose fishing occupation, fishing income, and subsistence was affected by the dam at appraisal meant considerable unplanned cost escalation in terms of compensation. The participation of affected communities and civil society was elicited late in the process of compensation and mitigation. Confusion resulted from lack of clear division of institutional responsibility; this was compounded by lack of clarity in eligibility criteria, and, as a result, affected people spent nearly ten years negotiating compensation claims with the government.

With hindsight, as required by the World Bank guidelines, a fresh EIA for the redesigned project would have been called for whose terms of reference should have included nature and extent of impact of the project on livelihoods based on fisheries. Such a study would have been useful in making available relevant baseline for comprehensive identification of fishing villages, the extent of population affected, the level of dependency on fisheries by season, the prevailing income, and the resettlement location options allowing continued access to the riverine resources and alternatives.

If plans and policies were adequately implemented with respect to social impacts and resolution of conflicts, villagers would not have had to waste time and effort in negotiating and protesting against the dam. Nor would the country as a whole have lost an important ecosystem.

According to the study team, one of the study's key conclusions is that if all the benefits and costs were adequately assessed, the project would not likely have been built in the current context.

Source:

WCD. 2000. *Case Study: Thailand: Pak Mun Dam and Mekong/Mun River Basins*. Final Paper - Executive Summary. Available from http://geocompendium.grid.unep.ch/reference_scheme/final_version/GEO/Geo-2-054.htm

Case Study 2

An Example of an EIA conducted on a hydropower plant in Vietnam (Case study on Ba Ha Hydropower plant, GIZ-NSHD-M case studies).

Environmental impacts, recommendations and monitoring of Ba Ha Hydropower Plant[140]

Potential Environmental Impacts	Recommended actions, given by EIA	Actions taken by project developer
Construction Period		
Air and noise pollution are largely mud and dust from transportation and construction vehicles, dust from the concrete mixing station, and raw materials exploitation.	Improved construction method to utilise on-site materials and minimize transportation loads. Provide buffer zone to surrounding neighbourhood from raw material exploiting zone (510-720). Covering canvas for all vehicles transporting materials, spray water etc.	Implemented
Solid waste from worker's camp and solids washed off into the river. This was estimated at 0.3 kg/person/day, with a potential number of 3000 workers and technicians at the site.	Pile up solids into mounds, plant trees, dig ditches around disposal area to collect sediments in rainwater before discharging into river. Collect, deliver garbage to disposal places.	Implemented
Water pollution due to waste from maintenance & cleaning (mechanical oil, lubricants etc., from workers camp, as well as decaying biomass during reservoir filling).	Collect all the lubricant to specific oil drums; Collect water from camp and build toilet facilities; remove 75% of trees prior filling reservoir. Provide water supply to camps and resettled areas.	Waste oil is delivered. Trees are collected and cut down prior reservoir filling. Implementation at worker camp site (picture evidence and worker camp layout)
Impacts on land use, ecosystem;	Strictly protected forest areas. Pro-	Reforestation project

[140] **EIA report of Ba Ha hydropower plant, PECC1, 2003**

animals and fisheries.	hibited of hunting and wildlife animal trading (especially KrongTrai Natural Conservation Area). Plant trees to increase cover area.	
Social impacts to livelihood and socio-economics.	Minimize impacts through education of workers, compensation and resettlement. Set up public health clinic and water supply structures.	Implemented
Fire/Explosion risk by raw materials exploitation and health & safety	Fire alarm system, follow regulations, site surveillance to remove bombs. Safety and pr otection tools are provided to workers. Common cooking areas are monitored to ensure hygiene.	Regulations and safety standards during construction
Operation Period		
Change of hydro-geographical system and lack of downstream water.	Discharge a minimum flow to satisfy environmental flow at 18.92 m^3/s. Construct regulating reservoir downstream.	Implemented
Land erosion and riverside destruction.	Basic forestation measures.	
Ecosystem and fish migration, reservoir cleaning.	Reservoir cleaning according to “Environmental cleaning in Ba Ha Hydropower Plant” approved in May, 2006 by EVN. Cleaning up to design water level at 105.95m. Banning hunting and controlling fishery.	Implemented
Living disorder and relocation.	Compensation and relocation measures.	Implemented (see photo-proof)

Source: Ha Thanh Lan, Thai Gia Khanh, Nguyen Van Tuan, Case study on Ba Ha Hydropower Plant, 2013. EIA report of Ba Ha Hydropower plant, PECC1, 2003.

Case Study 3

This case study briefly notes the use of strategic environmental assessment for long-term planning of dam construction in South Korea.

South Korea: SEA for Long-term Plan for Dam Construction

Strategic Environmental Assessment (SEA) was integrated into South Korea’s Long-Term Plan for Dam Construction (LPDC). It raised the effectiveness of the planning process through feedback of environmental and social results to the plan. The SEA process also improved the inclusion of environmental priorities and factors that could lead to negative public opinion in the evaluation of water supply alternatives and dam construction sites. Strategic Environmental Assessment created a paradigm shift from functional planning toward sustainable dam planning that considers local situations.

Source: Young-Il Song *et al.* 2010. Strategic environmental assessment for dam planning: a case study of South Korea’s

experience. *Water Int*. 35:4, 397-408

8.2 The EIA Process

Key aspects	• EIA is a well-developed methodology with standardised steps. • EIA is a *process* not just a product (the Environmental Impact Statement). • EIA is *iterative*, examining issues in increasing depth as the project cycle progresses. • The participation of all stakeholders in the EIA process is essential if the results are to have credibility and be effectively implemented.

TRAINING AIDS	
Purpose of session	To remind trainees of the standard steps in the EIA process and the importance of consultation.
Learning objectives	• To know and understand the standard steps in the EIA process. • To understand the principles of effective consultation and participation.
Key readings	1) UNEP. 2002. *EIA Training Resource Manual (2^{nd} ed.).* http://www.unep.ch/etu/publications/EIAman_2edition_toc.htm

8.2.1 Standard Steps

EIA is a well-developed methodology with standard steps. These are listed in Table 8-7 with summary descriptions and illustrated in

Figure 8-3.

Table 8-7: Major Components of the EIA Process

Major Components of the EIA Process

The EIA process should provide for:

- **Screening** - to determine whether or not a proposal should be subject to EIA and, if so, at what level of detail.
- **Scoping** - to identify the issues and impacts that are likely to be important and to establish terms of reference for EIA.
- **Examination of alternatives** - to establish the preferred or most environmentally sound and benign option for achieving proposal objectives.
- **Impact analysis** - to identify and predict the likely environmental, social and other related effects of the proposal.
- **Mitigation and impact management** - to establish the measures that are necessary to avoid, minimize or offset predicted adverse impacts and, where appropriate, to incorporate these into an environmental management plan or system.
- **Evaluation of significance** - to determine the relative importance and acceptability of residual impacts (i.e., impacts that cannot be mitigated).
- **Preparation of environmental impact statement** (EIS) or report statement (EIS) or report - to document clearly and impartially impacts of the proposal, the proposed measures for mitigation, the significance of effects, and the concerns of the interested public and the communities affected by the proposal.
- **Review of the EIS** - to determine whether the report meets its terms of reference, provides a satisfactory assessment of the proposal(s) and contains the information required for decision making.
- **Decision making** - to approve or reject the proposal and to establish the terms and conditions for its implementation.
- **Follow up** - to ensure that the terms and condition of approval are met; to monitor the impacts of development and the effectiveness of mitigation measures; to strengthen future EIA applications and mitigation measures; and, where required, to undertake environmental audit and process evaluation to optimize environmental management.*

* It is desirable, whenever possible, if monitoring, evaluation and management plan indicators are designed so they also contribute to local, national and global monitoring of the state of the environment and sustainable development.

Source: IAIA. 1999. *Principles of Environmental Impacts Assessment Best Practice.* http://www.iaia.org/publicdocuments/special-publications/Principles%20of%20IA_web.pdf

Figure 8-3: Standard Steps in EIA

- **Scoping**
- **Preparation of TOR**
- **Data collection & analysis**
- **Impact prediction**
- **Analysis of alternatives**
- **Mitigation planning**
- **Monitoring plan**
- **Institutional analysis**
- **Cost estimation**

CONSULTATION

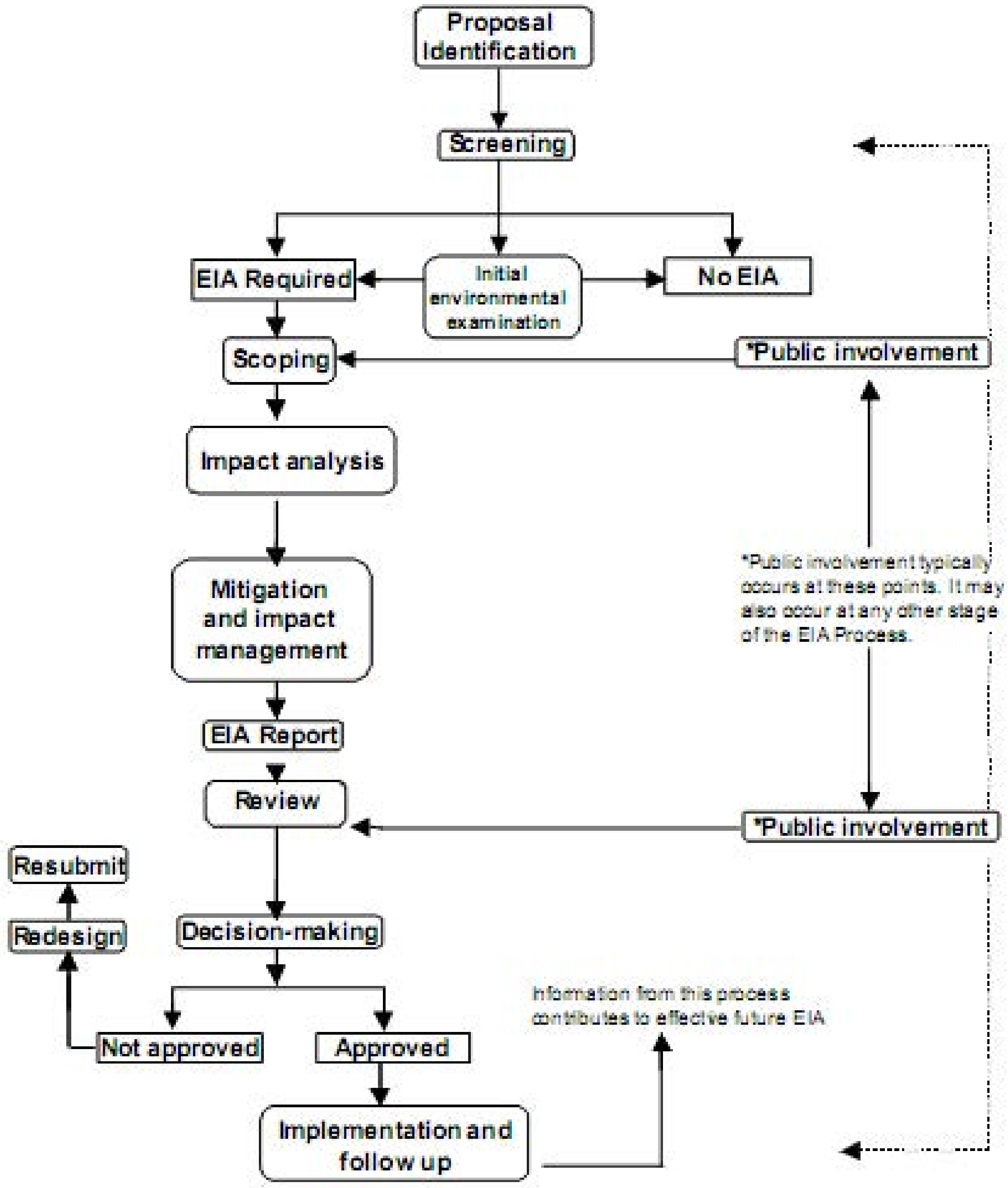
ESIA Report

Includes: ***Environmental and Social Management Plan (ESMP)***

A generalised flowchart of the EIA process is given in

Figure 8-4, including two of the decision points by the environmental regulator – EIA needed or not needed, environmental impact statement (EIS) satisfactory or not.

Figure 8-4: Generalised EIA Process Flowchart



Source: UNEP. 2002. *EIA Training Resource Manual*.

Figure 8-5 illustrates a systematic approach to the determination of **significance**, which is an important component of the impact analysis as it determines the need for mitigation action.

Figure 8-5: Standard Flowchart for a Systematic Approach to Determination of Significance

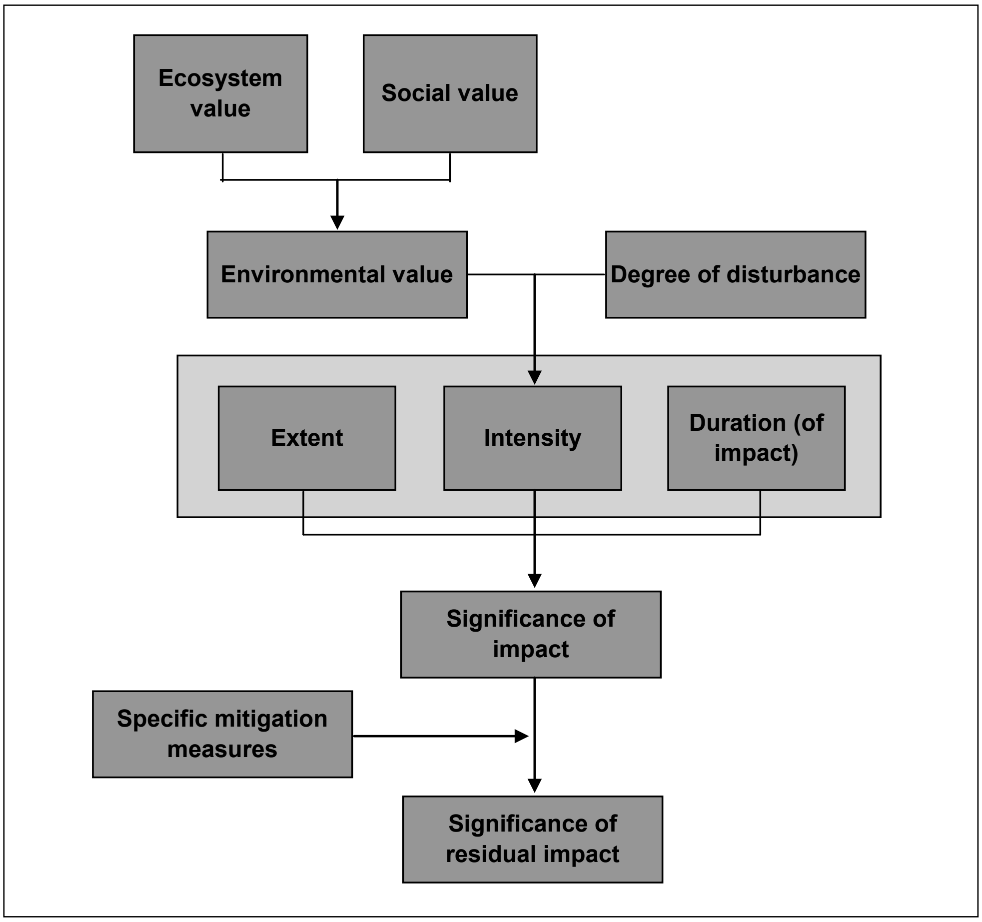
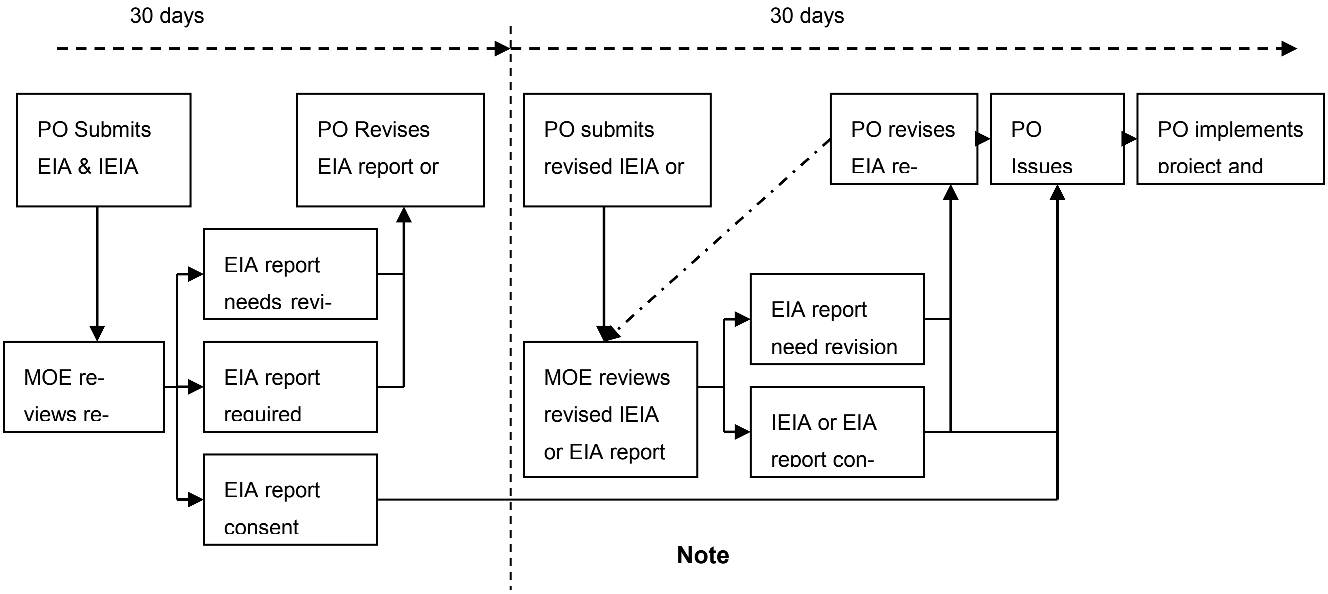


Figure 8-6: Procedure of Environmental Impact Assessment in Cambodia



Note

PO: Project Owner

EIA: Environmental Impact Assessment

IEIA: Initial Environmental Impact Assessment

EMP: Environnemental Management Plan

The Sub-decree on EIA process, enacted in 1999, lists different scales of projects, which requires either IEIA (Initial Environmental Impact Assessment) or EIA, submitted by project owners (POs). IEIA and EIA process are noted below with a full description afterwards:

- The project owner (PO) first prepares Initial Environment Impact Assessment (IEIA) reports, based on assessment of existing environmental conditions and identification of environmental impact and magnitude. PO submits the report to MOE, together with an Environmental Examination Application (EEA) and Pre-Feasibility report.
- MOE reviews whether it is acceptable to comply with the sub-decree or if the project needs a full-scale EIA. The result of this review is delivered to POs within 30 days reports are submitted.
- The PO revises and/or prepares report, based on t he instruction from MOE and submits it again.
- MOE examines the IEIA or EIA report and notifies the PO, if need be, within another 30 days after the 2nd submission. The PO then can receive the approval from MOE for project implementation after report is revised.
- In addition, the format of the EIA report is guided by the IEIA or EIA instructions, clearly defined in the sub-decree in 1999.

8.2.2 Consultation

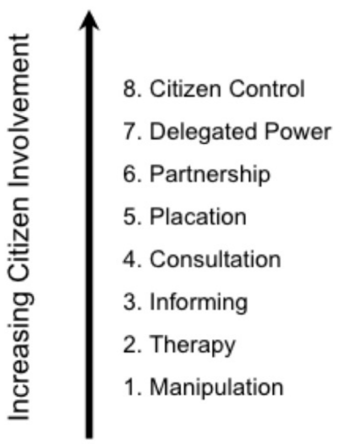
Stakeholder participation is essential throughout the EIA process (see the Training Manual *Dealing with Social Aspects* for more details). There are two major reasons for stakeholder consultation and participation:

- **Ethical:** people have a right to be consulted about decisions, which might affect them.
- **Practical:** consultation makes for better project designs and smoother project implementation.

Note: **consultation** means the exchange of information; **participation** means that those consulted have a direct influence on decision-making – this is a form of **empowerment**, as famously illustrated by the “participation ladder” **(Figure 8-7**).

Participation mechanisms, or techniques, need to be based on stakeholder participation objectives, stakeholder preferences, the languages and cultures of the stakeholders, the resources available (including money, time and skills), and the size and complexity of the project. The choice of technique or mechanism should not drive the process but should adapt to it. Above all else, communication during the participation process must be transparent, honest and comprehensive including particularly clear expositions of the potential negative effects.

Figure 8-7: Participation Ladder



Source: after Arnstein, S.R. (1969), "A Ladder of Citizen Participation", *Journal of the American Planning Association* 35 (4): 216–224

Some participation principles are noted in **Table 8-8**.

Table 8-8: Participation Principles

Participation Principles
• Utilise local knowledge in location decisions for dams, quarries, service towns, etc.
• Be prepared to negotiate with the local community over issues that might cause impacts.
• Pay attention to local power relations and social structures, and respect lines of authority. Go through the appropriate gatekeepers in the community.
• Consider local cultural sensitivities and protocols.
• Ensure that sufficient time and resources are available for participation, and ensure that participa-

tion is actively encouraged, primarily by changing the manner of participation to suit the specific circumstances and cultural context. This may require different participation strategies and different media.

- Provide multiple opportunities for local people to express their concerns and interact with project design so that participation processes do not just become venting exercises, where residents express their anger.
- Be as open and transparent as possible.
- Don’t renege on agreements.
- Have dispute management and mediation processes in place.
- Realise the importance of true public participation and the consequences that might arise from a lack of participation.
- Recognise the existence of diversity within communities, and involve the diverse publics as soon as possible.
- Triangulate responses and do not take sources at face value.
- Develop processes that lead to social inclusion and reject processes that lead to social exclusion.
- Maximise the involvement of local people in: (a) assessment processes; (b) project design; (c) project implementation; and (d) operation, monitoring and evaluation of the project.
- Use local language in communication with local people.
- Consider the vulnerability of certain groups.
- Identify and involve marginalised peoples.
- Identify under-representation by people who are potentially affected and either seek to change participation processes so that they will not be under-represented or ensure that their interests are considered.

Source: Vanclay, 1999, quoted in Brian Hollingworth. 2010. *Sustainable Major Water Infrastructure Devlopment: Training Manual 1: Environmental Management Plans.* SADC, EAC, UNEP, GEF, InWent.

There are many mechanisms for engaging stakeholders in decision-making; **Table 8-9** shows three categories of tools that can be used to achieve the objectives of a consultation programme.

Table 8-9: Techniques and Tools for Stakeholder Participation

Tools to share information	Tools to gather and aggregate data	Tools to enable interaction
• Media advertising • Newsletters • Open house displays • Websites • Briefings • Community meetings • Public exhibitions	• Community meetings • Surveys • Comment forms • Interviews • Focus groups • Public hearings • Review panels	• Community training • Workshops • Discussion groups • Public meetings • Ongoing stakeholder committees

Source: *DDP Compendium* (with additions)

The World Bank[141] describes additional tools, classifying collaborative decision-making methods into:

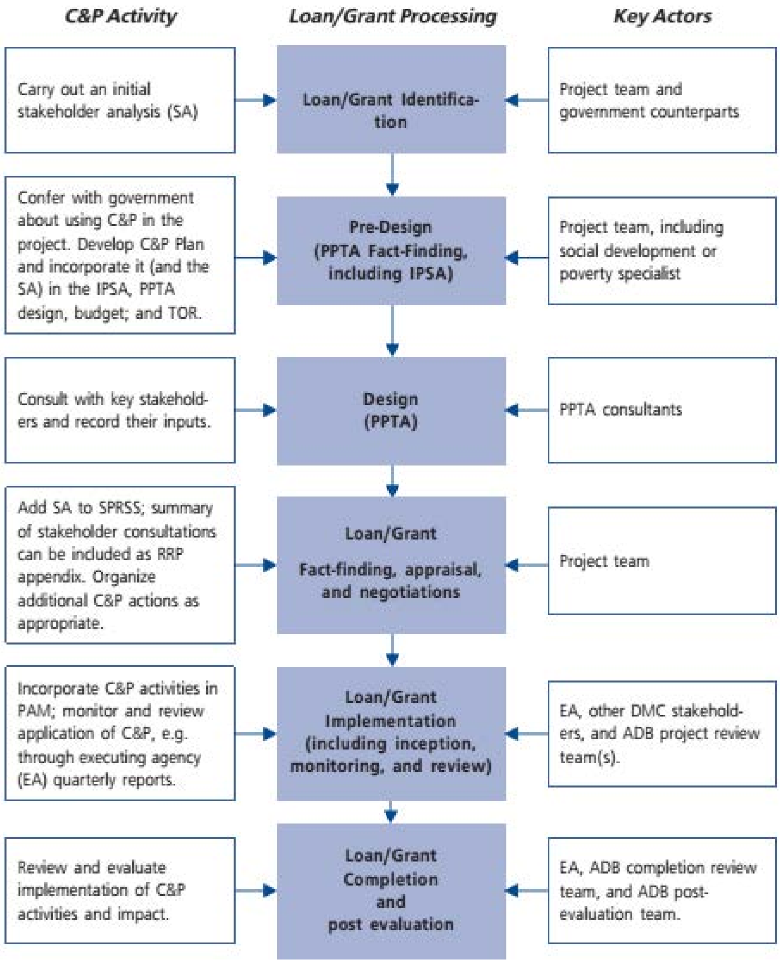
- **Workshop-Based Methods**
  - Appreciation-Influence-Control (AIC): AIC is a workshop-based technique that encourages stakeholders to consider the social, political, and cultural factors along with technical and economic aspects that influence a given project or policy.
  - Objectives-Oriented Project Planning (ZOPP): ZOPP is a project planning technique that brings stakeholders to workshops to set priorities and plan for implementation and monitoring.
  - TeamUp: TeamUp builds on ZOPP but emphasizes team building.

- **Community-Based Methods**
  - Participatory Rural Appraisal (PRA): PRA is a label given to a mature family of participatory approaches and methods that emphasise local knowledge and enable local people to do their own appraisal, analysis, and planning. PRA uses group animation and exercises to facilitate information sharing, analysis, and action among stakeholders.
- **SARAR**
  - This participatory approach, geared specifically to the training of local trainers/facilitators, builds on local knowledge and strengthens local capacity to assess, prioritize, plan, create, organize, and evaluate. The five attributes promoted by SARAR are: Self-esteem, Associative strengths, Resourcefulness, Action planning, and Responsibility.

The following figure (**Figure 8-8**) shows various entry-points for consultation and participation activities in the project cycle.

Figure 8-8: Consultation and Participation Entry Points in the Project Cycle

[141] *The World Bank Participation Sourcebook*, 1996. Appendix 1.



Source: ADB (2006: see Additional Readings)

Effective stakeholder engagement during EIA requires effective **stakeholder analysis**. This is a process, which first identifies the various stakeholders and stakeholder groups with a legitimate interest in a proposed programme or project, and then analyses their characteristics (representativeness, influence, etc.) in order to design appropriate communication methods. In-depth advice is available from many sources, including, for example, the World Bank's *Participation Sourcebook* (see Additional Reading).

An important principle in all EIA processes involving indigenous people is that of **free, prior and informed consent** (FPIC). FPIC is the principle that a community has the right to give or withhold its consent to proposed projects that may affect the lands it customarily owns, occupies or otherwise uses. FPIC is now a key principle in international law and jurisprudence related to indigenous peoples and is being incorporated into standard practice. For example, the UN-REDD Programme has just launched the UN-REDD Programme Guidelines on Free, Prior and Informed Consent (FPIC) (Working Final version) and an associated Legal Companion, which outlines existing international law and emerging State practice affirming that indigenous peoples have the right to effective participation in the decisions, policies and initiatives that affect them and that FPIC is a legal norm that imposes duties and obligations on the States.

<table>
<tr><th colspan="2">TRAINING AIDS</th></tr>
<tr><td>Discussion topics</td><td>1) Does EIA in your country follow the standard steps described here?
2) In many cases the Terms of Reference for large impact studies are written before Scoping. Why is this? What is the result? How can this be changed?
3) How much consultation is mandated in your country’s EIA system? Is this enough? And when is it implemented, is it just token, or actually effective?
4) Do decision-makers regard an EIA as an obstacle, and administrative necessity, or a source of useful information for project optimisation?</td></tr>
<tr><td>Exercises</td><td>Hydropower Role Playing:
• Select a group of trainees to participate in a hydropower role play.
• Randomly assign a role to each individual to represent a different hydropower development stakeholder such as: proponent (energy authority), financing agency (bank), the minister of energy, a minister of environment from a downstream country, a fisherman, a farmer, a development NGO, a conservation NGO, a foreign ambassador representing a development partner, a representative of a regional river body, etc.
• Each role player is asked to express and defend the view of the role he/she assumes about a proposed major hydropower development on a shared international river.
• Start the conversation.</td></tr>
</table>

Additional reading and re-sources	1) Sadler, B. & M. McCabe. 2002. *EIA Training Resource Manual* (2^{nd} ed). UNEP. Available from: http://www.iaia.org/publicdocuments/EIA/ManualContents/Intro_manual.PDF 2) Howe *et al.* 1992. *Manual of Guidelines for Scoping EIA in Tropical Wetlands.* 262p. Wetlands International. 3) World Bank. 1996. *Participation Sourcebook.* World Bank, Washington. Available from: http://documents.worldbank.org/curated/en/1996/02/696745/world-bank-participation-sourcebook 4) ADB. 2006. *Strengthening Participation for Development Results: A Staff Guide to Consultation and Participation.* ADB, Manila.

Case Studies

Case Study 1

This case study gives ADB's view on the consultation process for the Nam Theun 2 project in Lao PDR.

Lao People's Democratic Republic: Nam Theun 2 Hydroelectric project

Recognized for its high social and environmental risks, the Nam Theun 2 project developed a detailed and extensive stakeholder analysis and C&P Plan. A PPTA provided four months of support to help prepare and implement extensive local consultations with affected communities. Households and villagers in the Nam Theun Watershed, Nakai Plateau, and downstream communities were extensively consulted to mitigate social and environmental risks. Experts from the Greater Mekong Subregion created a set of documents and visual aids providing information about the project and its expected impacts. In light of the high-profile nature of the project, a series of international stakeholder workshops were organized with other project partners for hundreds of interested persons in Bangkok, Tokyo, Paris, Washington D.C., and Vientiane. International NGOs were involved in assessing potential environment and social impacts.

See the project website at: http://www.adb.org/Projects/Namtheun2/default.asp

Source: ADB. 2006. *Strengthening Participation for Development Results: A Staff Guide to Consultation and Participation.* ADB, Manila

Case Study 2

This case study illustrates the valuable lessons that can be learned about hydropower project planning from stakeholders.

TucuruÌ Hydropower Complex, Brazil: Lessons Learned from Stakeholders

This section presents the lessons to be learned from this Case Study, proposed both by the members of the team as well as the representatives of the different stakeholder groups who attended the meeting of the Consultation Group, held in January 2000. These lessons are divided into general and specific lessons, indicated by the technical staff of the participant in the Consultation Group meeting.

1. Future hydropower projects should be implemented according to a new model, which includes regional and local development objectives right from the initial conceptualisation, rather than being limited solely to power generation for ventures producing benefits outside the region.

2. In order to implement new hydropower projects, studies of the hydropower inventory of the entire basin should be reviewed in advance, incorporating in the location and power choice of each power plant location assessments of the resulting social and environmental impacts of all alternatives.

3. The importance of a prior assessment process for the environmental impacts of various alternative sites demands the introduction and fine-tuning of new public participation mechanisms throughout all stages of large-scale dam design: planning, construction and operation.

4. The implementation of large-scale hydropower ventures requires a development committee to be set up for the entire basin, responsible for conducting the project and disciplining negotiations among the various social agents involved.

5. The criteria for defining the area directly affected by hydropower ventures should be reviewed, particularly those with the right to compensation or royalties. This should not restricted to the percentage of the area flooded, and should also introduce social control mechanisms for the allocation and investment of funding.

6. A lack of scientific certainty regarding the scope and relevance of the environmental impacts and risks of the venture cannot serve as an alibi for its failure to consider them, but should rather urge the adoption of the 'precautionary principle' throughout all stages of the project: planning, construction and operation.

7. The lessons learned from the TucuruÌ Hydropower Complex case study should be deployed during the planning, construction and operation of new hydropower projects in Amazonia, ensuring that they make a real contribution to the participatory and sustainable development of both the region and the country.

Lessons learned proposed by the participants in the final stakeholder meetings include:

1. Redefinition of the concept of the populace affected, ensuring that this is no longer restricted solely to the population living in the area to be submerged by the future reservoir.

2. Acknowledgement by the project entity that grassroots movements are the legitimate spokespersons for the definition of public policies in taking decisions that affect their lifestyles.

3. The project entity should start off from the principle that community perceptions of impacts affecting their lifestyles, even when lacking scientific proof, should be taken under consideration and be dealt with through social welfare measures and policies.

4. The knowledge already built up of the environmental impacts caused by large-scale hydropower projects should underpin the preparation of social policies for dealing with the associated social issues.

5. Access should be assured to technical information in language appropriate to the public domain, covering the project and its associated impacts.

6. There is a need to establish permanent channels of communication between the project entity and the

communities affected by the venture throughout the entire project cycle.

7. Promoting integrated development actions for rural areas, stressing renewable energy projects and upgrading the quality of life for local communities, taking into consideration the fact that the urban populace has easier access to the benefits of these ventures, in addition to poor service levels in rural Amazonia.

Source: La Rovere, E.L. & F.E. Mendes. 2000. *TucuruÌ Hydropower Complex Brazil*. WCD Case Study.

8.3 Legal and Administrative Framework

Key aspects	• Environmental Impact Assessment (EIA) is used worldwide as an instrument for development planning and control. • Impact assessment is usually prescribed by national law or funding agency policy, and amplified in regulations, directives, guidelines, procedures, and administrative orders. • Impact assessment regulations usually also cover Environmental Management Plans (EMPs).

TRAINING AIDS	
Purpose of session	To introduce trainees to the wide range of policies, laws and regulations governing impact assessment.
Learning objectives	• To understand that impact assessment is governed by a wide range of laws and regulations at the national level. • To understand that most international funding institutions (IFIs) have policies and regulations on impact assessment. • To understand that there is a large body of international law relevant to impact assessment through its effect on relevant topics such as biodiversity, climate change and human rights.
Key readings	1) Donnelly *et al.* 1998. *A Directory of Impact Assessment Guidelines (2nd ed).* IIED, London. http://pubs.iied.org/pdfs/7785IIED.pdf

8.3.1 Legislative Frameworks

More than 100 countries worldwide now have some form of domestic legislation concerning impact assessment. Typically this covers projects, but increasingly some form of strategic assessment is mandated for policies and programmes. In some federated jurisdictions impact assessment of some (if not all) projects is relegated to the province, region or state.

Impact Assessment is usually prescribed by law or policy, and amplified in regulations, directives, guidelines, procedures, and administrative orders. Experience indicates that an effective EIA institutional framework includes the following enabling conditions:

- A clear statement of purpose and principles;
- Legal provision and requirements;
- Procedural controls and accountabilities;
- Understood scope of application to proposals with potentially significant impacts;

- Prescribed process of steps and activities;
- Opportunities for public consultation and access to information;
- Linkage to project approval and condition setting; and
- Follow up and monitoring mechanisms.

The eight conditions above represent legal and institutional prerequisites for sound EIA, and comprise an initial checklist for assessing how current processes measure up. Where these basic components are in place, they do not guarantee, in themselves, good EIA practice and effective performance. However, where they are not well established, the process is highly unlikely to move in that direction.

Many EIA commentators argue that a standing mechanism for independent review of EIA reports is critical for sound practice. Examples include the Netherlands EIA Commission and the Canadian system of independent panel reviews. Other countries operate more informal or internal processes, such as the US system of inter-agency EIA review or the multi-stakeholder committee approach of Brazilian states, which may be equally effective.

A sample of national normative frameworks for EIA is given in **Table 8-10**.

Table 8-10: Sample of National Normative Frameworks for EIA

Country	Normative Framework
Australia	Environmental Protection Act (1994) Environment Protection and Biodiversity Conservation Act (1999) http://www.deh.gov.au/epbc/index.html Environment Protection and Biodiversity Conservation Regulations (2000) http://www.deh.gov.au/epbc/about/index.html
Brazil	National Environmental Policy Act (Law 6938, 1981) Environmental Crimes Act (1998) http://www.brasembottawa.org/en/environment/legislation/env_crimes_act.html
Canada, British Columbia	Canadian Environmental Assessment Act (1992, amended 2003) http://laws.justice.gc.ca/en/c-15.2/text.html British Columbia Environmental Assessment Act (1995, 2002) http://www.qp.gov.bc.ca/statreg/stat/E/02043_01.htm Guide to the British Columbia Environmental Assessment Process (2003) http://www.eao.gov.bc.ca/publicat/guide-2003/guide-home.htm Canada-British Columbia Agreement for Environmental Assessment Cooperation (2004) http://www.ceaa-acee.gc.ca/010/0001/0003/0001/0002/2004agreement_e.htm

Country	Normative Framework
Egypt	Law No. 4 of 1994 promulgating the Environment Law (1994) http://www.eeaa.gov.eg/english/main/law4.asp Executive Regulations (338/1995) http://www.fao.org/figis/servlet/static?dom=legalframework&xml=nalo_egypt.xml#tcNE0014 Guideline on Egyptian Environmental Impact Assessment (1995)
Iran	Law for Environmental Protection and Development (1991)
Nepal	Environmental Protection Act (Act 2053, 1996) Environmental Assessment Guidelines (2002)
Russia	Law about Environmental Protection (2002) http://www.inece.org/conference/7/vol1/Sapozhinikova.pdf
South Africa	National Environmental Management Act (1998) http://www.polity.org.za/govdocs/legislation/1998/act98-107.html National Environmental Management Amendment Act (2004) http://ww.polity.org.za/pdf/NatEnvmanAmedAct8.pdf EIA Regulations 2006 http://www.environment.gov.za/Documents/Documents/2005Mar17/eia_luanch_13042006.html# General Guide to the EIA Regulations (2006) http://www.environment.gov.za/Documents/Documents/2005Mar17/eia_luanch_13042006.html#
Tajikistan	The law “On environmental protection” of 1993 as amended by Law No. 30 of 2002 and Law No. 75 of 2002 Regulation on EIA (2002) The law “On Environmental Review” of 2003
Vietnam	Law on Environmental Protection (1993) http://unsite.nus.edu.sg/apcel/dbase/vietnam/primary/viaenv.html Decree on providing Guidance for the Implementation of the Law on Environmental Protection (1994) (Government Decree No. 175-CP, 1994) http://sunsite.nus.edu.sg/apcel/dbase/vietnam/regs/videnv.html

Source: Ramsay, J. 2006. *Compendium on Relevant Practices on Improved Decision-Making, Planning and Management of Dams and their Alternatives. Key Issue - Environmental Management Plans, Final Report*. UNEP-DDP, Nairobi.

EIA and EMPs: the concept of Environmental Management Plans emerged from the field of Environmental Impact Assessment (EIA). Following the prediction of potential impacts and an evaluation of their significance, the next stage in the impact assessment process is the development of mitigation measures to prevent, minimise or offset significant adverse impacts. For projects that proceed, these measures must then be formally integrated into the project design. In impact assessment theory, this step is considered part of the environmental impact assessment (EIA) follow-up process.

The document, which clearly describes what and how certain measures will be incorporated into further stages of project implementation and operation, is termed an Environmental

Management Plan (EMP). EMPs provide an essential link between the impacts predicted and mitigation measures specified within an impact assessment report and final design, implementation and operational activities. EMPs may be given legal status by being referred to or incorporated into environmental permits, financing agreements, and other contractual documents.

In most jurisdictions, EMPs are standard products of the impact assessment process; as such, they are governed by EIA normative frameworks at both the international level and country level, as well as at provincial or state levels in federal countries. EMP requirements may be formulated in framework environmental protection laws, in specific impact assessment laws, in regulations, or in formal guidelines. In some cases, EMPs are specified together with their contents and format; while, in other cases, EMPs are required only by implication or as a matter of best practice.

Briefly stated, the EIA in the planning and approval stages in the project cycle is converted into an EMP for the implementation stage and beyond. The EMP directs how the mitigation measures that were identified during the EIA (and which are usually included into the environmental authorisation), will be done. It also assigns responsibility to individuals or organisations, sets a budget and determines a programme.

8.3.2 International Norms

In 1992, at the United Nations Conference on Environment and Development, IA received international endorsement. Principle 17 of the Final Declaration is dedicated to EIA and article 14 of the Convention of Biological Diversity is about IA.

In the 1990s there was increasing emphasis on establishing internationally recognised principles and standards of good practice, instilling a diverse range of guidance down to the fundamentals and basic elements. Key documents included:

- The International Study of the Effectiveness of Environmental Assessment (1996).[142]
- The UNEP Environmental Impact Assessment Training Resource Manual (1996, revised edition 2002).[143]

The Principles of EIA Best Practice, issued by the International Association for Impact Assessment and the UK Institute of Environmental Assessment (1999)[144] (

[142] Barry Sadler ed. *Environmental Assessment in a Changing World: Evaluating Practice to Improve Performance*. Final Report. International Study of the Effectiveness of Environmental Assessment. Canadian Environmental Assessment Agency & International Association for Impact Assessment. June 1996. http://www.ceaa.gc.ca/Content/A/F/B/AFB7DF6E-7212-451B-A27E-9A56035CD913/iaia8_e.pdf

[143] Ridgeway, B., McCabe, M., Bailey, J., Saunders, R., Sadler, B. *Environmental Impact Assessment Training Resource Manual.* Prepared for the United Nations Environment Programme by the Australian Environment Protection Agency. Nairobi, Kenya. 1996. Second edition 2002. http://www.unep.ch/etu/publications/EIAMan_2edition_toc.htm

[144] http://www.iaia.org/publicdocuments/pdf/Principles%20of%20IA_web.pdf

Table 8-11). The principles comprise a broadly based framework of guidance, applicable to all types of proposals and consistent with generic EIA requirements and procedures, established by different countries.

Table 8-11: Basic Principles of EIA

Basic Principles of EIA - Issued by the International Association for Impact Assessment (IAIA) and UK Institute of Environmental Assessment

Environmental Impact Assessments should be:

- **Purposive** - the process should inform decision-making and result in appropriate levels of environmental protection and community well-being.
- **Rigorous** - the process should apply best-practice science, employing methodologies and techniques appropriate to address the problems being investigated.
- **Practical** - the process should result in information and outputs that assist with problem solving and are acceptable to and able to be implemented by proponents.
- **Cost-effective** - the process should achieve the objectives of EIA within the limits of available information, time, resources and methodology.
- **Efficient** - the process should impose the minimum cost burdens in terms of time and finance on proponents and participants consistent with meeting accepted requirements and objectives of EIA.
- **Focused** - the process should concentrate on significant environmental effects and key issues; i.e., the matters that need to be taken into account in making decisions.
- **Adaptive** - the process should be adjusted to the realities, issues and circumstances of the proposals under review without compromising the integrity of the process; and be iterative, incorporating lessons learned throughout the proposal's life cycle.
- **Participative** - the process should provide appropriate opportunities to inform and involve the interested and affected publics, and their inputs and concerns should be addressed explicitly in the documentation and decision-making.
- **Interdisciplinary** - the process should ensure that the appropriate techniques and experts in the relevant biophysical and socio-economic disciplines are employed, including use of traditional knowledge as relevant.
- **Credible** - the process should be carried out with professionalism, rigor, fairness, objectivity, impartiality and balance, and be subject to independent checks and verification.
- **Integrated** - the process should address the interrelationships of social, economic and biophysical aspects.
- **Transparent** - the process should have clear, easily understood requirements for EIA content; ensure public access to information; identify the factors that are to be taken into account in decision-making; and acknowledge limitations and difficulties.
- **Systematic** - the process should result in full consideration of all relevant information on the affected environment, of proposed alternatives and their impacts, and of the measures necessary to monitor and investigate residual effects.

Source: IAIA in cooperation with IEA, UK, 1999: Principles of EIA Best Practice.
http://www.iaia.org/publicdocuments/pdf/Principles%20of%20IA_web.pdf

Many international agencies have established impact assessment policies to guide their actions and investments (Table 8-12).

The EIA systems established under national laws and under the policies of international agencies differ in a number of respects. Some of these are significant (e.g. limited versus broad scope of application, mandatory versus discretionary provisions, varying degrees to which participation is encouraged or discouraged, and different powers of Ministerial override). However, the EIA process also has widely accepted objectives, principles, elements, and steps. With few exceptions, these elements and steps are followed internationally.

Some of the major elements of the international framework are:

- **International financing institutions** (IFIs), such as the World Bank, Asian Development Bank, European Community, and the many bilateral aid agencies (CIDA, DFID, JICA, SIDA, USAID etc.). The activities of national export credit agencies are much less constrained by environmental and social considerations.
- **Commercial financing institutions:** many private sector banks have signed up to the **Equator Principles**, a set of environmental and social safeguards based on the policies of the International Finance Corporation (IFC).
- **World Commission on Dams (WCD):** the WCD's recommendations are widely considered to be the 'gold standard' by environmental and social NGOs and development practitioners; and have been accepted by some states and water and energy organisations.
- **International environmental agreements:** conventions such as those on biodiversity, heritage and migratory species are often directly relevant to ecological issues during hydropower planning.
- **Regional organisations and agreements:** in some cases regional agreements on water-sharing or power planning are relevant to river management (as in SE Asia).

In addition to these policies and laws, a volume of guidance on all aspects of impact assessment, especially in the water and energy sector, also exists. The World Bank's 1991 *Environmental Assessment Sourcebook* and its numerous *Updates* are a widely used reference source. Volume III of the Sourcebook contains sectoral and technical guidelines for EIAs of hydroelectric projects—including dams, reservoirs and power generation and transmission facilities. Until the publication of the WCD report in 2000, these guidelines approximated to an international standard for application of EIA, especially for use in and by developing countries. The WCD report "moved the goalposts", and, together with new guidelines and standards on environmental and social assessment from the World Bank group and the regional banks (especially the ADB), and with documentation on emerging disciplines such as sustainability assessment[145], the process of impact assessment continues to evolve and

[145] See, for example, the International Hydropower Association's *Sustainability Guidelines* available at http://www.hydropower.org/sustainable_hydropower/IHA_Sustainability_Guidelines.html, the subsequent Hydropower Sustainability Assessment Forum (http://www.hydropower.org/sustainable_hydropower/HSAF.html), and the associated forceful civil society critique at http://www.internationalrivers.org/en/social-and-environmental-standards/hydropower-sustainability-assessment-forum

become more complex (and often considerably exceeds the resources available to actually carry out impact assessment studies).

Table 8-12: Sample International Normative Frameworks for EIA

Organisation	Normative Framework
Commercial finance	
Private sector banks	Revised Equator Principles (July 2006) http://www.equator-principles.com/principles.shtml
Multilateral	
African Development Bank	Environmental Review Procedures for Private Sector Operations of the African Development Bank (undated – probably 2004) Environmental and Social Assessment Procedures for African Development Bank's Public Sector Operations (2001) http://www.afdb.org/pls/portal/url/ITEM/FF9B90B12042E7C3E030C00A0C3D64EE#search=%22african% Integrated Environmental and Social Impact Assessment Guidelines (2003) Strategic Impact Assessment Guidelines (2003) African Development Bank Group's Policy on the Environment (2004)
Asian Development Bank	Environment Policy of the Asian Development Bank (2002) Environmental Assessment Guidelines (2003) http://www.adb.org/Documents/Guidelines/Environmental_Assessment/default.asp
European Bank for Reconstruction and Development	Environmental Policy (2003) EBRD Environmental Procedures (2003) http://www.ebrd.com/about/policies/enviro/procedur/procedur.pdf#search=%22ebrd%20environmental% EBRD Environmental Risk Management Manual (currently on version 3; http://www.ebrd.com/enviro/init/erm.htm) Sub-sectoral Environmental Guidelines: Building and Construction Activities (undated)
European Investment Bank	The Project Cycle at the European Investment Bank (2001) Environmental Procedures (2002) EIB Sustainable Development and Environment Documents (2002) Environmental Statement (2004)
European Union	Directive 85/337/EEC on EIA, amended 97/11EC and subsequently by other Directives (see http://ec.europa.eu/environment/eia/eia-legalcontext.htm) Directive 2001/42/EC on Strategic Environmental Assessment

Organisation	Normative Framework
Inter-American Development Bank	Procedures of the Committee on Environmental and Social Impact (undated) http://www.iadb.org//sds/env/publication/gen_183_57_e.htm Environment Strategy (2003) Safeguard Implementing Guidelines of the Draft Environment and Safeguards Compliance Policy (draft) (2004) http://www.iadb.org/idbdocs.cfm?docnum=680331#search=%22iadb%20safeguard% Environment and Safeguards Compliance Policy (2006) http://www.iadb.org/sds/env/site_5512_e.htm
Organisation for Economic Cooperation and Development – Development Assistance Committee	Guidelines on Aid and Environment: No. 1 Good Practices for Environmental Impacts Assessment of Development Projects (1992) Guidelines on Aid and Environment No. 3: Guidelines for Aid Agencies on Involuntary Displacement and Resettlement in Development Projects (1992) Both above available at: http://www.oecd.org/document/26/0,2340,en_2649_33721_1887578_1_1_1_1,00.html Good Practice Guidance on Applying Strategic Environmental Assessment (SEA) in Development Co-operation (2006)
OECD - Export Credit Agencies	OECD Updated Recommendation on Common Approaches on Environment and Officially Supported Export Credits (2005) http://webdomino1.oecd.org/olis/2005doc.nsf/Linkto/td-ecg(2005)3 Statement on Export Credits and Hydro-Power Projects (2005) http://www.oecd.org/document/41/0,2340,en_2649_34181_35688937_1_1_1_1,00.html Note: the Export Credit and Guarantees Group (ECG) is negotiating an agreement on common approaches among OECD countries to take into account the environmental impact of projects when providing officially supported export credits.
United Nations	Development Assistance Framework http://www.undg.org/content.cfm?id=831, http://www.un.org.in/undaf.htm
World Bank Group:	

Organisation	Normative Framework
International Bank for Reconstruction and Development	Bank safeguard policies and procedures http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/EXTPOLICIES/EXTSAFEPOL/0,,menuPK:584441~pagePK:64168427~piPK:64168435~theSitePK:584435,00.html Operational Policy and Bank Procedure 4.01 Environmental Assessment (1999) http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTENVASS/0,,menuPK:407994~pagePK:149018~piPK:149093~theSitePK:407988,00.html Guidance: Environmental Assessment Sourcebook (1991) and subsequent Updates, in particular No. 25 Environmental Management Plans (1999) http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/EXTPOLICIES/EXTSAFEPOL/0,,contentMDK:20509076~hlPK:1287595~menuPK:1286567~pagePK:64168445~piPK:64168309~theSitePK:584435,00.html
International Finance Corporation	IFC's Policy on Social and Environmental Sustainability (2006) http://www.ifc.org/ifcext/enviro.nsf/Content/SustainabilityPolicy IFC Environmental and Social Review Procedures (2006) http://www.ifc.org/ifcext/enviro.nsf/Content/ESRP Performance Standard 1: Social and Environmental Assessment and Management Systems (2006) http://www.ifc.org/ifcext/enviro.nsf/Content/PerformanceStandards Guidance Note 1: Social and Environmental Assessment and Management Systems (2006) http://www.ifc.org/ifcext/enviro.nsf/Content/GuidanceNotes
Bilateral	
Canadian International Development Agency	Canadian Environmental Assessment Act (1992) http://lois.justice.gc.ca/en/C-15.2/
Department for International Development (UK)	Environment Guide (2003) http://www.iema.net/readingroom/show/616/c175
Japanese International Cooperation Agency	Guidelines for Environmental and Social Considerations (2004) http://www.jica.go.jp/english/about/policy/envi/index.html

Organisation	Normative Framework
Kreditanstalt für Wiederauf-bau (Germany)	Environmental Report (2003) http://www.kfw.de/EN_Home/Die_Bank/Our_Tasks/Environmen35/KfWsPublic20/KfW-Enviro.jsp Environmental Guidelines for Financial Cooperation (FC) by KfW with Developing Countries (2001) http://www.kfw.de/DE_Home/Service/OnlineBibl48/PDF-Dokumente_Umweltschutz/stu_fz_englisch_131101.pdf General Environmental Guideline (2002) http://www.kfw.de/EN_Home/Die_Bank/Our_Tasks/Environmen35/KfWsPublic20/Guidelines49/KfWGeneral.jsp Export and Project Finance: Guidelines for Environmental Protection (2002) http://www.kfw.de/EN_Home/Die_Bank/Our_Tasks/Environmen35/KfWsPublic20/Guidelines49/Guidelinef1.jsp Environmental Guideline for Investment Finance by KfW (2002) http://www.kfw.de/EN_Home/Die_Bank/Our_Tasks/Environmen35/KfWsPublic20/Guidelines49/Guidelinef.jsp
Swedish Inter-national De-velopment Agency	Guidelines for the Review of Environmental Impact Assessments (2002) http://www.sida.se/sida/jsp/sida.jsp?d=118&a=2532&language=en_US
United States Agency for International Development	Numerous laws requiring environmental compliance http://www.usaid.gov/our_work/environment/compliance/ Title 22, Code of Federal Regulations, Part 216 (22 CFR 216) (EIA procedures: 1980) http://www.usaid.gov/our_work/environment/compliance/22cfr216.htm USAID Automated Directives System Chapter 204 (ADS 204) http://www.usaid.gov/our_work/environment/compliance/22cfr216.htm
US Overseas Private In-vestment Cor-poration	Environmental Handbook (incorporates WCD core values and strategic priorities) http://www.opic.gov/doingbusiness/investment/environment/documents/opic_env_handbook.pdf
Other organisations	
International Association for Impact As-sessment (IAIA)	Principles of Environmental Impact Assessment Best Practice (1999) http://www.iaia.org/Non_Members/Pubs_Ref_Material/pubs_ref_material_index.htm Other IAIA impact assessment best practice guidelines, including social, biodiversi-ty, and health impact assessment, public participation, impact assessment in a cor-porate context, and strategic environmental assessment http://www.iaia.org/Non_Members/Pubs_Ref_Material/pubs_ref_material_index.htm
International Commission on Large Dams (ICOLD)	Position Paper on Dams and the Environment (1997) http://www.icold-cigb.org/chartean.html

Organisation	Normative Framework
International Energy Agency (IEA)	Hydropower Implementing Agreement (ongoing) http://www.ieahydro.org/agreement.htm
International Hydropower Association (IHA)	Sustainability Guidelines (2004) http://www.adb.org/water/dams/pdf/IHA-Guidelines.pdf
The World Conservation Union (IUCN)	Dams and Development: a New Framework for Decision-Making (2000) http://www.dams.org/
WWF	An Investor's Guide to Dams (2003) http://www.panda.org/about_wwf/what_we_do/freshwater/our_solutions/policies_practices/removing_barriers/dams_initiative/index.cfm

Source: Ramsay, J. 2006. *Compendium on Relevant Practices on Improved Decision-Making, Planning and Management of Dams and their Alternatives. Key Issue - Environmental Management Plans, Final Report*. UNEP-DDP, Nairobi.

TRAINING AIDS	
Discussion topics	Can politicians override EIA recommendations in your country? Is this a good idea? How can trans-boundary impact assessment processes be made effective? Do some banks have stronger environmental and social safe-guards than others? Do you think the increasing influence of hydropower finance from sources with 'no strings attached' is driving down the safeguards standards of other financing institutions?
Exercises	• For a large, internationally funded hydropower project you are familiar with, attempt to map all the environmental policies, laws and associated institutional responsibilities affecting the project (international, national, local).
Additional reading and resources	1) World Bank. 1991. *Environmental Assessment Sourcebook* and subsequent *Updates.* Available from World Bank website. 2) IFC. 2012. *Performance Standards* and *Guidance Notes.* Available from IFC website. 3) World Bank Group. 2007. *Environment, Health and Safety Guidelines.* Available from IFC Sustainability website. 4) Revised Equator Principles (July 2006) http://www.equator-principles.com/principles.shtml 5) IAIA Best Practice Principles and other guidance documents. Available from IAIA website at Revised Equator Principles (July

	2006) http://www.equator-principles.com/principles.shtml

9 ENVIRONMENTAL MANAGEMENT PLANS

MODULE 9: ENVIRONMENTAL MANAGEMENT PLANS		
Scope	**Session/Sub-Topic**	**Scope**
Introduction to Environmental Management Plans	**Session 9.1: Background**	
	Scope of module	Focus on environmental issues, not social
	Purpose of EMPs	Purpose, rationale for EMPs
	EMP evolution	Stages of EMP evolution through to EMS
	EMP normative frameworks	National, bilateral, international
	EMP glossary	Example EMP glossary
	Session 9.2: EMPs and Project Management	
	EMPs in the project cycle	EMP cycle (sequence), project cycle
	Preparation of EMPs	EMPs as outcomes of EIAs
	Core elements of EMPs	Description of core elements (list from DDP Compendium)
	Implementation of EMPs	Timing, responsibilities, process
	EMP authorisation	The environmental regulator; Record of Decision
	Session 9.3: The Environmental Management Plan	
	Scope of EMPs	Scope and outline content of EMPs; desirable attributes
	Costs	Importance of fully identifying all costs
	Catchment or basin management plans	See Module 5, Session 5.2
	Structure of EMPs	Contents, components, structure, sub-plans
	Mitigation measures	

MODULE 9: ENVIRONMENTAL MANAGEMENT PLANS		
Scope	**Session/Sub-Topic**	**Scope**
	Section 9.4: Institutional Arrangements	
	Responsibilities	Responsibilities and roles
	Rights, risks and contracts	Contractual commitment approach
	Institutional strengthening, change and capacity building	Importance of institutional strengthening component of EMP
	Dispute and grievance resolution	Importance of effective mechanism
	Cost and financing	Approaches to financing; public and private sector; trust funds
	Section 9.5: Environmental Management Systems (EMS)	
	Overview	Definition, ISO, QA, EMAS, EMS & EIAs; examples
	Section 9.6: Managing EMP Implementation	
	Introduction	Introduction
	Governance	Governance, good governance
	Organisation	Tasking; organisational arrangements; sub-plans; independent monitors and auditors
	Programming and budgeting	Integration with overall project budget
	Record keeping	Importance; technology - GIS, MIS
	Monitoring	See Module 10
	Reporting	Arrangements; transparency
	Adaptation, flexibility and corrective action	Need for flexibility as circumstances change
	Compliance and enforcement	Introduction; cross-reference to Module 10, Session 10.2

MODULE 9: ENVIRONMENTAL MANAGEMENT PLANS		
Scope	**Session/Sub-Topic**	**Scope**
	Stakeholder participation	Importance, purpose, benefits; tools; examples
	Communication	Importance; example
	Exit strategy	Need for exit strategy; hand-over of programmes

9.1 Background

Key aspects	
Key aspects	• An EMP is a management tool, used to ensure that, based on the outcomes from the EIA process, the mitigation measures and the conditions attached to the environmental authorisation are realised. • EMPs have evolved over the last 30 years and now cover all aspects of environmental and social management during final planning and design, project construction, project operation, and decommissioning. • EMPs may comprise multiple plans with different levels of detail. • In many jurisdictions, EMPs are standard products of the impact assessment process, and as such, are governed by EIA normative frameworks. • Internationally, the main categories of organisations with normative frameworks covering EMPs, directly or indirectly, are the multilateral development and financing organisations, bilateral aid and export credit agencies, commercial banks, and interest groups ranging from industry associations to NGOs.

TRAINING AIDS	
Purpose of session	To introduce EMPs and trace their evolution over the last few decades.
Learning objectives	• Introductory understanding of what EMPs entail. • Appreciation that EMPs have evolved over time, parallel to environmental impact assessment. • Appreciate that there are many normative frameworks that determine the nature of EMPs.
Key readings	1) DDP Compendium, Chap. 6: Environmental Management Plans

9.1.1 Scope of this Module

Environmental Management Plans (EMPs) relate to both the natural and the social environment. However, as this module is part of a manual on ecosystems, the focus is on aspects related to the natural environment. For social management plans the principles remain the same, but details differ; the trainer interested in the social aspects, and particularly public participation, is referred to the parallel manual on social aspects. An EMP case study on the social aspects of Maguga Dam, Swaziland is available online[146].

Following the publication in 2000 of the report of the World Commission on Dams, the international community decided that further work was needed on the practical aspects of the Commission's recommendations. The United Nations Environment Programme agreed to host the initiative entitled the Dams and Development Project (UNEP-DDP). This initiative identified EMPs as one of the priority topics needing practical expression. The core of this module is drawn from the principal publication output of the DDP, titled *A Compendium of Relevant Practices for Improved Decision-Making on Dams and their Alternatives* as well as the preparatory report on the topic[147]. The Compendium was published in 2007. In the ensuing years, InWent, a forerunner to GIZ, compiled a manual on EMPs, based on the Compendium, and ran a training programme in the Southern African Development Community. This module benefits from that training programme and uses several examples from the region. In addition, a number of examples where international practice has advanced, as well as examples from south-east Asia, have been introduced.

9.1.2 Purpose of EMPs

Environmental Management Plans (EMPs)[148] is defined below:

> *EMPs are tools to ensure that environmental factors are carefully managed throughout the project cycle. They are intended to document the actions necessary to prevent or minimise predicted negative impacts, to maximise benefits, and to provide a framework for systematic management of environmental responsibilities, impacts and risks.*

An EMP is the management mechanism used to ensure that all of the environmental issues identified during the impact assessment (and incorporated into the environmental approval) are actually put into effect during the design, construction, and further phases of project implementation. Without an EMP, there is every likelihood that the biophysical, social and economic components that are part of the overall project design will not be given sufficient attention, particularly during the activity-intense period of project construction.

EMPs are derived from the outcomes of the environmental impact assessment (EIA) process and the project approval process of the environmental authority. These processes incorporate public participation, which must continue into the formulation of the EMP. The EMP is an operational plan that details what has to be done, by whom, how compliance will be assured, and how environmental management in the design, construction and operational phases will

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[146] Keevy, C, Malzbender D. and Petermann T. (eds). 2009. *Dams and Development: The KOBWA Experience. Practices for balancing social, environmental and economic aspects in water infrastructure development*. InWEnt. Available at www.giz.de.

[147] Ramsay, J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.

[148] Also less commonly referred to as “Programmes”, “Environmental and Social Management Plans” (ESMPs), “Comprehensive Mitigation Plans” (CMPs) or “Environmental Action Plans” (EAPs).

be programmed and financed. This need for structure has increased in recent years as the international community examines whether the World Commission on Dams has had a material effect (**Box 9-1**).

An EMP is not necessarily a single document but may consist of several component plans—each addressing a coherent part of the works. Examples of component plans could be a relocation action plan, a plan for control of oil spills from construction activity, and a plan for preservation of archaeological artefacts.

Box 9-1: The World Commission on Dams: Ten Years On

The World Commission on Dams: Ten Years On
"Despite the WCD process, the legacies and controversies of the world's 45,000 large dams continue to cause conflict between providing hydropower, water supply, flood control, irrigation and other substantial benefits to many, while devastating the basic rights and livelihoods of others, and damaging shared rivers and ecosystems. Dams control floods and regulate irregular water regimes, generate hydropower, provide storage for domestic, industrial or agricultural use, and allow the development of recreation. But these benefits are not well distributed socially, often favouring urban dwellers, industries and certain types of farmers disproportionally; and they come with large social and environmental costs that for too long were overlooked. Few rivers remain that have been untouched by some type of dam. ***Displaced populations, estimated between 40-80 million****, have frequently been resettled with minimal or no compensation, often in marginal lands, and in the majority of cases have become and remained poorer. Large-scale alteration of natural hydrologic regimes has had massive impacts on fisheries, water-based livelihoods, aquatic ecosystems and environmental services as a whole. Some scientists also believe that many reservoirs emit large amounts of greenhouse gases, up to 4% of all human-induced GHG emissions, as reviewed in this volume by Mäkinen and Khan. Indeed, the first-ever global estimate of the number of river-dependent people potentially affected by dam-induced changes in river flows and other ecosystem conditions is presented in this volume by Richter et al.: that* ***472 million river-dependent people have had their livelihoods negatively affected by dams****."*
Moore, D.; Dore, J. and Gyawali, D. 2010. *The World Commission on Dams + 10: Revisiting the large dam controversy*. Water Alternatives 3(2): 3-13

Environmental management is not usually of a straightforward "cause-and-effect" nature. Nevertheless, EMPs are intended to result in smoother project implementation and better project outcomes by applying two of the central tenets of integrated water resources management (IWRM), namely social equity and environmental sustainability. Their preparation requires significant resourcing (time, money, information and skills).

Knowledge about the framework of international conventions and the existence of a widely accepted body of knowledge can provide confidence to the policy-maker, decision-maker and professional alike that they are "doing the right thing" in preparing comprehensive EMPs to address the challenges that large water infrastructure brings to environmental and social management.

The terminology of EMPs varies around the world. An EMP Glossary is given below (9.1.6).

9.1.3 EMP Evolution

The evolution of EMPs is closely linked to that of environmental awareness.

EMPs have emerged from the methodology of impact assessment (IA). Their scope and form have changed over time, reflecting the evolution of the IA process. Five broad stages can be determined:

- **Stage 1 (circa 1980):** Initially, impact assessment focused on environmental impact assessment (EIA), limiting its consideration to the potential impacts of proposed projects on important elements of the biophysical environment. EMPs were, therefore, similarly limited, dealing with the implementation of mitigation measures for biophysical impacts (on air, water, soil, wildlife) and with monitoring. This early type of EMP tended to focus on the direct impacts of projects and on the construction phase. In some jurisdictions EMPs remain limited to this scope.
- **Stage 2 (circa 1990):** Subsequently, social impact assessment (SIA) developed and evolved into a mainstream impact assessment topic, partly to cover the critical issue of involuntary resettlement. This resulted in the emergence of socially related plans such as Resettlement Action Plans (RAPs) and Indigenous Peoples' Development Plans (IPDPs) (international terminology as used in the Compendium). In accordance with this approach, large projects financed by multilateral funding agencies could be required to develop an EMP covering biophysical mitigation and monitoring and some social issues, a RAP covering compensation and resettlement, and a separate IPDP covering specific actions needed to support indigenous people.
- **Stage 3 (circa 1995):** The picture changed again because of (a) widespread recognition that separation of EIA and SIA denies the links between natural resources and rural livelihoods in many large dam projects, and (b) reconsideration of impact mitigation as a planning principle. Simple mitigation is now widely regarded as an inadequate approach to sustainability. It is being complemented or replaced by a proactive "development" type approach to maximise the developmental benefits of projects and to ensure equitable outcomes for all stakeholders and affected parties. Combined with the need to avoid further fragmentation of impact assessment reporting and simplify project management, this led to the development of integrated impact assessment procedures and the production of integrated environmental and social management plans - for example, the International Finance Corporation's Environmental and Social Action Plans (ESAPs).

  Under this approach, what was once a relatively straightforward biophysical EMP, became a much more complex product, potentially including substantive stand-alone sub-plans, such as Basin Management Plans, Integrated Water Resources Management Plans, RAPs, Community Development Plans, and Cultural Heritage Management Plans. In turn, these could include descriptions of further specialised programmes and plans, such as Environmental Flow Plans, Participation or Public Consultation and Disclosure Plans, Gender Action Plans, and Environmentally Friendly Procurement Plans. The World Commission on Dams' recommended Mitigation, Resettlement and Development Action Plans (MRDAPs) fall within this group; in this case, the plans emphasise formal obligations and entitlements of stakeholders in accordance with the 'rights and risks' approach.

- **Stage 4 (circa 2000):** An emerging theme is the integration of EMPs into quality assurance and quality control (QA/QC) systems; in particular, environmental management systems (EMS), based on the ISO 14000 series of international standards. Environmental management systems have evolved in parallel with EMPs over the last decade and now appear set to take over or absorb many of the functions of EMPs.

  The three major themes noted above - integrated impact assessment, EMPs and EMS - have been combined in the latest safeguards terminology from the World Bank Group: the IFC's new Performance Standard 1: Social and Environmental Assessment and Management Systems states[149]:

  > *Social and Environmental Management System: The client will establish and maintain a Social and Environmental Management System appropriate to the nature and scale of the project and commensurate with the level of social and environmental risks and impacts. The Management System will incorporate the following elements:*
  >
  > *i social and environmental assessment;*
  >
  > *ii management program;*
  >
  > *iii organizational capacity;*
  >
  > *iv training;*
  >
  > *v community engagement;*
  >
  > *vi monitoring; and*
  >
  > *vii reporting.*

  The Asian Development Bank's Environmental Safeguard Policy (June 2009) requires:

  > *"Avoid, and where avoidance is not possible, minimize, mitigate, and/or offset adverse impacts and enhance positive impacts by means of environmental planning and management. Prepare an **environmental management plan (EMP)** that includes the proposed mitigation measures, environmental monitoring and reporting requirements, related institutional or organizational arrangements, capacity development and training measures, implementation schedule, cost estimates, and performance indicators. Key considerations for EMP preparation include mitigation of potential adverse impacts to the level of no significant harm to third parties and the polluter pays principle."*

- **Stage 5 (current and future):** Further evolution of the project management process for water resources projects is likely to include "sustainability" as the overarching principle, with mechanisms including sustainability assessment. Useful approaches

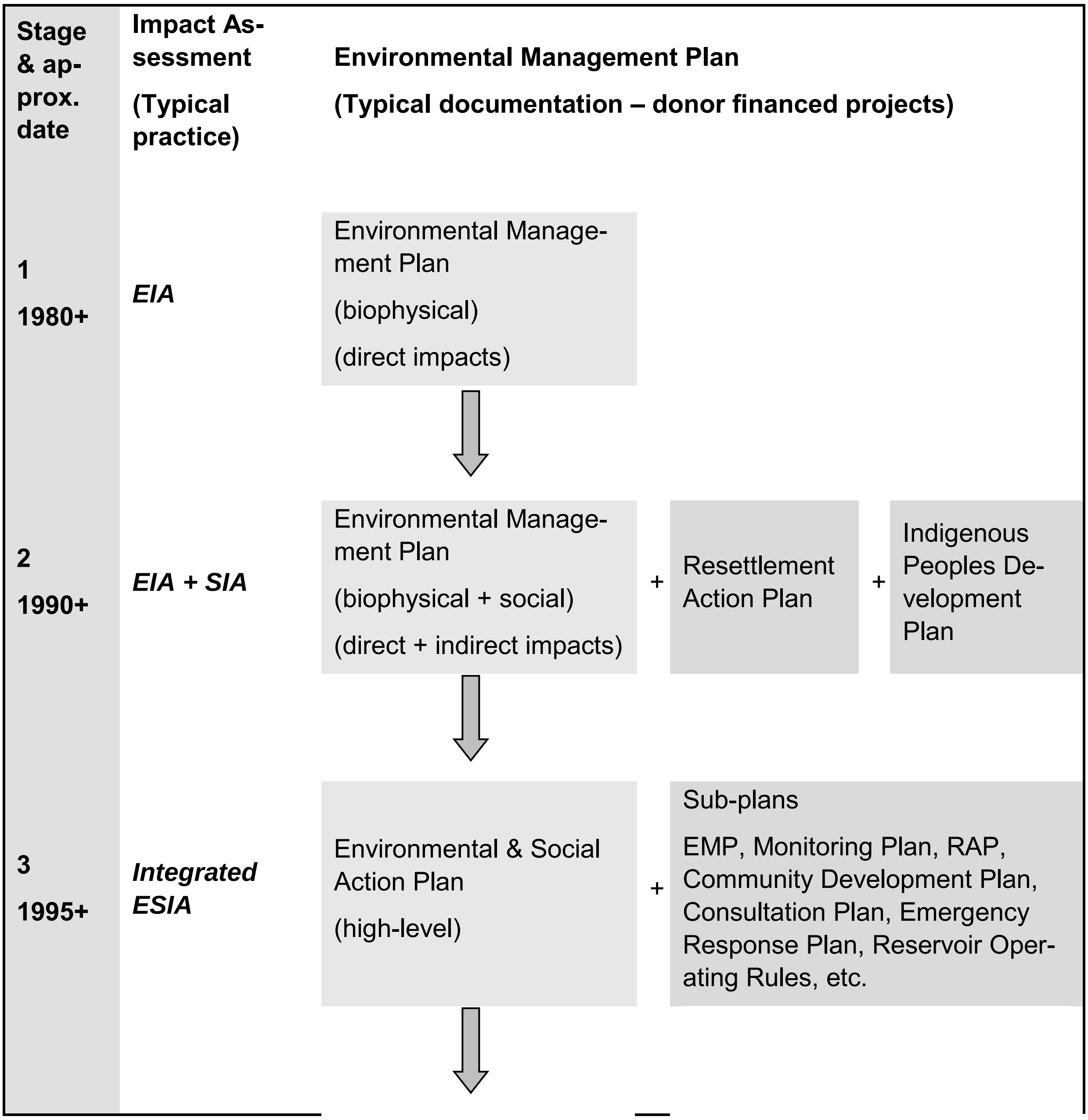
[149] http://www.ifc.org/ifcext/sustainability.nsf/Content/PerformanceStandards

and tools are given in the International Hydropower Association's 2010 Hydropower Sustainability Assessment Protocol.

The evolving scope of EMPs is shown in

Figure 9-1.

Figure 9-1: The Evolving Scope of Environmental Management Plans



4 **2000+**	***ESIA +*** ***EMS***	Action Plan (high-level) + Social & Environmental Management System (internal / operational)	+	Sub-plans Numerous plans for many topics at different administrative levels and project stages Plans designed to enable quality control throughout project cycle
5	***Future: Sustainability Assessment as framework?***			
Key	EIA : Environmental Impact Assessment EMP: Environmental Management Plan EMS: Environmental Management System			ESIA : Environmental & Social Impact Assessment RAP : Resettlement Action Plan SIA: Social Impact Assessment
Source: Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.				

9.1.4 EMP Guiding Principles

One description of the principles guiding EMPs is given in **Table 9-1**.

Table 9-1: EMP Principles

EMP Principles	
Principles of sustainable development	Sustainable development is the ultimate goal of an EMP.
	Incorporates the biophysical, social and economic dimensions of sustainable development.
Principles of professionalism, ethics and quality	Consistency with legal and planning context.
	Professional rigour.
	Clear and easily understood reporting.
	Professional capability commensurate with the complexity and scope of the EMP.

EMP Principles	
Principles specific to EMPS	Continuous improvement.
	Broad level of commitment from all involved
	Flexible and responsive, regular updating
	Integration across operations of role players.
Source: (Adapted from) Lochner, P. 2005. *Guideline for Environmental Management Plans*. CSIR Report No ENV-S-C 2005-053 H. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs & Development Planning, Cape Town.	

9.1.5 EMP Normative Frameworks

The main organisations with normative frameworks covering EMPs, directly or indirectly, are: states, the multilateral development and financing organisations, bilateral aid and export credit agencies, commercial banks, and a wide range of interest groups ranging from industry associations through to NGOs. In general, international organisations are in advance of national frameworks with respect to incorporating state of the art EMP concepts into policies, regulations and procedures (see **Table 9-2** for examples; see **Box 9-2** for Asian Development Bank position).

In most jurisdictions, EMPs are standard products of the impact assessment process, and, as such, are governed by EIA normative frameworks at both the international level and country level, as well as at the provincial or state level in federal countries. They may also be linked to Strategic Environmental Assessment (SEA)[150]. EMP requirements may be formulated in framework environmental protection laws, in specific impact assessment laws, in regulations, or in formal guidelines. In some cases, EMPs are specified, together with their contents and format; in other cases, EMPs are required only by implication or as a matter of best practice. EMPs are often tied in with land use planning and development control legislation. At lower levels of government local authorities may mandate EMPs as part of the development permitting process. Organisations that implement environmental management systems (EMS) may also require EMP-type documentation (e.g. an "environmental management programme" as specified in ISO 14001, 2004, clause 4.33).

Table 9-2: A Sample of Frameworks that Prescribe the Contents of an EMP or EMP-type Document

Institution	**Framework**

[150] SEA is an impact assessment approach that investigates the potential effects of policy, plans or programmes at sectoral, regional or national scale. It can assist with decision-making between alternative projects and designs.

Private sector banks and Export Credit Agencies	Equator Principles (July 2006 – EPIII was at an advanced stage of preparation at December 2012)
Asian Development Bank	Environmental Assessment Guidelines (2003)
African Development Bank	Environmental and Social Assessment Procedures for African Development Bank's Public Sector Operations (2001)
International Bank for Reconstruction and Development	Operational Policy and Bank Procedure 4.01 Environmental Assessment (1999)
	Guidance: Environmental Assessment Sourcebook (1991) and subsequent Updates, in particular No. 25 Environmental Management Plans (1999)
International Finance Corporation	Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts (2012) Guidance Note 1: Assessment and Management of Environmental and Social Risks and Impacts (2012)
Swedish International Development Agency	Guidelines for the Review of Environmental Impact Assessments (2002)
Canada	Canadian Environmental Assessment Act (2012)
Source (with updating): Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.	

Depending on one's perceptions, the leading edge of EMP practice could be regarded as somewhere between the WCD's Mitigation, Resettlement and Development Action Plans and the International Finance Corporation's (IFC) new Social and Environmental Assessment and Management Systems. This spectrum is reflected in the private finance sector, where many commercial banks voluntarily subscribe to the Equator Principles[151], which are based on the IFC's approach. At least one of the major commercial banks (HSBC) has committed to following the WCD framework for decision-making.

Box 9-2: ADB Safeguard Policy on EMPs

"The borrower/client will prepare an environmental management plan (EMP) that addresses the potential impacts and risks identified by the environmental assessment. The EMP will include the proposed mitigation measures, environmental monitoring and reporting requirements, emergency response procedures, related institutional or organizational arrangements, capacity development and training measures, implementation schedule, cost estimates, and performance indicators. Where impacts and risks cannot be avoided or prevented, mitigation measures and actions will be identified so that the project is designed, constructed, and operated in compliance with applicable

[151] http://www.equator-principles.com/index.shtml

laws and regulations and meets the requirements specified in this document. The level of detail and complexity of the environmental planning documents and the priority of the identified measures and actions will be commensurate with the project's impacts and risks. Key considerations include mitigation of potential adverse impacts to the level of "no significant harm to third parties", the polluter pays principle, the precautionary approach, and adaptive management."
Source: Asian Development Bank. 2009. *Safeguard Policy Statement*

Where a project is transboundary in nature, the normative framework is more complex. Each country will have its own normative framework for environment and water management. Generally there will be a tendency to resort to the most demanding elements from each of the involved states, international financiers and international best practice. In this compounded raising of standards, there is minimal opportunity for realistic cost tradeoffs.

9.1.6 Example of EMP Glossary

Glossary

Approved Professional Person

Also referred to as the project manager.

Auditing

A systematic, documented, periodic and objective evaluation of how well the environmental management plan is performing, with the aim of helping safeguard the environment, by facilitating management control; this would include meeting regulatory requirements.

Authority

National, regional or local authority that has a decision-making role or interest in the development.

Compensation

Trade-offs between different parties affected by the proposed development to the mutual satisfaction of all concerned parties.

Contractor

Individual and/or company responsible for the construction activities, the related activities and the implementation of the environmental management plan. In the case where DWAF is the Contractor, the Resident Engineer will be addressed as the Contractor. Otherwise, the Contractor is a private contractor qualified to Tender for DWAF projects.

Contractor's representative

Person on the site representing the Contractor who is knowledgeable in environmental issues and is responsible for the implementation of the findings of the environmental plan. May be a representative for the natural environment and one for the social environment.

Corrective (or remedial) action

Reactive response required to address an environmental problem that is in conflict with the require-

Glossary

ments of the EMP. The need for corrective action may be determined through monitoring, audits or management review.

Cumulative impact

An action that, in itself, is not significant—but is significant when added to the impact of other activities in the area.

Environment

According to the South African National Environment Management Act, the environment is the surroundings within which humans exist, being made up of:

- the land, water and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any plant or combination of i) and ii) and the interrelationships among and between them; and
- the physical, chemical, aesthetic and cultural properties and conditions of the above that influence human health and well-being.

However, for the purposes of this document, the environment includes both the biophysical, as well as the social and economic, aspects of the area.

Environmental Management Plan Audit (EMP Audit)

A systematic, documented, and objective evaluation of the environmental performance of a project, by obtaining and analysing evidence to determine whether the implementation of the EMP conforms to its requirements.

Environmental Impact

Change in an environment resulting from the effect of an activity on the environment, whether positive or negative. Impacts may be the direct consequence of an individual's or organisation's activities or may be indirectly caused by them.

Environmental Impact Assessment (EIA)

The process of examining the environmental effect of development. It is the process of assessing and incorporating potentially significant environmental impacts into the planning, design, approval and implementation of a project.

Environmental Management System (EMS)

That part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, maintaining and reviewing an environmental policy.

Environmental Objective

Overall environmental goal as stated in the EMP.

Environmental Policy

Statement of intent and principles in relation to overall environmental performance, providing a framework for the setting of objectives and targets.

Glossary

Environmental Risk

The probability of a prescribed undesirable effect. Risks result from the existence of a hazard and uncertainty about its expression.

Environmental Target

Detailed requirement against which performance may be assessed, quantified where practicable, arising from an environmental objective and that needs to be met in order to achieve the associated objective. A target against which performance can be assessed.

Interested and Affected Party (I&AP)

Individuals or groups concerned with, or affected by, an activity and its consequences. These include the authorities, local communities, investors, work force, customers and consumers, environmental interest groups and the general public.

Mitigation

Measures designed to avoid, reduce, or remedy adverse impacts.

Monitoring

The repetitive and continued observation, measurement and evaluation of environmental criteria to follow changes over a period of time and to assess the efficiency of control measures.

Pollution

The residue of human activity that adversely affects the next user or environmental resource.

Preventative Action

A predetermined action to address potential problems before they develop into situations that would be contrary to the requirements of the EMP. Preventative action is most often determined from the results of monitoring and audits during management review.

Project Appraisal

The collection and evaluation of detailed information concerning a proposed project, usually to assess risk associated with it.

Project manager

Department of Water Affairs and Forestry representative charged with coordinating and managing the various stages of a project.

Significant impact

An impact that has crossed the threshold of significance.

Site-specific investigation

An assessment or evaluation of the impact of the proposed development on the immediate environment.

Source: South African Department of Water Affairs and Forestry. Guidelines for Standardised Environmental Management Plans. 2002. http://www.dwaf.gov.za/Docs/Other/Environment/EMPGuide2May.pdf)

TRAINING AIDS	
Discussion topics	1) Should public sector and private sector projects follow the same rules with respect to environmental permitting and environmental documentation? 2) Some financial institutions do not apply internationally recognised safeguards to project design or implementation. How can the rights of affected people and important environmental values be protected under these circumstances? Can the group speculate as to why such institutions do not adopt, for example, the Equator Principles? 3) Are EMPs an institutionally or culturally appropriate format for embedding safeguards? If not, what else might be proposed?
Exercises	1) Draw a time line of the most important international events in the development of EMPs. Add those of your country. 2) Make a list of environmental laws and regulations in your country. Do any of these laws or regulations call for EMPs, either explicitly or implicitly?
Additional reading and resources	1) WCD (2000): Dams and Development: A New Framework for Decision Making - Chapter 3 Ecosystems and Large Dams: Environmental Performance 2) Equator Principles. www.equator-principles.com (look out for EPIII due in 2013; see http://www.equator-principles.com/index.php/ep3)

9.2 EMPs and Project Management

Key aspects	• EMPs are normally prepared as a product of the environmental and social impact assessment process. • Preparation, approval and implementation of an EMP align with the project cycle. • The project proponent or developer is normally responsible for preparation of the EMP. • Responsibility for implementation of an EMP will be described in the EMP. • EMP costs vary greatly, reflecting their widely varying scale, scope, and complexity. • The DDP identified core elements of leading edge EMPs; these form the main content of this Module.

TRAINING AIDS	
Purpose of session	The purpose of this session is to place the EMP within the overall implementation process of a project.
Learning objectives	• To be able to describe the constituent elements of the project cycle. • To be able to describe how an EMP fits into the overall project cycle
Key readings	1) DDP Compendium, Chapter 6: *Environmental Management Plans*.

9.2.1 EMPs in the Project Cycle

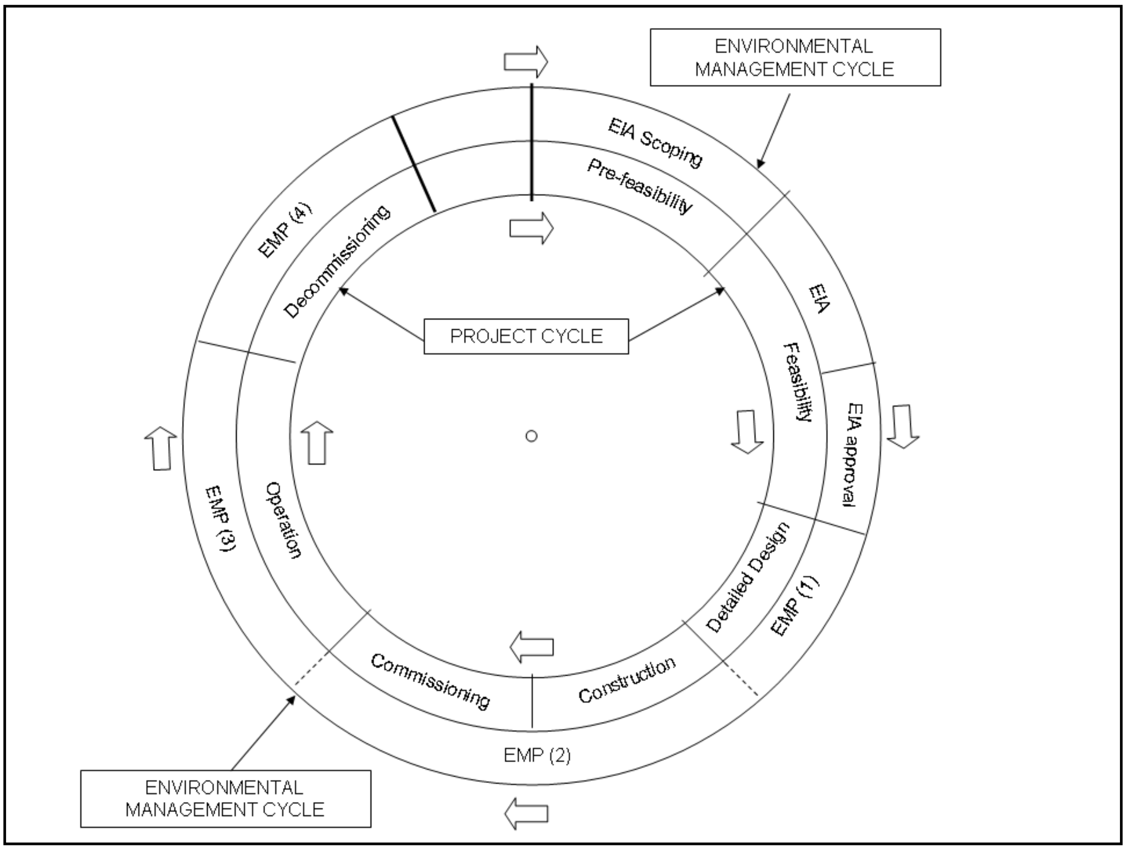
The development and implementation of a major water resources project occurs in a number of iterative steps involving a large number of data-gathering, analytical, administrative and decision-making steps. The five main stages, which may overlap, are:

- Planning (project concept, pre-feasibility study, feasibility study—including feasibility-level design and environmental and social assessment—approval, financing);
- Design (tender design and documentation, tendering and contract documentation, preconstruction activities including land acquisition and resettlement);
- Construction (construction, commissioning);
- Operation (operation and maintenance); and

- Decommissioning (a major stage in the project cycle, but which is, at present, seldom considered during the planning stage of large dam projects).

Figure 9-2 illustrates the relationship between the project cycle and the environmental management cycle. Note that the environmental management cycle is far less precise than the project management cycle, and planning for potential inconsistencies is essential.

Figure 9-2: The Project Cycle and Environmental Management



Source: Brian Hollingworth

The EMP can be conceived in four phases, the nature of which varies with the project cycle:

- During **design** the EMP provides guidelines that ensure the design will allow the final structure to meet the environmental requirements (e.g. the size of river outlets to pass environmental flow requirements).
- During **construction** the EMP is focused on the potential impacts of the construction methods and of the temporary works (e.g. the river diversion and therefore includes emergency plans).
- During **operation**, the EMP must, for example, guide river releases and the associated monitoring protocol.
- **Decommissioning** may be mentioned in the EMP required for project approval, but by the time decommissioning is actually needed, an entirely new EIA and EMP will be required.

9.2.2 Preparation of EMPs

EMPs are normally prepared as a product of the environmental impact assessment (EIA) process (which itself should be informed by strategic environmental assessment (SEA) (Table 8-5)) during project planning, and then continue to evolve in scope and depth with subsequent stages of project preparation and implementation. The assessment process starts with a scoping phase, which determines the nature and extent of the assessment proper. (We assume that in all jurisdictions, all large water projects will require a full EIA). The EIA report (or environmental impact statement (EIS)) is generally prepared at the feasibility study stage in the project cycle, but this varies by jurisdiction. Some jurisdictions require an outline EMP to be submitted with the EIA report. This is submitted to the environmental regulator with an application for permission to proceed with the project.

The normative frameworks of most international funding agencies require full environmental management plans as a product of the environmental impact assessment process. In the consultant's experience, this seldom occurs, due to resource constraints. The resulting environmental management plans are, in effect, outlines, requiring considerable further development in subsequent project planning stages[152].

Use of the terms "record of decision", "permit", "approval" and other, similar phrases depend on the jurisdiction; however, they have in common that they are issued by an agency independent of the project proponent (except where line ministries approve their own projects)—and are conditional.

The project developer is normally responsible for preparation of the EMP; this is achieved by appointing planning and design consultants. In the traditional approach, environmental specialists on the consultancy consortium preparing the project will undertake the EIA and write the EMP; however, with the increasing popularity of contracting design-and-construct and concessions forms, particular attention should be paid to the contractual arrangements.

As with other aspects of project planning and impact assessment, good practice (and in some instances, national legislation) requires the effective participation of stakeholders in EMP development. This is particularly important where projects are large, complex, and risky, and have significant social and environmental implications. Trainers interested in this topic are referred to the Training Manual on *Dealing with Social Aspects*.

EMPs are generally incorporated into environmental permitting conditions and project financing agreements. Their use as regulatory and contractual documents increases the requirement that they are written clearly and with great attention to accuracy, detail and wording.

9.2.3 Core Elements of EMPs

The trend in EMPs is to produce a number of sub-plans or document types that address specific aspects of a project's overall environmental and social management requirements. There is no standard format for these new types of plans, since the contents and level of detail need to fit the specific circumstances of the project. As EMPs evolve into environmental and social management programmes (ESMPs), which may include multiple policies, pro-

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[152] UNEP- DDP. 2007. *A Compendium of Relevant Practices for Improved Decision-Making on Dams and their Alternatives* p99

cedures, practices, management plans and actions; the nature and content of the documentation required will continue to change.

A key criterion for good EMP documentation is that it is easy to use and clearly integrated with other project documents—including, for example, the engineering specifications and construction contracts. Too often, provisions in different documents are inconsistent.

Notwithstanding the current dynamic nature of the form of EMPs, the following are the core elements of leading edge EMPs for large water infrastructure projects, as identified in the 2007 DDP Compendium:

- Mitigation measures;
- Environmental flows;
- Catchment or basin management;
- Conservation offsets or mitigation measures, typically by creating protected areas (PAs) or improving their management and conservation effectiveness;
- Social issues, including health, resettlement and community development;
- Public involvement;
- Institutional arrangements, including responsibilities, capacity issues, timing, costs, and new initiatives, such as payment by utilities for ecosystem services;
- Environmental management systems;
- Monitoring and auditing;
- Decommissioning

The social issues and public involvement are dealt with in the Training Manual on *Dealing with Social Aspects.* The remaining core elements are elaborated in this and other modules of this training manual.

9.2.4 Implementation of EMPs

The use of EMPs and their derivatives varies. Typically they are implemented during both project construction and operation, but they may also be used during detailed design (to adjust the design and tender documents), tendering (to ensure that the selected contractor is socially and environmentally competent), pre-construction (for example, to ensure that adequate pre-project baseline surveys are carried out or that land acquisition is implemented fairly), and decommissioning.

Responsibility for the implementation of the EMP will be described in the EMP document itself. Overall responsibility rests with the project proponent (owner/operator), who will have legal responsibilities for performance under domestic legislation and likely additional contractual duties, with respect to the project financing agencies (and, increasingly, with affected people). Typically, large, complex projects necessitate a specialised unit to manage social and environmental issues. The establishment of the capacity within the authority, the implementing agency, on the construction site, and within the stakeholder group, will normally be one of the first actions in the EMP—and should be well-advanced, if not completed, before site establishment commences.

Responsibility for physical implementation of the various measures described in the EMP will vary according to the type and timing of the measure. Institutional roles in the EMP change during the project cycle. For example, civil works contractors are often required to prepare and implement comprehensive environmental management plans during construction; utility operators must develop and implement detailed operating rules for reservoirs; line agencies may undertake statutory monitoring activities; local governments will implement land use and zoning plans; and local and international NGOs may partner with the proponent to assist in, for example, biodiversity conservation and community development in upper watersheds.

A key process during EMP implementation is monitoring and evaluation (M&E)—checking that the measures described in the EMP are being undertaken in the right place, at the right time, to the right standard, and, importantly, that the measures are effective. In addition, the M&E system should be alert to the unexpected issues and impacts that invariably arise during project implementation.

The general process of management is described in **Box 9-3**.

Box 9-3: The Management Process

The Management Process

In the context of accepted international frameworks for quality and environmental management systems, the management process can be summarised as follows:

- Identification and review of the social and environmental impacts and risks of the operation.
- Definition of a set of policies and objectives for social and environmental performance.
- Establishment of a management programme to achieve these objectives, including capacity development.
- Monitoring performance against these policies and objectives.
- Reporting of the results appropriately.
- Review of the system and outcomes; striving for continuous improvement.

A good management system enables continuous improvement of the project's social and environmental performance, and can lead to improved economic, financial, social and environmental project outcomes.

9.2.5 EMP Authorisation

In all jurisdictions an EMP requires approval by the environmental authority or **'regulator'**. In some countries this may be part of the EIA approval in a one-step process, but in the majority the EIA approval sets out the requirements for subsequent preparation and approval of the EMP. The former procedure has the advantage that, in approving the EIA, the authority simultaneously approves precisely how environmental management will be applied to the project. The latter procedure has the advantage of establishing the principles but delaying the detail until the detailed design has been prepared. Another variation is that a draft EMP is required to be submitted with the EIA—and refined—after provisional approval.

In the case of De Hoop Dam, South Africa, the EIA Record of Decision (RoD) contained a number of conditions, including the requirement that a suite of EMPs would have to be approved before the commencement of any of the activities related to the EIA authorisation[153]. This suite included EMPs for several items of ancillary infrastructure, such as the realignment of roads and pipelines that would convey water to the demand areas. Moreover, EMPs were required for each of the phases:

- Pre-construction
- Construction
- Post construction
- Operational

In addition the RoD required the EMPs to include, but not necessarily be limited to, the aspects listed in **Box 9-4**.

Box 9-4: De Hoop Dam: Record of Decision - Aspects to be Included in EMPs

a) Mitigation measures recommended in the Environmental Impact Report.
b) Rehabilitation of areas to be disturbed during the construction of the project.
c) Siting and management of construction camps outside urban areas.
d) Access roads to individual construction areas.
e) Rare plant search and rescue before the commencement of any construction activity,
f) Implementation of measures aimed at controlling invasive plant species and weeds. The route alignment and construction sites must be monitored for re-growth of invasive vegetative material at least twice a year for a period of up to two years after the completion of this development.
g) Protection of the heritage sites likely to be impacted by the construction of the dam and pipelines.
h) Waste avoidance and minimisation during construction.
i) Management of traffic during the construction of the dam and the pipelines (where the pipelines cross roads or other transportation networks).
j) The planning and implementation of a water conservation and demand management strategy for the Olifants Water Management Area in parallel with the construction of infrastructure (i.e. approximately 10 years).

Source: Ministry of Environmental Affairs and Tourism (South Africa) *Revised Record of Decision: De Hoop Dam*

[153] Ministry of Environmental Affairs and Tourism (South Africa). 2006. Revised Record of Decision: De Hoop Dam. Downloaded on 06 January, 2013 from http://www.dwaf.gov.za/Projects/Olifant/documents/pdf/RevisedROD16Oct06.pdf

The RoD also required **actions** that would ensure the implementation of the required environmental measures (**Box 9-5**).

Box 9-5: De Hoop Dam: Record of Decision - Actions to be Taken to Ensure Implementation

Actions to be Taken to Ensure Implementation of Mitigation Measures

- Compliance with the approved EMPs must form part of the project documentation of all contractors working on the project, and must be clearly indicated in all contractor's contracts.
- A copy of the authorisation and RoD must be available on site during construction and all staff, contractors and sub-contractors must be familiar with or be made aware of the contents of the authorisation and RoD.
- The applicant must notify the Authority if any condition of the authorisation cannot be, or is not, adhered to. The notification must be supplemented with reasons for non-compliance.
- Non-compliance could lead to withdrawal of the authorisation, the imposition of penalties or criminal action against functionaries.
- Compliance/non-compliance records must be kept and must be made available on request
- An Environmental Monitoring Committee (EMC) must be established with the following members:
    - An independent chairperson who has appropriate people and project management skills;
    - The developer's representatives;
    - Representatives of the affected residents / rate payers' association;
    - Ward councillors;
    - Non-Governmental Organisations;
    - Community leaders;
    - Representatives of Farmers Associations; and
    - An aquatic and terrestrial ecologist/s.
- An Independent Environmental Control Officer must be appointed to assist the EMC.
- The purpose of the EMC is to:
    - To monitor and audit project compliance to the specific conditions of the record of decision, environmental legislation and specific measures as stipulated in the environmental impact report and the environmental management plans.
    - To make recommendations to the Director General of the Authority on issues related to the environmental monitoring and auditing of the project.
- An Authorities Co-ordinating Committee with representatives from all relevant departments of state must be established to oversee that all commitments in the record of decision (RoD) and the environmental management plan (EMP) are met.
- Relocation of burial sites in terms of legislation and the wishes of the next of kin and descendants.

TRAINING AIDS	
Discussion topics	1) Discuss why EMP formulation is an iterative process during project planning, i.e. it takes place in steps of increasing detail and complexity, rather than all at one stage. 2) Have EMPs become an end in themselves to which developers often pay lip service but never really internalise? 3) Can EMPs become mechanisms for national oversight bodies to extort fines from developers? If so, what could be done to prevent this?
Exercises	• Draw a project preparation flow chart for your country. When is the EMP prepared? Is this the best time?
Additional reading and resources	1) WCD Report Chapter 9 Pages 261 - 275 “The five stages”.

Case Studies

See the DDP Compendium: *Berg Water Project Case Study*, para 14, p 62-63, noting the several project cycle phases over which the EMP extended.

9.3 The Environmental Management Plan

Key aspects	• The EMP is a comprehensive operational plan that assigns responsibilities directly to functionaries; • The EMP extents over the area impacted by the project, which may be the whole river basin; • The EMP derives from and gives effect to the EIA and the environmental authorisation; • The structure and content of an EMP depends on the nature of the project and the applicable legislative framework but international practice provides guidelines • The EMP and all the mitigation measures are financed from project funds.

TRAINING AIDS	
Purpose of session	The purpose of this session is to describe an environmental management plan.
Learning objectives	• To understand the range of topics that should be included in an EMP.
Key readings	1) Chapter 6 of the DDP Compendium.

9.3.1 Scope and Contents of EMPs

One common framework that has been proposed for the contents of an EMP is as follows[154]:

- Summary of potential impacts
- Planned mitigation measures
- Monitoring programmes and parameters
- Public participation
- Mechanism for feedback and adjustment
- Institutional arrangements for mitigation and monitoring
- Measures for capacity building
- Responsibilities for reporting and review

[154] Multilateral Financial Institutions Working Group on Environment. 2005. *A common framework for environmental assessment: A good practice note*.

- Implementation schedule and work plan
- Cost estimates
- Environmentally responsible procurement

Issues typically addressed in an EMP are listed in **Box 9-6**.

Box 9-6: Issues Typically Addressed in Traditional Environmental Management Plans

- Impact summary, from the environmental impact assessment report;
- Description of mitigation measures, linked to each corresponding impact and required conditions; and reference to technical details, such as methods, equipment and operating procedures;
- Public participation, including access to information and disclosure of project documentation;
- Institutional arrangements and responsibilities for implementation of each measure, including monitoring and supervision, the legal framework and capacity-building required for effective environmental management plan implementation;
- Monitoring programme;
- Reporting procedures, including mechanisms for evaluation and feedback;
- Timing of implementation schedule; and
- Costs, including sources of funds.

DDP Compendium, p 94

A compilation for the case studies and references used as sources for this manual suggests the contents of EMPs could generally be as shown in **Table 9-3**.

Table 9-3: Typical Outline Contents of EMP

Outline Content

An EMP will generally contain:

- A project description;
- The philosophy and policy of the proponent, implementing agent, government and financial institutions;
- The legislative framework;
- The outcomes of the EIA process;
- The mitigation measures;
- The conditions of the record of decision (environmental authorisation, licence);
- The higher level institutional arrangements assigning responsibility for implementation and

setting up reporting responsibilities;
- Capacity building within all role players;
- With respect to each mitigation measure, the details of assignment of responsibilities to operational staff - the who, what, how and when;
- The monitoring and evaluation programme;
- A public participation strategy, incorporating communication and outreach; and
- The financial plan for the EMP.

Spatial Extent

Large hydro projects inevitably affect a far wider area than the immediate construction site. This may result from a number of causes, including:

- Cumulative impacts from a number of projects.
- Changed hydrological regime downstream of a dam.
- A need to protect the catchment area above the dam.
- Water quality changes.
- The outcomes of strategic environmental assessment (SEA).
- Compliance with legislation and policy.

Timing

The EMP changes with the phase of the project, for example:

- During detailed design, specifications of environmental flow releases are required to size the outlet works.
- Before construction, the focus is on the relocation of people affected by the construction; and later, those affected by inundation.
- During construction environmental and social site management may come to the forefront. Aspects of this include oil pollution from machinery, noise and dust, health and safety, and worker welfare.
- During commissioning, riverine dwellers must be warned of any unexpected river surges caused by testing.
- During operation the management of releases may become the focus.

Compliance

An EMP contains clear commitments, framed to enable assessment of the extent to which these commitments have been met. The commitments should be auditable. Measurable performance criteria for all elements are determined in the process of formulating an acceptable EMP. Compliance is achieved in several ways, normally specified in the EMP's compliance plan (see Session 10.2):

- The environmental regulator enforces compliance on the proponent through legislation and the licensing process;
- The financial institution enforces compliance on the proponent through conditional terms in the financing agreement; while
- The proponent in turn enforces compliance on the contractor through contractual arrangements.

Like EIAs, EMPs are driven by international, national, regional and local policies and regulations relating to environment and development. For example, EMPs must be informed by international conventions, such as the Convention on Biodiversity. At the national level the legislation may contain guiding principles for all aspects of environmental management; at local level, there may be policies related to hazardous construction materials. In addition, the overall approach may be driven by considerations such as benefit-sharing, community or regional development, or "no net loss" of habitat.

Australian guidance recommends that EMPs should have the following attributes (**Box 9-7**).[155]

Box 9-7: Desirable Attributes of EMPs

Desirable Attributes of EMPs

- Integration of the various regulations pursuant to a development approval in an ordered, flexible and integrated format that is auditable by the proponent and administering agency;
- Integration of the terms of operational approvals, such as licences, with the provisions of planning and land use development approvals;
- Translation of the studies and scientific reports from the Environmental Impact Statement (EIS) into achievable (viable and affordable) management strategies;
- Facilitation of developer planning for protection of the environment; and
- Consistency with, and forming part of, a company's EMS (term used by International and British Standards: ISO 14001 and BS 7750) or Integrated Environmental Management System (term used in the Queensland Environmental Protection Act) or Quality Assurance system (business term).

Source: Queensland Government (Australia): Guideline: Preparing environmental management plans. http://www.ehp.qld.gov.au/register/p00706aa.pdf

9.3.2 Costs

EMPs often involve considerable costs. These are of two types: (i) the costs of the mitigation measures, and (ii) the cost of administering the environmental management programme.

EMP implementation proceeds most smoothly when all costs have been identified in advance and are fully budgeted. An adequate contingency must be included for inevitable, un-

[155] Queensland Government (Australia). *Guideline: Preparing environmental management plans*.

foreseen tasks. Inadequate funding for EMP preparation invariably results in inadequate funding for plan implementation, with unwelcome cost and budgetary surprises.

The cost of each measure must be estimated and included in the overall plan budget, together with the source of financing.

9.3.3 The Structure of EMPs

An effective EMP should be structured to address all agreed environmental and social management tasks for the life of the project. Typical issues in a “traditional” EMP are listed in Box 9-6. Note that these issues are now incorporated in more detailed and complex plan formats, as described in

Figure 9-1.

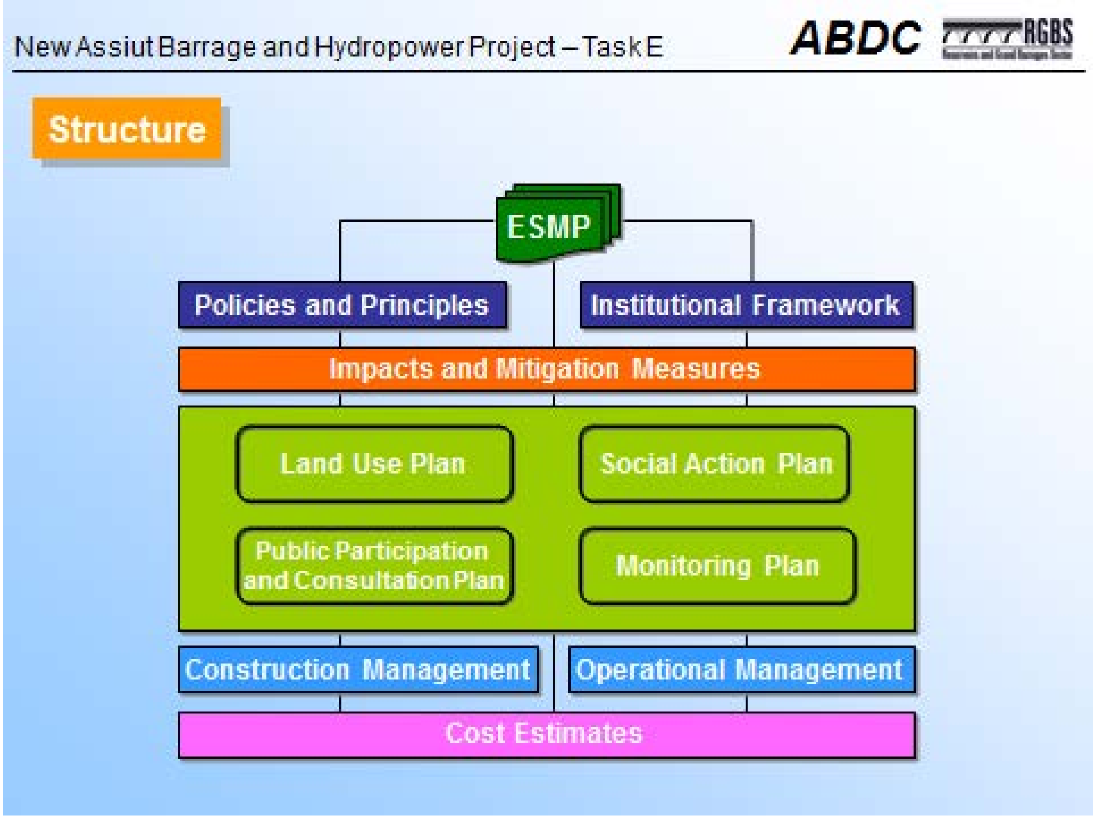
An EMP may be made up of several documents and programmes. As an example,

Figure 9-3 shows the structure of the Environmental and Social management Plan ESMP) currently being implemented for the **New Assiut Barrage and Hydropower Plant Project** in Egypt.

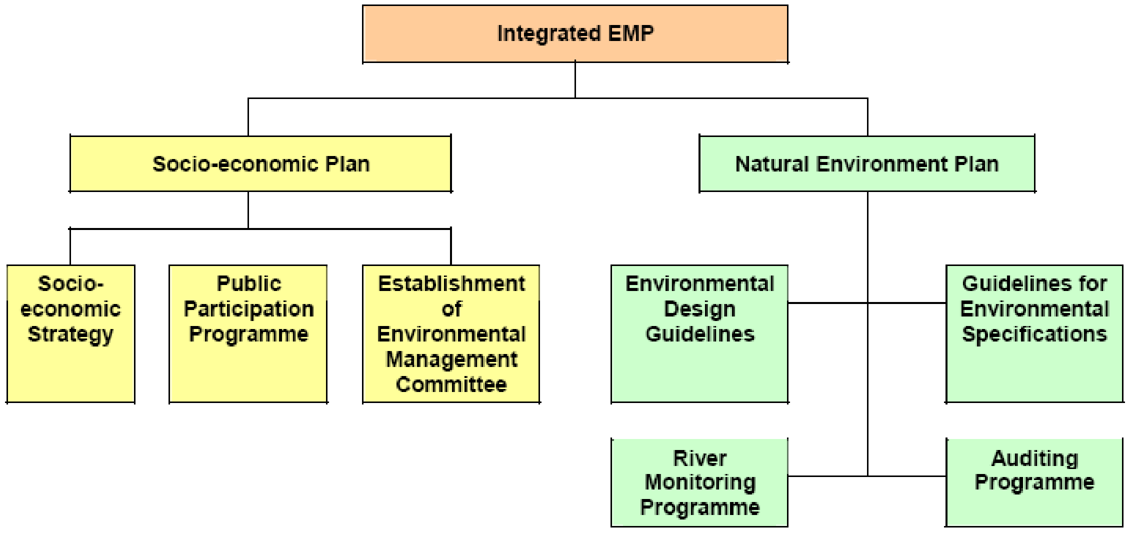
Another example is the **Berg Water Project (BWP)** in South Africa, one of the case studies prepared as part of the preparatory report for the DDP Compendium. The main components of the BWP EMP are shown in

Box 9-8. Public participation and the Environmental Management Committee (EMC) were the mechanisms for monitoring and auditing.

Figure 9-3: Structure of ESMP for New Assiut Barrage and Hydropower Plant Project, Egypt



Box 9-8: Main Components of Integrated EMP, Berg Water Project, South Africa



Source: James Ramsay. 2006. *Key Issue Report for DDP - Environmental Management Plans,* p56, from BWP documentation.

For the Berg project:

- The **Environmental Management Committee** was a requirement in the environmental approval (in the event, it operated as an Environmental Monitoring Committee).
- The **Socio-Economic Strategy** presented proposals for a holistic approach to compensate and mitigate for the identified social issues. This included both the curtailment and minimisation of negative impacts, and enhancement and maximisation of social benefits, arising from the implementation process. The strategy incorporated a Public Participation Programme, developed to ensure continued and meaningful involvement of stakeholders.
- The **Environmental Design Guidelines** detailed the issues that had to be incorporated into every aspect of the project's design. This included compliance with all requirements and standards. The expressed policy, however, went beyond this—and is to achieve the highest possible environmental standards.
- The **Guidelines for Environmental Specifications** were a strategic framework containing the issues that were subsequently incorporated - as detailed specifications - into the construction contracts.
- The **River Monitoring Programme** made provision for continuous monitoring and evaluation of environmental data to track changes and assess the performance and effectiveness of the mitigation measures. It included the whole Berg River catchment.
- The **Auditing Programme** provided for regular, objective, systematic and documented evaluation of performance against the EMP.

Another approach was followed on the **Mooi-Mgeni Transfer Scheme**, also in South Africa. In this case the EMP was divided into 17 sections as shown in **Table 9-4**. These sections are illustrative, and will differ for other projects.

Table 9-4: Sample EMP Structure and Contents

Section	Title	Explanation
A	*Environmental Management Framework (EMF)*	This section sets out the overall strategy for environmental management on the project. It includes the TCTA Environmental Policy, legal requirements, a project description, summary of key issues identified, and mitigation measures recommended in the EIA. The format of the EMP, including targets, objectives, specifications and method statements is described. Responsibilities for management and mitigation measures are assigned.
B	*Environmental Design Criteria*	This section provides the specifics that need to be addressed during the design of the project to ensure that the environmental standards, where they are necessary, can be met.
C	*Socio-economic Plan*	This section outlines the objectives and targets for each social and economic aspect that could be impacted upon during construction.
D	*Construction of the Spring Grove Dam Wall*	This section provides the specifications for the construction of the dam wall, Eskom power switchyard, and the pump station.
E	*Preparation of the Impoundment*	This section focuses on the preparation of the dam basin before the first filling of the dam.
F	*Construction of the Pipeline from the Spring Grove Dam to the Mpofana River*	The environmental management specifications required for the construction of the transfer pipeline and break pressure pump are contained in this section.
G	*Re-alignment of Landowner's Access Roads*	This section includes specifications for the construction of the realigned access roads of affected landowner's.
H	*Construction of weirs*	This section applies to the construction of any weir, required as part of the project. It includes any flow gauging weir as well as the fish barrier weir.

Section	Title	Explanation
I	*Mpofana River Outfall Works*	The new outfall works that will be constructed next to the existing one in Mpofana River will be constructed in accordance with the specifications stated in this section.
J	*Relocation of Services*	Relocation of services (e.g. sewage systems and power lines) that will be inundated, is covered in this section.
K	*Rescue and Re-location Plan*	The Rescue and Relocation Plan (RRP) specifies the rescue and/or relocating of plants, animals, heritage resources and graves.
L	*The Quarry Site*	A quarry north of the dam wall will be utilised to source some of the material for construction. The Environmental Management Programme prepared for the Department of Mineral Resources (DMR) is in this section.
M	*Wetlands Off-site Mitigation Plan*	This section outlines measures that must be followed to mitigate the loss of wetland habitat and functions in the Mooi River Catchment.
N	*Relocation Action Plan (Executive Summary)*	A Relocation Action Plan (RAP) was compiled in order to guide compensation and relocation of affected landowners and communities. The Executive Summary of the RAP is presented in this section.
O	*Checking and Corrective Action*	This section focuses on the on-going monitoring of the project activities and the implementation of the relevant corrective action.
P	*Receiving Streams*	This section will be based on the MMTS Phase 1 receiving streams EMP.
Q	*Operational Management Plan*	This section was added later.
R	*Biodiversity*	A detailed plan for action to establish offset areas to compensate for loss of biodiversity and habitat and for the management of such areas was to be compiled as a separate document.
Source: TCTA (South Africa) 2009. *Environmental Management Plan for the Mooi-Mgeni Transfer Scheme: Phase 2*. Downloaded from http://www.springgrovedam.co.za/emp.html on 09 Jan 2013.		

As an example of additional detail, the section of the EMP for D: Construction of Spring Grove Dam Wall, dealing with the construction process, had operational constituent management elements or sub-plans as follows (the list would be different for any other project):

- Construction camp
- Air quality
- Hazardous substance
- Spill contingency
- Fire risk
- Noise
- Water
- Waste
- Traffic
- Community engagement
- Heritage
- Terrestrial ecosystems
- Social strategy (Social monitoring, Public participation, Compensation and Mitigation, Employment, Procurement (local), Education, Health, Safety and Security, Exit strategy for vacating the construction site.)

9.3.4 Mitigation Measures in EMPs

EMPs normally include descriptions of each approved mitigation measure, together with (i) a description of its corresponding impact, (ii) the conditions under which it is required, and (iii) the details (or a reference to where the details will be documented) of how, when, and by whom the measure will be implemented (including equipment and procedures used). Cost estimates and budgets for mitigation must be included in the EMP or at least clearly referenced elsewhere in the project documentation.

For the Salto Caxias Hydroelectric Power Plant project, some 26 separate programmes for mitigating the project's social and environmental effects were implemented (**Box 9-9**).

In Swaziland, national environmental legislation requires a comprehensive mitigation plan (CMP, a form of EMP) to be submitted to the environmental authority for approval—simultaneous with the EIA. An extract of the Maguga Dam CMP, related to graves, is presented in **Box 9-10**.

Box 9-9: Case Study on Mitigation: Salto Caxias Hydroelectric Power Plant, Brazil

Salto Caxias Hydroelectric Power Plant: Mitigation Measures
Environmental
• Plan for conservation and protection of natural ecosystems. • Programme for the implementation of a Conservation Unit. • Programme for scientific research on flora.

• Programme for scientific research on fauna. • Programme for recovery of degraded areas. • Programme for landslide evaluation and control. • Programme for cleaning of the area to be flooded. • Construction of a sluice gate to maintain a minimum flow downstream during the filling of the reservoir
Social
• Programme for social communication. • Programme for support to the affected municipalities. • Programme for upgrading the community infrastructure of the affected municipalities. • Programme for public health. • Programme for rescue of archaeological sites. • Programme for indemnification of properties. • Programme for reorganisation of the remaining areas. • Programme for reconstruction of affected community infrastructure. • Programme of support to the rural areas of the affected municipalities. • Programme for settlement of the attracted population (incomers). • Programme for multiple uses for the reservoir.
Owner's Commitments
• To build two routes for access to the site, one on each side of the river. • To implement a Conservation Unit in the region. • To elaborate and implement the master plan for the reservoir and surrounding areas respecting 100 m as protection belt for the lake. • To perform cleaning of the reservoir basin (mainly cutting all trees) to maintain good water quality. • To install a meteorological station to monitor microclimatic changes. • To acquire the native forest remaining around the new reservoir. • To resettle the affected population and implement a socio-economic development plan. • To indemnify (pay compensation for) all properties. • To hold public hearings and meetings and to ensure participation of the communities in the discussions and elaboration of the programmes. • To reconstruct community infrastructure.
Source: Hydro-Québec International/Vincent Roquet & Associates. 2004. *Quality Management of Safeguards in Dam Projects. Final Report - Volume 1: Guiding Principles.* World Bank, unpublished report. Cited in J. Ramsay (2006). *Key Issue Report for DDP - Environmental Management Plans.*

Box 9-10: Extract on Graves from Maguga Dam Comprehensive Mitigation Plan, Swaziland

Extract from Maguga Dam Comprehensive Mitigation Plan

Graves

The Resettlement and Compensation Policy and Procedures specify that affected graves must be treated in accordance with the wishes of the relatives of the deceased. Key stipulations in this regard are:

- All affected graves must be identified in conjunction with the Ekuvinjelweni Resettlement Committee (ERC):
- The ERC must be assisted to locate relatives not residing in the Project Area, through radio announcements and newspaper notices;
- The location of each affected grave site must be determined by GPS and plotted on orthophoto maps;
- Graves that belong to homesteads who are resettled to the Host Area can be re-interned at the new residential areas or in a designated cemetery as approved by the Traditional Authorities. For homesteads exercising the free-choice resettlement option, exhumation and reburial fees will not be borne by the Project if re-internment does not take place in a designated cemetery; and
- Graves will be exhumed and reburied, with the costs being borne by the Project in accordance with limits established by the compensation rates. Compensation will include a coffin and a shroud. Apart from exhumation and reburial costs, each affected homestead will be entitled to one sacrificial beast and one wake fee for every five graves. The Project will assist with the identification and purchasing of sacrificial beasts.

The exhumation and reburial of the affected graves was undertaken between November 1999 and May 2000 by an association established by the affected homesteads, and funded and supported by KOBWA.

Source: Komati Basin Water Authority. 2001. *Comprehensive Mitigation Plan for Maguga Reservoir Area.* p 5-2.

TRAINING AIDS	
Discussion topics	1) Select a hydropower project in your country. Discuss how widely its benefits and negative impacts will be felt and how these could be managed. 2) Identify a negative impact from a hydropower project that you are aware of, and discuss mitigation options for this impact. What parameters would you set? 3) Discuss the influence of financial institutions on an EMP. 4) In paragraph 9.3.3 an example of the management elements of an EMP from a case study is provided. What other elements might be necessary on another project you know about?
Exercises	• Choose a familiar hydro project you know—or invent a new one—then develop an ideal set of EMP documents / programmes, covering: - pre-construction - construction - operation For each document or programme, outline the contents.
Additional reading and resources	1) The Asian Development Bank. 2012. *Implementation of the Environmental Management Plan for the Son La Hydropower Project*. Technical Assistance Completion Report. TA 4711-VIE. 2) The World Bank. 1999. *Environmental Management Plans*. Environmental Assessment Sourcebook: Update No 25.

Case Studies

Trung Son Hydropower Project Management Board. 2008. *Trung Son Hydropower Project: Environment Impact Assessment Report*. Chapters 4 to 6.

Maguga Dam (Swaziland): Keevy C, Malzbender D and Petermann T (eds). *Dams and Development: The KOBWA Experience. Practices for balancing social, environmental and economic aspects in water infrastructure development*. InWEnt 2009.

9.4 Institutional Arrangements

Key aspects	• In many countries, the institutional framework for project environmental and social management is weak or fragmented. A central purpose of EMPs is to clarify responsibility for the activities that have to be undertaken. • EMPs typically detail the legal framework, the responsibilities for implementing specific measures and organizational relationships. • EMPs specify the institutional strengthening requirements needed to create the institutional capacity necessary to implement the EMP. This usually includes the ability of stakeholders to participate meaningfully. • The EMP clarifies amount and source of the financial resources necessary for each task and activity. • The EMP may be the basis for contractual arrangements between project partners and stakeholders.

TRAINING AIDS	
Purpose of session	The purpose of this session is to introduce the organisational requirements for EMP implementation, emphasising that the EMP is the mechanism for assigning responsibility for the mitigation measures.
Learning objectives	• Gain insight into the institutional arrangements necessary for effectively implementing an EMP.
Key readings	1) WCD report, 2000: Chapter 9, Guideline 19 *Implementation of the Mitigation, Resettlement and Development Action Plan* (p298-300)

9.4.1 Responsibilities and Roles

A central purpose of environmental management plans is to clarify responsibility for the activities that have to be undertaken. EMPs typically detail:

- The legal and policy framework;
- The responsibilities for implementing specific measures, whether these are further high-level programmes, such as a Resettlement Action Plan, or detailed activities like installation of wastewater treatment systems during construction;
- Organizational relationships; and
- Costs and sources of funds.

The parties in a typical institutional setup are described in Box 9-11. Note that institutional roles change as the EMP is implemented.

Box 9-11: Parties in a Typical Institutional Setup for an EMP

- The **competent authority** usually oversees the implementation of the terms and conditions of approval.
- The **proponent** (often through sub-contractors) normally carries out the scheduled activities, such as site clearance and preparation, construction and environmental management.
- The **environmental or regulatory agency** usually inspects mitigation measures, reviews monitoring data, and verifies compliance and effectiveness.
- The **public** can have a formal role in environmental monitoring and audit (e.g. where a stakeholder or community review committee is in place). In other cases, there may be provision for public disclosure of monitoring and audit reports and opportunities for informal review and comment.

Source: UNEP. *Environmental Impact Assessment: Training Resource Manual* -Second Edition. Topic 11

Role Players: there are a number of role players involved in an EMP as depicted in **Box 9-11** and

Table 9-5. A description of each follows:

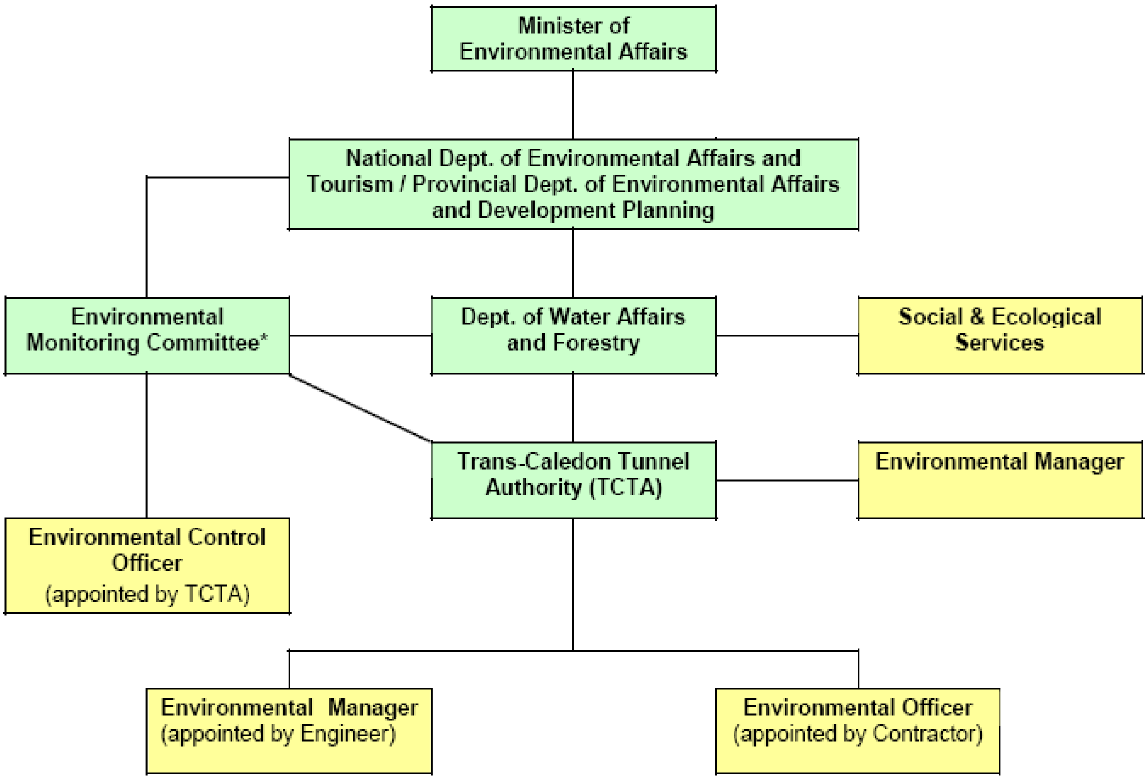
- The "**authority**" is the institution in government that is charged with enforcing environmental legislation and which has the authority to permit a defined activity such as a hydropower project to proceed.
- The "**proponent**" or "**owner**" is the individual, company or organ of state that is the owner of the project and is responsible for complying with environmental legislation.
- The "**contractor**" is the company that undertakes the construction under contract to the proponent. The terms of the contract are used to ensure that the construction complies with the conditions of the environmental authorisation given by the authority and the EMP. The contractor is usually required to appoint to his staff an "environmental manager" and/or a number of "environmental officers" (ecosystems and social) that are responsible for ensuring the contractor's compliance, as well as for matters, such as training of staff in environmental awareness and contract provisions.

The "**environmental monitoring committee**" is typically an independent vehicle through which stakeholders can monitor the environmental performance of the project, particularly during construction. A typical setup is described in **Box 9-12.**

The **"environmental control officer" (ECO)** is an independent specialist that monitors the environmental performance on behalf of the EMC and the authority in accordance with the requirements of the RoD and the approved EMP. A typical setup is described in

Box 9-13.

Figure 9-4: Environmental Management Hierarchy, Berg Water Project, South Africa



Source: Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP. Case Study No 3.

Clarifying Mandates: environmental and social management invariably involves many government departments and agencies due to their statutory responsibilities, together with the private, public or parastatal organisations and NGOs that may be involved in the implementation of each measure. Using catchment or basin management concepts (see Section 5.2) increases the challenges of coordination. Governments are not immune from institutional conflicts, characterised by rapid policy shifts, institutional territoriality, and information hoarding. Overlapping mandates are common, especially for environmental issues and natural resource management. Acknowledgement of these constraints during the preparation of the EMP will assist in establishing a clear set of links, responsibilities and reporting pathways. The time and resources required to do this may be greater than initially envisaged.

Table 9-5: EMP Role Players and their Responsibilities

Pre- detailed design phase	**Implementing Agency**	Project Management Appoint Engineer
	Environmental Consultant	Draft Environmental Management Plan & Generic Specifications
	Environmental Man-agement Committee	Input into & endorse Environmental Management Plan for Authorization submission
Detailed design phase	**Implementing Agency**	Project Management Appoint Environmental Control Officer Appoint Contractor
	Engineer	Detailed Design of components of the system Finalize Environmental Project Specifications Appoint Environmental Officer
Construction phase	**Implementing Agency**	Project management
	Environmental Man-agement Committee	Oversee the Environmental Management Process and the implementation of the EMP
	Engineer	Oversee the construction both from a technical and contractual perspective
	Environmental Control Officer	Monitor and audit overall compliance by the relevant parties with the requirements of the ENT, and report to the EMC in this regard
	Environmental Officer	Assist the Engineer in ensuring compliance with the environmental management requirements for the construction activities on site
	Environmental Manager	Environmental monitoring to ensure Contractor's internal compliance with the CEMP requirements

Source: TCTA (South Africa) 2003. *Berg Water Project – Environmental Management Plan*

Box 9-12: The Environmental Monitoring Committee (EMC)

The purpose of the EMC is to provide a structure where representative sectors of society (e.g. government, NGOs, private sector, community and civil society organizations) collaborate with the authorities to monitor the compliance of the Mooi-Mgeni Transfer Scheme - Phase 2 in the implementation of project specific environmental objectives. The EMC must be established prior to commencement of the project.

The specific functions of the EMC are to:

- Periodically monitor and review progress towards adhering to the conditions of the RoD and EMP;
- Review and comment on subsequent revisions of the EMP;
- Promote understanding by the developer of the nature of the project's impacts (both positive and negative) on the local social and natural environment; and
- Ensure information exchange between project activities and interested and affected parties.

Members of the EMC include:

- An independent chairperson;
- A representative of TCTA (implementing agent);
- A representative of the national Department of Water Affairs (proponent);
- A representative of the national Department of Environment Affairs (authority);
- A representative of Umgeni Water (the main off-taker);
- A representative of the provincial Dept. of Agricultural and Env. Affairs and Rural Development;
- One representative from each of the affected residents'/ratepayers' associations;
- The ward councillor(s);
- Two representatives of NGOs; and
- One representative of the Mooi River Farmers' Association.

Source: TCTA (South Africa) 2011 *Mooi-Mgeni Transfer Scheme - Phase 2, Project Description and Environmental Management Philosophy Rev 2.* http://www.springgrovedam.co.za/docs

Box 9-13: The Environmental Control Officer (ECO)

The role and function of the ECO is to:

- Conduct third-party monitoring and auditing;
- Regularly monitor and review the progress towards achieving the specific strategies, objectives and performance targets of the EMP;
- Independently verify that mitigation measures and conditions in the EMP are being applied;
- Conduct site inspections on a regular basis and issue inspection reports;
- Review monitoring data and evaluate against performance targets;
- Provide routine reporting to the authority and other state institutions;
- Provide independent professional advice to the EMC in the execution of its functions; and
- After consultation with TCTA, inform decision-making authorities when there is non-compliance with conditions of approval.

As an independent Consultant, the ECO is NOT responsible for:

- EMP implementation;
- Primary environmental data collection, monitoring and analysis; and
- Resolving I&AP complaints.

The ECO is NOT accountable for the implementation of the RoD and the EMP and is also not linked to the project authorities or the Engineering Consultant or Contractor.

Source: TCTA (South Africa) 2011 *Mooi-Mgeni Transfer Scheme - Phase 2, Project Description and Environmental Management Philosophy Rev 2.* http://www.springgrovedam.co.za/docs

9.4.2 Rights, Risks and Contracts

In some jurisdictions, the traditional model of EMP implementation arrangements is being superseded or complemented by contractual relationships. Under these, the proponent and other parties are contractually bound to undertake certain activities and face legal sanctions, if they do not perform. This is consistent with the approaches advocated by the WCD.

An example of a plan detailing the proponent's responsibilities during project construction and operation is given in **Box 9-14**.

Box 9-14: Proponent's Responsibilities, Arrow Lakes Generating Station, Canada

The Arrow Lakes project involved the addition of a 185 MW power plant to an existing 52 m high dam built for river regulation on the Columbia River in Canada. The project was in an environmentally and socially sensitive area and subject to tight controls through both the provincial and federal administrations.

To clarify responsibilities, a plan entitled **Owner's Commitments, Responsibilities and Assurances** was prepared to cover power plant construction, power plant operation, and transmission line construction and operation. The plan laid out the various commitments and assur-

ances made by the proponent as part of the project planning and permitting process, together with detailed responsibilities by party (owner, owner's consultants and the design-build contractor).
Source: Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.

9.4.3 Dispute and Grievance Resolution

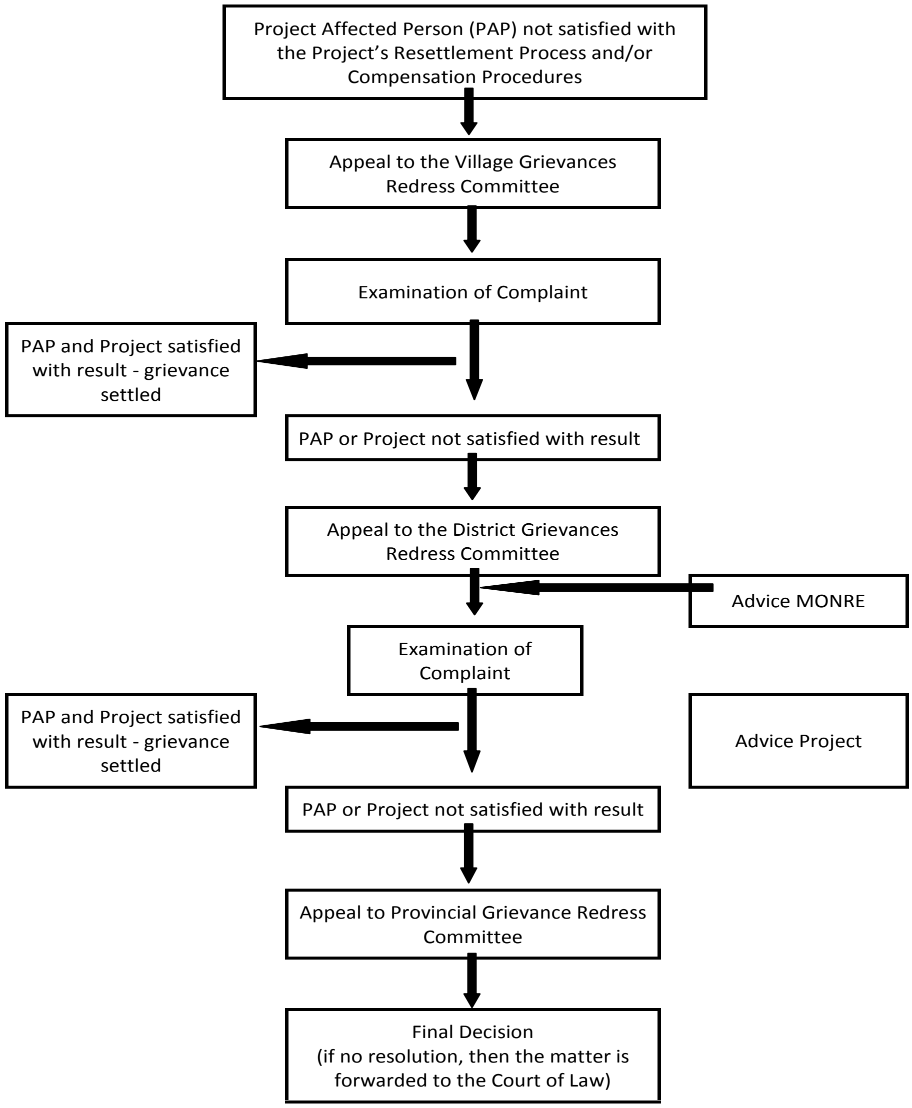
It is essential that a robust dispute resolution mechanism is established, available, and widely publicised to all stakeholders. It must be possible for an aggrieved party to escalate their dispute to the highest levels of the political process that mandated the project. Such a mechanism should not deter any complainant by bureaucratic complexity or narrowly defined mandate. In many instances the project should assist the complaint in obtaining third party assistance for advancing the grievance. An ombudsman is an option that was used, for example, on the Lesotho Highlands Project. A flow diagram of the grievance procedure on the Nam Ngum 3 Hydropower Project is presented in

Figure 9-5.

9.4.4 Institutional Strengthening, Change and Capacity Building

In many countries the institutional framework for project environmental and social management is weak or fragmented. An institutional analysis is usually carried out during the EIA process. During EMP preparation, this is extended to give a full picture of the organisations, which will be involved in EMP implementation, so that weaknesses and capacity issues are identified. A programme of institutional strengthening and capacity building is then developed, detailed, budgeted and included in the EMP itself, with the necessary responsibilities, timelines, milestones and resources.

Figure 9-5: Grievance Redress Mechanism, Nam Ngum 3 Hydropower project, Laos



Source: Nam Ngum 3 Power Company. 2012. *Resettlement & Ethnic Minority Development Plan of the Nam Ngum 3 Hydropower Project*.

9.4.5 Financing of EMPs

EMP costs vary enormously, reflecting their widely varying scale, scope and complexity. The basic cost categories are: EMP preparation and EMP implementation. EMP implementation, in turn, has two major cost elements: programme implementation (the cost of the measures themselves) and administrative overheads. These cost elements cover many sub-elements, each of which may be a major programme in its own right; for example, public participation, environmental flow determination, watershed management, compensation and resettlement, monitoring, or human resources development.

EMP implementation proceeds most smoothly when all costs have been identified in advance, fully budgeted, and an adequate contingency allowed for the inevitable unforeseen tasks. Inadequate funding for EMP preparation invariably results in inadequate funding for EMP implementation, with unwelcome cost and budgetary surprises.

The Compendium points out that, in the international arena, the increasing use of public-private partnerships for large water resources projects brings with it a tendency to divest environmental and social management tasks to the public sector partner ("government responsibility"), whilst the private sector partner focuses on building and operating the scheme. The attendant risk of under-financed and un-synchronized social and environmental measures can be minimised by transparency during project planning and by paying close attention to the terms of the partnership.

There is increasing interest in the use of trust funds and other forms of not-for-profit financing for some mitigation and management measures, such as watershed protection and community development.

The cost of programmes to mitigate social and environmental impacts varies greatly. On the Salto Caxias Hydroelectric Power Plant, these costs amounted to 25% of the project cost[156]. On the Arrow Lakes case study, the Columbia Basin Trust fund was established (see Box 9-15). The case study on the National Water Fund of Ecuador (FONAG) demonstrates the establishment of a pilot payment for ecosystem services.

Box 9-15: Columbia Basin Trust

The Committee, in partnership with elected officials from the region, negotiated with the Province, with two objectives:

- The creation of a trust governed by a board of Basin residents.
- The allocation to the region of funds representing a fair share of the ongoing downstream benefits earned under the CRT, to be managed by the trust.

On both counts negotiations were successful and the **Columbia Basin Trust** was formed. The Trust received a C$ 295 million endowment by the Province.

C$ 250 million was committed to finance power project construction:

As directed by Basin residents, C$ 45 million has been reinvested for the benefit of Basin residents through short-term cash investments, business loans, real estate ownership, and venture capital projects.

In addition, the Columbia Basin Trust received C$ 2 million per year from 1996 to 2012.

The Province further committed to transfer C$ 250 million to the Columbia Power Corporation, the Columbia Basin Trust's Joint Venture Partner in power projects in the Basin. Fifty percent of the net profits go to the Columbia Basin Trust for the benefit of the people of the Basin. The income from the investments is being spent on social, economic and environmental benefits for the residents of the Basin.

Source: Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP. p 39

[156] Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.p 122.

TRAINING AIDS	
Discussion topics	1) Does the institutional setup in your country provide the inter-departmental checks and balances that are necessary for effective implementation of EMPs? 2) "All of the costs of the EMP must be part of the project budget". Discuss whether there is justification for this statement.
Exercises	• For your country, make a list of government agencies concerned with large water infrastructure and the environment. Add the law under which they operate, and set out their functions. Identify gaps and overlaps in institutional mandates that might affect EMP structuring and implementation.
Additional reading and resources	1) WCD Report. Chapter 10: *Taking the Initiative – Institutional Responses*. pp 313 - 316 2) UNEP's *Environmental Impact Assessment Training Resource Manual* - Second Edition, May 2002, pp 405 – 413 (Note that this source uses the terminology "EIA implementation and follow-up" rather than "EMP")

Case Studies

Spring Grove Dam Available from http://www.springgrovedam.co.za/emp.html

9.5 Environmental Management Systems (EMS)

Key aspects	• Environmental management systems (EMS) are procedures that systematise an organisation's activities with the aim of improving **organisational** environmental performance. This is distinct from environmental management processes, including EMPs that focus on projects. • Within the organisation, the EMS provides a framework and guides the functional preparation of the EMP. It is not a substitute and is distinct from it. The EMS is not project-specific. • Environmental management systems are governed internationally and have a consistent terminology and approach. • The importance of environmental management systems for EMP implementation is that they facilitate systematic management of activities and tasks, within the **organisation**, by project owners, builders and operators.

TRAINING AIDS	
Purpose of session	The purpose of this session is to introduce environmental management systems (EMS), as an increasingly important environmental and social management tool in the water sector, and to review their role in EMP implementation.
Learning objectives	• To understand the nature of environmental management systems and their relevance to EMP implementation.
Key readings	1) Wikipedia article on ISO 14000: http://en.wikipedia.org/wiki/ISO_14000

9.5.1 Overview

A good definition of an Environmental Management System (EMS) is provided below:

> *"Environmental management systems (EMS) are procedures that systematise an organisation's activities with the aim of improving organisational environmental performance. They are focused on internal management and are most easily applied to re-*

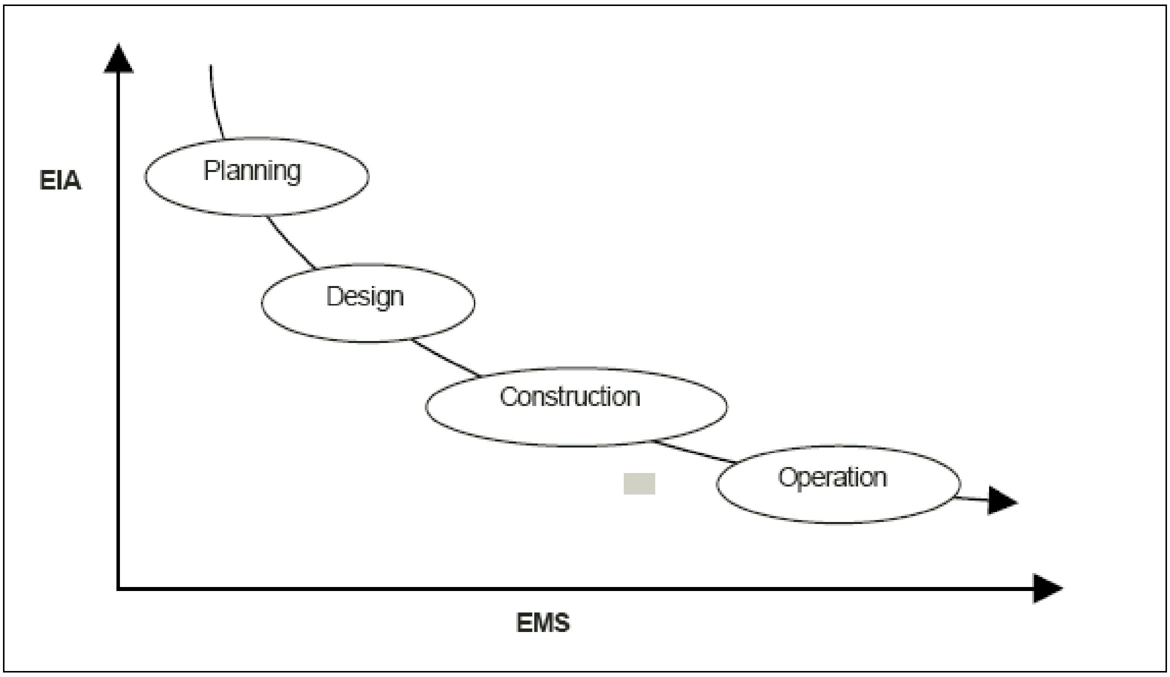
petitive tasks that can be turned into controlled procedures. They are usually implemented voluntarily".[157]

EMS approaches and terminology are derived from the wider concept of Quality Assurance (QA) and are largely standardised. There are two main normative frameworks: (i) the International Organisation for Standardisation, through the ISO 14000 family of standards on environmental management; and (ii) the European Union's Eco-Management and Audit Scheme (EMAS). The adoption of an ISO 14001 environmental management system is voluntary, but application of the Eco-Management and Audit Scheme can be required by European Union Law. Both systems are subject to certification through independent external audits.

EMSs are governed internationally and have a consistent terminology and approach—in contrast with EIA, a process normally regulated at the national level, which has developed numerous variants.

EMS and EIA processes are distinguished, mainly by the fact that the former is organisationally based, and the latter is project based. A certified organisation approaches EIA or EMP management in terms of the procedures established in its EMS. EMS tools thus assist with the delivery of EIA and EMP outcomes. Clearly, where the project stakeholders already use an EMS framework in their overall business, the EIA process is facilitated and enhanced. The relationship during the project cycle is depicted in Figure 9-6.

Figure 9-6: Relative Usefulness of EIA and EMS by Project Phase



[157] Bronwyn Ridgway (2005). *Environmental management system provides tools for delivering on environmental impact assessment commitments*. Impact Assessment and Project Appraisal. Vol 23, No 4. December 2005, pp 325–331

Source: Bronwyn Ridgway. *Environmental management system provides tools for delivering on environmental impact assessment commitments*. Impact Assessment and Project Appraisal, volume 23, number 4, December 2005, pp 325–331

The intention of ISO 14001:2004 is to provide a framework for a holistic, strategic approach to an organisation's environmental policy, plans and actions. ISO 14001:2004 gives the generic requirements for an EMS. The underlying philosophy is that whatever the organisation's activity, the requirements of an effective EMS are the same. This has the effect of establishing a common reference for communicating about environmental management issues between organisations and their customers, regulators, the public and other stakeholders.

A core concept of an EMS is continual improvement in performance. An organisation can enter the cycle of continual improvement at any stage. As an example, an EMS meeting the requirements of ISO 14001:2004 is a management tool, enabling an organisation of any size or type to[158]:

- **identify and control** the environmental impact of its activities, products or services;
- **improve** its environmental performance continually; and to
- **implement** a systematic approach to setting environmental objectives and targets, to achieving these and to demonstrating that they have been achieved.

Another example of the typical components of an EMS is given in **Box 9-7**.

Table 9-6: Typical Components of an EMS

Typical Components of an EMS

- Management Commitment
- Environmental Policy
- Environmental Aspects and Impacts
- Objectives and Targets
- Roles and Responsibilities
- Planning and Programs
- Regulatory Compliance
- Document Control
- Operational and Emergency Procedures
- Training
- Monitoring and Measuring
- Review (including environmental audits) and Improvement

Source: IHA. 2004. *Sustainability Guidelines.* http://www.hydropower.org/sustainable_hydropower/IHA_Sustainability_Guidelines.html

[158] www.iso.org

Because ISO 14001:2004 does not lay down levels of environmental performance, the standard can be implemented by a wide variety of organisations, whatever their current level of environmental maturity. However, a commitment to compliance with applicable environmental legislation and regulations is required, along with a commitment to continual improvement - for which the EMS provides the framework.

The importance of EMSs for EMP implementation is that they facilitate systematic management of activities and tasks—within the organisation, by project owners, builders and operators. They are most effective where these organisations already use quality assurance procedures for their day-to-day business.

An example of early adoption of an EMS by a power and water utility is given in **Box 9-16**.

Transfer of EMP requirements and other commitments in the project documentation to an EMS can be done by identifying all required tasks and standards and creating a database or register of commitments. In EMS terminology, such a register becomes an "environmental management programme" (ISO 14001:2004, Clause 4.3.3). The commitments can be classified as design commitments, management commitments and monitoring commitments. They can be actioned through the development of operational control procedures, and checked through building auditing and reporting requirements into the project's internal management systems.

Box 9-16: Early Adoption of an EMS: ACTEW, Australia

The ACT Electricity and Water Corporation Limited (ACTEW) provides electricity, water and sewerage services to Australia's Capital Territory, including the management of four large dams and their reservoirs. The corporation is required by legislation to conduct its operations in accordance with the principles of environmentally sustainable development. Following the preparation of an environmental management plan for the period 1995-2000, the corporation established an environmental management system to implement both the environmental management plan and its annual environmental action plans. Three ACTEW facilities were amongst the first sites to be ISO 14001 certified in Australia.

Because of its reputation for an excellent environmental management system, the corporation has gained considerable overseas work, in addition to improved customer satisfaction, more efficient operations and significantly reduced levels of risk.

Source: Ramsay J. 2006. *Key Issues: Environmental Management Plans*. Final Report to UNEP-DDP.

The effectiveness of an EMS can be enhanced by the presence of favourable conditions in the organisation **(Box 9-17)**.

Box 9-17: Conditions for Enhanced EMS

- A corporate environmental ethos where environmental excellence and business excellence are twin goals.
- Senior management leadership and commitment drives environmental understanding throughout the organisation.
- There is a corporate commitment to continuously improve environmental management systems.

- Operating practices as well as training and awareness raising in the workforce.
- Employees work to a common environmental or "sustainability" goal.
- There is a clear line of accountability and responsibility for environmental impacts.
- There is corporate recognition of employees initiating environmental improvements.

Source: International Hydropower Association. 2004. *Sustainability Guidelines*. p13.

EMS are becoming increasingly important for EMP implementation as a result of the increasing popularity of alternative project delivery strategies (such as design and build; and build, own, operate and transfer (BOOT)), which introduce contractors earlier into the project cycle and also because of the increasing importance of environmental certification for corporate reputation and commercial viability.

For implementing a large water infrastructure project, the proponent, consultants and contractors may all benefit from establishing an EMS. This ensures that environmental issues, including the EMP, are managed by standardised methods and procedures—thus ensuring that organisational outcomes related to the environment are consistent, compliant, and predictable.

As a specialised public sector example, in South Africa, all government departments are required to have an Environmental Implementation and Management Plan (EIMP). The primary purpose of the EIMP is to align that department's environmental management policies and functions with those of other government departments, and vice versa. It is, therefore, similar to an EMS.

TRAINING AIDS	
Discussion topics	What benefits could a standardised EMS bring to implementation of an EMP? For developing hydropower, what organisations could or should implement an EMS?
Exercises	• Identify any water and energy sector organisations in your country or region that have implemented an EMS, and from online research list the benefits this has brought to the organisation.
Additional reading and resources	1) ISO 14001:2004 or any explanation of its purpose and nature, e.g. http://www.iso-14001.org.uk/ or http://www.recycle-it.org/toolkits/EMSGuide.PDF 2) USEPA online training course: *Introduction to Environmental Management Systems Training*. http://www.epa.gov/osw/inforesources/ems/ems-101/

Case Studies

The following case study is from Sri Lanka, where the main contractor attempted to implement an EMS during construction.

Implementation of an EMS during Construction of the Kukule Ganga Hydropower Project, Sri Lanka

The project: the Kukule Ganga Hydropower Project is a run-of-river electricity generation project. The scheme consists of a low weir (20 m high by 110 m long), a small regulating reservoir (area 88 ha, volume 1.6 million m^3), a 5.65 km headrace tunnel, a 121 m vertical pressure shaft, an underground power cavern, a 1.6 km tailrace tunnel, 24 km of access roads and 27 km of 132 kV transmission line. The gross head is 186 m. The installed capacity is 80 MW, giving an annual power output of 317 GWh. During the dry season the plant will be run in peaking mode, using the regulating reservoir to assist power generation in daytime and refilling it at night. During the wet season, the plant will provide base load.

The environment: the project is located on the Kukule River ('Ganga') in the Province of Sabaragamuwa in southern Sri Lanka, some 70 km south-east of Colombo, the capital. The surrounding forest region is an offshoot of the Sinharaja, the last viable area of primary tropical rainforest in Sri Lanka, now recognised as a Biosphere Reserve and a World Heritage site.

The contractor: the main contractor for the tunnels and underground power plant was Skanska International Engineering Consortium (Lahmeyer, Skanska, Electrowatt). In 1997 Skanska was prosecuted in Sweden for having used a hazardous material. Following this domestic environmental setback, the company significantly raised its level of ambition in the environmental field and decided to adopt the environmental management standard ISO 14001 on a Group-wide basis.

To implement the EMS across the company, Skanska developed a new organisation with QEW-departments (QEW = Quality, Environment and Working environment) in every business unit and in every project. The responsibility for implementing ISO 14001 was delegated to project level, where the QEW-departments developed the necessary routines with central support.

Skanska used the Kukule Ganga scheme as a pilot project in the company's quest for environmental certification. It was the first hydropower project in a developing country for which a major contractor gained ISO 14001 certification, and it was put forward by both Skanska and the Ceylon Electricity Board as "a model for how an environmental management system should be implemented on a large-scale project."

The EMS on site: the environmental management system (EMS) implemented by Skanska for its activities on site focused on air quality, pollution risk reduction, waste management, safety, and associated training:

- Air quality and noise: activities included commissioning the Ceylon Petroleum Corporation to manufacture a special diesel fuel with low sulphur content (maximum 0.5%) for use in Skanska machinery on the project, limiting the hours of deliveries to and from the work site, regularly wetting down the roads and conducting noise inspections.
- Risk reduction: procedures for purchasing, handling, and storing chemicals ensured that no items on Skanska's global list of prohibited substances were used in the project, and that chemicals at the work site were safely handled and stored. A water treatment unit was built, including sediment ponds and oil separators, to process tunnel water. To ensure that the treatment system was working satisfactorily, an outside organization conducted tests of river

water quality every month.

- Waste management: together with the local environmental agency, the company developed a waste management programme for the site. This included returning used batteries to the supplier, recycling paper and separating oil, tyres and metals. The contractor that provided waste disposal services received special environmental training on the purpose and contents of the waste management programme. Because Sri Lanka lacks the necessary supporting institutions for waste stream separation and recycling, at times Skanska had to improvise and innovate to ensure appropriate waste disposal and accept the increased costs internally.
- Training and regular inspections: everyone working for Skanska at the Kukule Ganga project underwent environmental awareness training. To monitor compliance with environmental management principles, the local environmental and quality departments conducted inspection rounds at the project every week and every month, respectively. There were also local environmental audits of the project's subcontractors. Twice yearly, a thorough environmental audit of the entire project took place.

Skanska's environmental department on site faced many challenges in implementing the EMS, including low environmental and safety awareness amongst workers. For example, at first, it was not easy to convince employees for example to wear boots and helmets, to stop washing cars in the river and burning worn-out tyres. In general the programme was successful. Non-compliance was associated with the short duration of the project and the widespread attitude - including in local authorities - that environmental care is 'a luxury of the rich'.

Source: Case Study 7 in J. Ramsay, 2006: *Compendium on Relevant Practices on Improved Decision-Making, Planning and Management of Dams and their Alternatives: Key Issue - Environmental Management Plans*. Report to UNEP DDP.

9.6 Managing EMP Implementation

Key aspects	• The EMP assigns responsibility for its implementation to specific individuals or institutions. Functionaries must be unequivocally informed of this responsibility. • The EMP also identifies and describes the institutional strengthening requirements needed to create the organisation capacity for effective EMP implementation. • Successful implementation of an EMP requires an effective governance system, both within governments at different levels and at the project level. • Monitoring and auditing should be carried out by independent institutions. • Structured reporting is essential. • Stakeholder participation and an effective communication strategy are as important—if not more so—than in any other phase of the project cycle.

TRAINING AIDS	
Purpose of session	The purpose of this session is to build understanding that EMP implementation must be managed through formal mechanisms, and that success depends on an effective governance system.
Learning objectives	• Understand the structured nature of EMP implementation and the management requirements for effective implementation.
Key readings	1) Review paragraph 9.2.1: EMPs in the project cycle

9.6.1 Introduction

Implementation of EMPs was touched on in Session 9.1 as part of the overall introduction to EMPs. It was noted that structures of EMPs vary greatly, depending on jurisdiction and the characteristics of the project; how the EMP assigns responsibilities for implementation; and the noted importance of monitoring and evaluation processes. Implementation of an EMP commences with the incorporation of environmental imperatives in the design and contract documentation; this is most intense during construction and continues during the operation of the project and on to decommissioning. This session draws together the management aspects of the topics presented in the earlier parts of the manual and introduces some additional topics that are necessary for effectively managing the EMP implementation process.

9.6.2 Governance

If the legislative and policy frameworks lay down what has to be done, the governance system, which is distinct from management, ensures that the goals and objectives are actually achieved in letter and spirit. It will also focus on the rights and risks approach advocated by the WCD.

> *"Governance is the system of values, policies and institutions by which a society manages its economic, political and social affairs through interactions within and among the state, civil society and private sector. It is the way a society organizes itself to make and implement decisions - achieving mutual understanding, agreement and action. It comprises the mechanisms and processes for citizens and groups to articulate their interests mediate their differences and exercise their legal rights and obligations. It is the rules, institutions and practices that set limits and provide incentives for individuals, organizations and firms. Governance, including its social, political and economic dimensions, operates at every level of human enterprise, be it the household, village, municipality, nation, region or globe*."[159]

Good governance systems should ensure that EMPs are implemented in both letter and spirit. This is not always the case: in a statement attached to the end of the Compendium, some of the civil society advocacy groups and people's movements involved in the DDP process say:

> *"The Compendium makes the fundamental error of assuming that what is written on paper in planning documents is what actually happens in the real world. In big-dam projects, even seemingly comprehensive plans often make little difference to outcomes. What actually happens is dictated by political interests and realities on-the-ground that are invariably detrimental to the interests of affected communities and the environment."*

"Good governance", which should overcome this difficulty, depends upon the principles of predictability, inclusivity, representativeness, accountability, efficiency, effectiveness, social equity and justice. Other principles, such as transparency, are necessary to ensure safeguards in the system, while cooperation is necessary in a highly complex system. Causes of "ineffective governance" include corruption, inadequate financial resources, inadequate labour and managerial skills, low prioritisation and poor communication.[160]

Good governance must be built on three pillars; namely, open policy-making, a professional bureaucracy, a strong, engaged civil society - and, of course, a free press. The absence of any one of these jeopardises effective governance, including the planning and implementation EMPs. Obviously, the EMP process at project level cannot itself guide national level

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[159] UNDP. *Strategy Note on Governance for Human Development*, 2004.

[160] Moss J et al. 2003. *Valuing water for better governance*. CEO Panel: Business and Industry.

http://www.pacinst.org/reports/valuing_water/

processes. In Session 1 of this Module the normative and legislative frameworks under which EMPs are implemented were examined. These frameworks are insufficient without a good governance system to support them. This highlights the need for government responsiveness and accountability to ensure good governance in the EMP context (and all other aspects of implementing large water infrastructure). UNESCO criteria for "effective water governance" are listed in **Box 9-18**.

Box 9-18: UNESCO Criteria for Effective Water Governance

- **Participation:** all citizens, both men and women, should have a voice – directly or through intermediate organizations representing their interests – throughout processes of policy and decision-making. Broad participation hinges upon national and local governments following an inclusive approach.
- **Transparency:** information should flow freely within a society. The various processes and decisions should be transparent and open for scrutiny by the public.
- **Equity:** all groups in society, both men and women, should have opportunities to improve their well-being.
- **Accountability:** governments, the private sector and civil society organizations should be accountable to the public or the interests they are representing.
- **Coherency:** the increasing complexity of water resource issues, appropriate policies and actions must be taken into account so that they become coherent, consistent and easily understood.
- **Responsiveness:** institutions and processes should serve all stakeholders and respond efficiently to changes in demand and preferences, or other new circumstances.
- **Integrative:** water governance should enhance and promote integrated and holistic approaches.
- **Ethical considerations:** water governance has to be based on the ethical principles of the society in which it functions, for example, by respecting traditional water rights and preventing corruption.

Source: UNESCO. *First World Water Development Report, 2003*: Chapter 15: Governing Water Wisely for Sustainable Development. p 373.
http://www.unesco.org/water/wwap/wwdr/wwdr1/table_contents/index.shtml

While these criteria are generally applicable at the national level, they create the enabling environment for effective EMP management, and several have direct equivalence at project level. A further important criterion is the predictability of the political and administrative governance system—in that all role players know the rules and accept that these will be applied consistently. Two practical problems are the political processes that led to the project, and the need to manage any lack of accountability of participating NGOs.

The governance system also works against corruption; however, it can also be undermined by it. This is important in the EMP context because:

"Corruption can also sacrifice environmental sustainability and the ecosystem services on which many people rely for livelihoods."[161]

9.6.3 Organisation

The EMP in the project cycle was presented in Session 9.2, while Session 9.4 presented some of the institutional arrangements. It remains to add a few pointers and to restate others.

Every organisation that undertakes work on the project must be contractually bound to the provisions of the environmental permit and the EMP during all project phases - design, construction and operation. All staff must be clearly informed of their assigned responsibilities.

[161] Larry Hass, Leonardo Mazzei, Donal O'Leary. 2007. *Setting Standards for Communication and Governance: The Example of Infrastructure Projects.* World Bank Working Paper No 121. p 9.

Figure 9-4 presents the institutional arrangements during the construction phase for the Berg Water Project. The responsibilities and powers of each of the institutions are set out in legislation, regulations and project documents—notably the environmental approval (“record of decision”, “permit” or “licence”). Each institution designates, in writing, a person to represent that organisation and to exercise the powers and fulfil the roles and responsibilities that the institution carries. The project proponent is responsible for complying with all the provisions of the EMP approval—as far as the implementing organisations are concerned. A distinction is that the environmental authority uses legislated powers to enforce compliance, while the project proponent uses contractual terms. While a focus on the legislative and contractual nature of the EMP is necessary, this should not be carried so far as to preclude flexibility as new issues and unintended consequences arise as the project is implemented. Finally, it bears noting that using catchment or basin management concepts, as advocated in Section 5.2, increases the challenges of coordination.

During construction, responsibility for some operational aspects of EMPs may be delegated in writing to the proponent’s site representative, usually the Engineer designated in the construction contract documents. The environmental regulator usually maintains oversight of the administrative functions of the government departments involved.

Each institution involved with EMP implementation must staff and organise a specialist group or groups the capacity of which must be commensurate with each EMP function. Where an EMP is strategic in nature and the project large, a further level of detailed operational planning may be formalised. Separate constituent plans for major activities or along discipline lines, such as resettlement, river monitoring, cultural artefacts etc. (See Table 6 of the DDP Compendium for an example). Depending on the complexity, each of these headings may justify an operational sub-plan.

In some instances, the EMP or sub-plans may not be sufficiently detailed to guide effective execution of an environmentally sensitive aspect of the construction works. In these circumstances, use should be made of the “method statement” process, contained in most contracts. In terms of this, before undertaking a specific task the contractor is required to submit to the Engineer, for approval, a detailed statement or plan of how it will undertake the work. As a matter of procedure, the concurrent approval of the on-site environmental officer should be required.

In addition to the general assignment of EMP tasks and functions to institutions, the responsibility for each EMP activity should be delegated, in writing, to an acknowledged person. On large dams, it is common for each institution to have a permanent representative on the site, from the earliest stages of construction. Depending on the circumstances—where, for example, large-scale resettlement is necessary—part of the EMP may be out-sourced to a specialist organisation.

Local government is inevitably an important stakeholder and has a significant role in large projects throughout the project cycle. Clearly the project proponent cannot impose obligations on local government so that the EMP must provide for liaison and cooperation structures. In many areas, institutional capacity is weak, and capacity-building initiatives may be necessary to facilitate local government services.

On large projects, it is advisable to ensure that organisations that perform important tasks in EMP implementation have a certified environmental management system.

It is good practice that the functions of implementing, monitoring and auditing are each carried out by independent institutions. Thus, for example, while the contractor may be responsible for making and reporting routine water quality measurements, another independent organisation, such as a laboratory, may be responsible for regularly taking confirmatory samples or regularly testing the calibration of the contractor’s equipment or confirming the validity of sampling and laboratory methods.

Finally, a formal grievance procedure should be implemented particularly with respect to resettlement issues. An environmental monitoring committee (see below) does not eliminate this need. Good management practice would suggest that most grievances should be resolved on site but complainants must have means for escalating their complaints to the highest authority.

9.6.4 Programming and Budgeting

The implementation of an EMP usually requires the assignment of considerable human and financial resources. An amount of 25% of project cost would not be untypical. Therefore the activities of the EMP must be programmed and budgeted to align with the design and contract document process, construction programme, project commissioning, project operation, and eventually decommissioning. The timing may be in outline in the EMP itself and in more detail in the operational plans. Project managers must be alert to any onset of "stakeholder fatigue" which will manifest if the participation process is not meaningful or if it stalls due to extraneous factors. Many EMP activities may have to be completed before construction commences—the most obvious example being land acquisition and resettlement.

9.6.5 Data Management and Record Keeping

EMPs are, by nature, data-intensive. Every organisation involved in the EMP must create and manage a well-documented system for acquiring and storing the data and records needed to fulfil its obligations. In particular, the records of stakeholder participation and resettlement planning in particular must be exemplary, as must the tracking of project-affected families. On the environmental side, the monitoring programmes for water quality, fisheries, etc. will generate large amounts of data, which must be stored for "conservation of evidence" as well as for direct management purposes.

Excellent record keeping is essential during the construction process in order to enable defence against false claims by the contractor or supposedly affected stakeholders. "As-built" drawings and operational manuals are important items if the operational EMP is to be effectively implemented.

All complaints on any matter related to the project must be registered and tracked, and must be open for inspection by any interested party.

In addition to basic office administrative systems (efficient filing etc.), effective data and information storage and management requires high-level technical skills, based on the use of Management Information Systems (MIS) and Geographic Information Systems (GIS).

Good practice requires **transparency**. Data and information must be made available to interested parties (at least) and the general public (as far as possible) to build trust and avoid corruption. This is often best done through project websites and (increasingly) social media. Data must therefore be formatted to be accessible.

9.6.6 Monitoring

Good monitoring practice is presented in Module 10. Every aspect of the implementation of the EMP must be monitored by a monitoring programme against set targets and indicators. This plan could include progress with and complaints related to relocation, water quality below the construction site, noise levels etc. Such a plan defines what is to be monitored, why, the indicators, the methods, and reporting and when an observation crosses a threshold and requires higher levels of responsibility and authority.

9.6.7 Reporting

The EMP must specify a reporting system. The reporting system defines what is to be reported, how frequently reports must be made, and who is responsible for the report. **Table 9-7** shows a typical reporting structure for a construction site. Management reporting requires a similar structure. All reports in the EMP reporting system should be readily available to all stakeholders.

Table 9-7: Typical Construction Site Reporting Structure

Functionary	Report	Frequency	Submitted to
Environmental Control Officer	Audit Report	Bi-monthly	Environmental Monitoring Com.
Engineer's Environmental Representative	Monitoring Report: Natural Environment	Monthly	Engineer
Engineer's Social Representative	Monitoring Report: Social Environment	Monthly	Engineer
Contractor's Environmental Representative	Inspection Report	Bi-weekly	EER and ESR
Source: TCTA 2009 *Environmental Management Plan for the Mooi-Mgeni Transfer Scheme: Phase 2. Section O: Checking and Corrective Action.*			

9.6.8 Adaptation, Flexibility and Corrective Action

The EMP and the required mitigation measures should be implemented strictly in accordance with the EMP. Nevertheless, flexibility is required to cope with unforeseen conditions, unintended consequences, and changing environments. For this purpose the EMP must contain a procedure for adapting its provisions in special circumstances. It must be a structured and documented procedure. The EMP should include a list of the authorities needed to make adjustments, and should provide for stakeholder participation in decision-making.

Conditions under which the EMP could require revision include[162]:

- changes in legislation;

[162] South African Department of Water Affairs and Forestry. 2002. *Guidelines for Standardised Environmental Management Plans*. http://www.dwaf.gov.za/documents.asp.

- occurrence of unanticipated impacts or impacts of greater significance, intensity, and extent than predicted;
- inadequate mitigation measures (i.e. where the level of an environmental parameter is not conforming to the required level, despite the implementation of the mitigation measure); and
- secondary impacts as a result of the mitigation measures.

In addition, routine formal review by the executive management of the proponent and any implementing agency of the progress with the EMP is essential. The purpose of this is to ensure that the EMP remains suitable, adequate, and effective; and that the objective in ISO 14001 of continual improvement is achieved.

9.6.9 Compliance and Enforcement

Compliance in the wider context applies to all processes in the project cycle and is a strategic priority of the WCD Report, as well as a separate priority topic in the DDP Compendium. Here reference is made to compliance with the EMP provisions.

Compliance with the EMP should be non-negotiable and the governance, monitoring, and reporting systems must ensure this is so. Where compliance is impossible, the adaptation process should be followed. Each aspect of the EMP, when satisfactorily completed, should be formally approved by a person designated to do so in the EMP.

Compliance may be achieved through incentives, but is generally achieved by sanctions, enforced through the environmental licensing conditions or the construction contracts.

Compliance is discussed further in Session 10.2.

9.6.10 Stakeholder Participation

Stakeholder participation is essential throughout EMP formulation and implementation. See the Training Manual *Dealing with Social Aspects* for more details.

Within EMPs, increasingly, stakeholder participation is formally structured into “environmental monitoring committees” (EMCs) (see Box 9-12). Often their formation is a condition of the environmental approval. Their form and function may vary considerably according to project circumstances. The purpose of an EMC is to provide a structure where representative sectors of society (e.g. government, NGOs, private sector, community and civil society) typically collaborate with the authorities to[163]:

- monitor a project during construction and operation to ensure it is compliant with approval and EMP conditions;
- promote the participation of key stakeholders in environmental monitoring;

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[163] South African Department of Environment Affairs and Tourism (DEAT). 2005. *Environmental Monitoring Committees (EMCs)*, Integrated Environmental Management Information Series No 21.

- provide an opportunity for information exchange between government authorities, the developer, and interested and affected parties;
- provide a structured forum for discussion, so as to make recommendations when appropriate;
- provide the opportunity to reach common understanding between interested groups about the nature, scope and results of monitoring and remedial actions undertaken, in terms of the project EMP—thereby increasing the scope for issues to be resolved amicably;
- promote understanding about the project operation more widely, through dissemination of relevant information by committee members; and
- promote understanding by the developer of the nature of the projects impacts (both positive and negative) on local communities.

An EMC however does not remove the need for a formal grievance procedure, particularly for displaced persons.

Three case studies reported in the Compendium (see

Box 9-19) illustrate effective tools used for engaging very different groups of stakeholders:

- Computer-based decision support tools for well-educated computer-literate participants with high expectations of influencing outcomes in the TVA Reservoir Operations Study, United States.
- Surveys and local expert panel of poorly educated fishing communities as part of the Thai Baan research project, struggling to be recognised in response to the Pak Mun Dam trial gates opening, Thailand.
- Public assemblies, joint study groups, and resource centres facilitating information sharing and interaction through a partnership approach, formalised by an agreement with the Cree indigenous community in James Bay, Canada.

Box 9-19: Tools for Engaging Different Groups of Stakeholders: Three Case Studies

Tennessee Valley Authority (TVA) Reservoir Operations Study

(Purpose of tools: to enable interaction)

The goal of the Reservoir Operations Study was to determine whether changes in TVA's reservoir operating policies would result in greater overall public value (for power, water supply, navigation and recreation). It included broad public outreach, community workshops (involving more than 3,000 people), targeted multi-stakeholder groups, an interagency team, and a public review group. Alternatives were developed, evaluated, and refined through data collection, statistical analysis, computer hydrologic modelling and qualitative assessment. An interactive, computer-based system was used for multi-voting on preferences and to encourage and record comments, which could be displayed electronically on a screen so that all could see the range of opinions. This facilitated interaction among interest groups and an understanding of the need to balance concerns.

Villager-led Thai Baan Consultation

(Purpose of tools: to gather and aggregate data)

This case study focuses on villager-led research supported by an NGO, the Southeast Asia Rivers Network, involving work with local communities to inform and consult post-construction on the mitigation of impacts related to the Pak Mun Dam, Thailand (Chinvarakomu 2002). The Pak Mun project is located on the Mun River, a tributary of the Mekong River, and incorporates a 123 megawatt hydropower plant. The research initially focused on the impact of opening the dam gates but was extended to cover broader issues. The methodologies applied to study each issue involved observation, in situ recording of field observations, validation of data by local experts, and data classification and analysis. The Thai Baan researchers included 200 villagers from 65 communities, nominated to collect data by the local communities for their expertise in different fields. They received no remuneration and were assisted by NGO advisers. The research demonstrated the impact on the fishery downstream of the dam and the inadequacy of compensation. This case study illustrates the cost-effective contribution that poorly educated people could have made if included in earlier stages of the impact assessment and development planning. According to civil society representatives, it also illustrates the important role the participation of affected people could play in finding solutions.

Eastmain 1A-Rupert Diversion, James Bay, Canada

(Purpose of tools: to inform and engage First Nations communities)

The Eastmain 1A-Rupert diversion involves the Eastmain and Rupert Rivers in Canada. This 770 MW project aimed to augment existing generation of power, by diverting some water from the Rupert River and constructing two other powerhouses at an already developed site. The river is of significant cultural value and runs through the territories of six indigenous Cree communities. A series of informal meetings and public assemblies, with senior Hydro-Québec managers and Cree leaders and the communities, and a signing of a nation-to-nation agreement between the Cree and the government of Quebec, resulted in the Boumhounan Agreement in 2002, which confirmed a partnership approach. The indigenous Cree were then involved at all phases of the project—from the concept onwards. The Cree provided ecological and traditional knowledge, and participated in a joint study group, as well as field investigations, to conduct environmental and social impact assessment data gathering and analysis.

The process was supported by locally employed Cree coordinators and fully equipped information and work offices in the communities, which provided a continuous forum for exchange, access to information, and videos translated into Cree language. The Cree were afforded time (more than three years) and financial resources to assess, consult and understand the nature and scope of the project, and were assisted by specialists and lawyers. Special funds were provided for a joint non-profit corporation for construction of remedial works and implementation of mitigation measures and economic and community benefits such as training, employment, contracts and environmental guarantees.

Under Canadian and Quebec legislation, a review panel comprising experts, including Cree representatives, held public hearings in the six Cree communities affected and in the cities of Chibougamau and Montreal. Hearings encouraged an exchange of views and commenced more than 45 days after public release of the impact statement, translated into relevant languages. In all, participation methods ranged from face-to-face meetings with key individuals, large public assemblies, joint data gathering groups and field trips, collaborative discussions about project design and the development of economic benefits, and more formal public review procedures where views of all parties could be shared. Civil society representatives noted that this case also illustrates how the principle of free, prior informed consent led to the success of the initiative.

Source: *DDP Compendium*

9.6.11 Communication

An effective communication strategy is of critical importance at all stages of EMP preparation and implementation. Often overlooked aspects of communication are (i) the need for adequate training of project engineering staff, who have frequent contact with local residents; and (ii) assistance for interested and affected parties (e.g. local residents) to engage effectively with the proponent and the authorities. Training and a remuneration and reimbursement programme is often necessary to ensure that stakeholder inputs are of good quality. See

Box 9-20 for an example.

Box 9-20: Communication Plan for Upgrading Wivenhoe Dam, Australia

The alliance formed to upgrade the water supply from the Wivenhoe Dam, on the Brisbane River, Australia, developed a communication plan that identified all stakeholders, established key messages and issues, and documented and justified engagement techniques, key activities and time frames. Stakeholders were identified through project planning workshops, site visits and an existing database of local residents, traditional owners, interest groups and local, state and federal government agencies. Core actions, such as newsletters, an information line and media releases, were identified, supplemented by additional activities tailored to specific interests. The plan included communication protocols. For example, all activities involving negotiations with traditional owners were managed through the stakeholder manager. The plan called for a community reference group to be formed and engaged early in the process. It also included mechanisms for community feedback, such as a questionnaire distributed with the newsletter. A stakeholder and environment plan complemented the communication plan by identifying risks and constraints, including the need to focus on negotiation with traditional owners, regular liaison with the government stakeholder group, identifying and implementing benefit sharing for the construction phase, and achieving non-cost key performance indicators.

DDP Compendium. Box 3.2. p36

9.6.12 Exit Strategy

During the implementation of large water projects, the implementing agency typically has significant management capacity on the site and is able to deal with issues as they arise. During the transition to the operation phase this capacity diminishes until only a few technical operating staff remain. In many instances the agency that implemented the project is not the agency that must operate the project. It may be advisable to include a specific exit strategy as one of the last items in the construction phase EMP, so that all of the initiatives of the construction and commissioning phase are satisfactorily concluded and handed over to the responsible agencies for project operation. Examples are:

- Facilities that will remain for community use (e.g. the construction camp water supply system).
- Community health programmes.
- Employment.
- Road maintenance.

TRAINING AIDS	
Discussion topics	1) Using an example of a large project with which you are familiar, discuss the nature and content of the proponent's communication strategy during EMP implementation. Does this encompass "participation" or is it just "public relations"? 2) Discuss the role of a stakeholder forum during EMP implementation. Should it be provided with resources so that it can consult independent expert opinion? 3) How can project financing mechanisms incorporate effective environmental and social safeguards ("leverage" or conditionality), especially once the project has started and construction is underway? 4) How can public sector proponents be held to account if they fail to deliver on promised activities and benefits?
Exercises	1) For a dam known to you, prepare a list of the major activities in the EMP that might justify a separate operational sub-plan. 2) For a large project known to you, make an organisation chart of the environmental and social management system. Indicate where improvements could be made to improve clarity, effectiveness and transparency.
Additional reading and resources	1) Peter Rogers and Alan W Hall. Effective Water Governance. GWP TEC Background Paper No 7. November 2002. pp 3 - 10. http://www.gwpforum.org/gwp/library/TEC%207.pdf 2) Useful Questions to Assess Management Capacity and Process. In: IFC. 2006. Guidance Note 1: Social and Environmental Assessment and Management Systems. IFC, Washington DC. http://www.ifc.org/ifcext/sustainability.nsf/Content/GuidanceNotes

Case Studies

This case study is from South Africa, where a water transfer scheme and large dam were subject to an EMP based on the EMS standard.

Mooi-Mgeni Transfer Scheme, South Africa

The Mooi-Mgeni Transfer Scheme Phase 2 (MMTS-2) comprises the construction of a 38 m roller compacted concrete dam with a storage capacity of 142 million m^3 on the Mooi River, upstream of the Mearns Weir, with an associated water transfer system to the Mpofana River. The Spring Grove Dam will be located about 2 km southwest of Rosetta on the farms Rosetta and Spring Vale. The dam lake will inundate portions of Vaale Kop, Inchbrakie, Riverholm, Ebernburg and Spring Grove, with the backwaters extending upstream to above the Inchbrakie Falls. The purpose of the MMTS-2 is to augment the growing water requirements of the Mgeni System by 60 million m^3 per annum. The

System supplies the eThekwini Metropolitan Municipality; Msunduzi Local Municipality; and the Ilembe, Ugu, uMgundgundlovu, and Sisonke District Municipalities.

A positive Record of Decision (RoD) was issued by the Department of Environmental Affairs on 15 June 2009. This authorised construction of the project activities, subject to specific conditions.

The purpose of the EMP is to ensure that:

a) All potential impacts on the environment as a result of construction and operation of MMTS-2 are recognised and understood and provision made for the effective management of such impacts. Management implies preventing or minimising negative impacts while maximising the positive impacts (benefits) of the activity;

b) All relevant environmental legal requirements are recognised, planned for, and met during construction and operation of the MMTS-2;

c) The conditions of the authorisation are recognised and upheld during the implementation of the project;

d) Best practice is promoted in implementing the required environmental management functions; and

e) A basis is established for continual improvement of environmental management into the future.

To achieve the above, the EMP has been based on the ISO 14001 Environmental Management System standard. The adoption of the standard is not so much to pursue certification, but rather to ensure the approach used in managing the potential impacts of the project is robust and effective—and, perhaps most importantly, adaptable. The EMP presented here is thus based on the policy, planning, implementation and operation, checking and corrective action and management review requirements of the management systems standard.

Source: from the Introduction to: TCTA. 2011. *Mooi-Mgeni Transfer Scheme Phase 2 (MMTS-2): Project Description and Environmental Management Philosophy* (document revision 2, 20 March 2011). http://www.springgrovedam.co.za/emp.html

10 MONITORING AND COMPLIANCE

MODULE 10: MONITORING & COMPLIANCE		
Scope	**Session/Sub-Topic**	**Scope**
Monitoring	**Session 10.1: Monitoring**	
	Types of Monitoring	Review of types of monitoring: baseline, effects, compliance, performance; audits.
	Effects Monitoring	Review of effects monitoring; definitions and approaches; indicators; role of independent monitors; QA systems & EMS.
	Session 10.2: Compliance	
	Compliance Monitoring	Review of compliance monitoring at different levels, transparency, compliance plans, approaches - incentives and sanctions - and dispute resolution.
	Auditing	Introduction to environmental auditing, quality assurance, auditors.

10.1 Monitoring

Key aspects	• Monitoring is the systematic, repetitive and continued observation, measurement, and evaluation of environmental criteria to follow changes over a period of time. • Auditing is a systematic, documented, periodic, and objective evaluation of how well an EMP is performing, in relation to established standards. • To ensure compliance with an EMP, a monitoring and auditing process is essential. • Compliance monitoring procedures may be laid out in a high-level Compliance Plan. • Monitoring programmes in an EMP normally: o Describe the ecosystem and social system components at risk. o Define the monitoring system. o Assign responsibilities and financial resources.

TRAINING AIDS	
Purpose of session	• The purpose of this session is to review the role and importance of monitoring and auditing during EMP implementation.
Learning objectives	1) To understand the nature and extent of monitoring required during the implementation of EMPs. 2) To understand the range of activities involved in effects or environmental performance monitoring.
Key readings	1) DDP Compendium, Chap. 7: Compliance

10.1.1 Types of Monitoring

Monitoring can be defined as *"The repetitive and continued observation, measurement and evaluation of environmental criteria to follow changes over a period of time and to assess the efficiency of control measures."*[164]

[164] South African Dept. of Water Affairs and Forestry. 2002. *Guidelines for Standardised Environmental Management Plans.* http://www.dwaf.gov.za/Docs/Other/Environment/EMPGuide2May.pdf

Environmental monitoring is usually divided into two categories: effects or performance monitoring (measuring changes associated with a projects against a pre-established baseline), and compliance monitoring. These are described in **Box 10-1**.

Box 10-1: Environmental Monitoring

Environmental monitoring refers to the systematic collection of environmental data through a series of repetitive measurements. A number of different monitoring activities are identified below:

- **Baseline monitoring** refers to the measurement of environmental parameters during a pre-project period for the purpose of determining the nature and ranges of natural variation.
- **Effects monitoring** involves the measurement of environmental parameters during project construction and implementation so as to detect changes in those parameters, which can be attributed to the project.
- **Compliance monitoring**, unlike the previous monitoring activities, takes the form of periodic sampling and/or continuous measurement of environmental parameters, levels of waste discharge or process emissions to ensure that regulatory requirements are observed, and standards met.

Source: UNEP. *Environmental Impact Assessment: Training Resource Manual* - Second Edition.

Some international financing agencies, such as the World Bank, use the term **environmental performance monitoring** which may be defined as "*technical and institutional activities that are implemented by a Borrower to measure and evaluate environmental (including health and socioeconomic) changes induced by a project. The overall objective of performance monitoring is to identify predicted and unanticipated changes to the physical, biological and social environment brought about by the project. …. monitoring is a dynamic activity as opposed to passive collection of data*."[165]

Auditing is a systematic evaluation of the environmental performance of an organisation or project, tested against the agreed objectives, standards, and procedures (see 10.2.2).

Note that EMP monitoring and auditing are distinct from project evaluation processes—in which the focus is on whether the project as a whole is meeting or has met its objectives. Evaluation is a topic on its own and outside the scope of this manual.

10.1.2 Environmental Effects or Performance Monitoring

10.1.2.1 Overview

Monitoring programmes normally describe the ecosystem (or social system) component at risk, with a link to the impact predicted in the EIA, and define the **indicators** to be tracked

[165] World Bank. 1996. Environmental Assessment Sourcebook Update 14, *Environmental Performance Monitoring and Supervision.*

and the exact **parameters** to be measured, the methods to be used, the sampling frequency, threshold levels that will trigger management action, and reporting systems. The characteristics of a good monitoring programme are listed in **Box 10-2**.

Monitoring and auditing are long-term activities. Intensity is highest during construction and commissioning and usually decreases progressively throughout the project life-cycle but *"....a programme of monitoring, evaluation, and adjustment – commonly referred to as 'adaptive management' – should be fully and explicitly integrated into any dam development or re-operation plan so that management approaches can be continually modified in light of increased understanding or changes in human and ecosystem conditions"*[166].

Box 10-2: Characteristics of Effective Environmental Monitoring Programmes

- A realistic sampling programme (temporal and spatial);
- Sampling methods relevant to source and/or type of impact;
- A targeted approach to data collection;
- Comparability of data with baseline and other relevant data;
- Quality control in measurement and analysis;
- Systematic record keeping and database organisation;
- Institutionalised ownership of programme and accountability for outcomes;
- Reporting requirements for internal and external checks;
- Provision for input from and response to third parties; and
- Presentation of results to the public.

Source: UNEP. *Environmental Impact Assessment: Training Resource Manual* - Second Edition. Topic 11.

A project's environmental and social monitoring programme should be defined within the EMP which normally:

- **Describes:**
  - the ecosystem and social system components at risk; and
  - links to the impacts predicted in the environmental impact assessment;
- **Defines:**
  - what is being monitored and why;
  - the indicators to be measured,
  - the methods to be used,

[166] Richter, B.D.; Postel, S.; Revenga, C.; Scudder, T.; Lehner, B.; Churchill, A. and Chow, M. 2010. *Lost in development's shadow: The downstream human consequences of dams*. Water Alternatives 3(2): 14-42

  - the sampling frequency,
  - any analytical or assessment methods;
  - threshold levels and compliance requirements that will trigger management action;
  - reporting systems including to the stakeholders; and
- **Assigns:**
  - Responsibilities; and
  - Financial resources for the monitoring programme.

10.1.2.2 Baseline Monitoring

Effects monitoring requires the establishment of a **baseline,** against which to measure change. This must done before construction starts, and, for some topics (such as for land values), before the start of significant pre-construction activities. A baseline description is a standard component of all EIA reports; however, EIA studies are seldom resourced to carry out the detailed primary surveys necessary for reliable baselines.

Establishment of baselines is often difficult: they need to be accurate and, as far as possible, easy to measure. Further factors are natural variability and ongoing change processes: decision-makers seldom realise the length of time needed to obtain a reliable picture of, for example, river flows or wildlife populations; in addition, the baseline itself may not be static. For example, both hydrological and biological processes are now significantly influenced by climate change. Fisheries are a particular challenge: they are notoriously difficult to measure accurately, both because of the invisible and transient nature of fish populations and because fishermen and women seldom have incentives for telling the truth about their catches.

Since monitoring can be resource-intensive, it is necessary to be very specific when designing monitoring programmes. It is essential to have clear **objectives** – what is to be monitored, and why (see example of monitoring objectives in

Box 10-3).

Box 10-3: New Assiut Barrage & Hydropower Plant, Egypt: Objectives of Monitoring Programme

Phase	Objective	Indicator
Pre-construction	To ensure that all required mitigation measures have been developed, agreed, and included in project documentation.	ESMP including Compliance Plan approved.
	To establish reliable pre-project baselines.	Quantitative baselines established, documented and entered in information management system (air, water quality, noise, groundwater levels, socio-economic condition of PAPs).
Construction	To ensure that all agreed measures are being implemented effectively	Compliance Plan implemented.
	To record key environmental parameters for comparison with baselines and standards	EEAA contract; monitoring ongoing; results evaluated.
	To track the socio-economic status of PAPs	Surveys implemented and evaluated.
	To track the health, safety and welfare of workers	Reports and inspections
	To track and evaluate community and residents' complaints	Complaints system records and activities
Operation	To ensure that all agreed measures are being implemented effectively	Compliance Plan implemented.
	To meet regulatory standards for barrage operation	Monitoring records
	To track changes in hydraulic conditions	Sedimentation or erosion
	To determine post-construction socio-economic status of PAPs	Surveys implemented and evaluated.

Brainstorming around cause-effect trees based on predicted project impacts can help to identify specific **indicators** of changes. Monitoring can then focus on those indicators, and in turn, they should be the focus of the baseline monitoring programme.

In some cases baselines have **contractual implications**. For example, if a construction contractor needs land temporarily during construction, and the only land available is agricultural, he will be required to restore the land to its original condition or better; consequently, a baseline soil survey will be needed to establish the precise physical and chemical characteristics of the original land, which the contractor then has to meet (for example soil texture, bulk density and organic matter status).

Baselines can also serve to protect project proponents from **false claims**, for example, from residents claiming that groundwater rise has affected their buildings or land, despite pre-existing high groundwater levels.

10.1.2.3 Biophysical Monitoring

Large and complex projects may require a variety of monitoring activities, best identified as sub-tasks. For example, on the Nam Ngum 3 Hydropower Project in Lao PDR, monitoring tasks identified were[167]:

- Monitoring of water quality
- Monitoring of operation activities
- Monitoring of construction activities
- Monitoring of resettlement activities and measures for women and ethnic minorities
- Fish catch monitoring programme
- Monitoring and reporting of water levels in the NN3 reservoir

An example of a water quality monitoring programme is given in **Box 10-4**.

Box 10-4: Water Quality Monitoring: King River Power Development, Australia

The King River project involved two large dams on the King River in Tasmania, creating a reservoir of 1,065 million cubic metres supplying a 143 MW power station. Construction was completed in 1993. Water quality was a major issue due to a long history of mining in the catchment, resulting in acid mine drainage and heavy metal contamination. The owner wished to establish a recreational fishery in the lake and therefore implemented an extensive water quality monitoring programme to measure ongoing changes in the reservoir and to check the effectiveness of mitigation measures upstream. The programme also identified an issue with de-oxygenation in the tail race water, due to thermal stratification in the reservoir, a problem solved by installing a jet pump on the turbine to provide aeration.

Source: *DDP Compendium,* EMP Report Case Study No 2

On the Lesotho Highlands Water Project, the in-stream flow requirements (IFR) were a major issue; consequently, an IFR Policy was developed with the following objectives:

- To provide for the maintenance of specific target river conditions;
- To provide for an appropriate release regime from each impoundment, namely, Katse and Mohale Dams, Muela Tailpond and Matsoku Weir, to achieve the above objective;

[167] Nam Ngum 3 Power Company. 2012. *The Nam Ngum 3 Hydropower Project: Resettlement & Ethnic Minority Development Plan*

- To establish principles of mitigation of impacts and compensation for losses;
- To establish the basis for the assessment of resource and social losses and levels of and procedures for compensation;
- To set out the objectives of a monitoring programme, which will support the IFR release regime, compensation and mitigation policy; and
- To provide for an appropriate IFR management system, which allows for the systematic and periodic review and audit of performance.

The IFR policy is supported by detailed monitoring procedures, an extract from which is provided for illustrative purposes in

Table 10-1.

Monitoring may also involve a variety of institutions including the financing agency, the national environmental authority, the project owner, the construction contractors, representatives of interested and affected parties and international NGOs.

10.1.2.4 Social Monitoring

Social monitoring is a large and complex subject. The trainer seeking more information is referred to the Training Manual *Dealing with Social Aspects.*

Table 10-1: Lesotho Highlands Water Project: Summary of Biophysical Data Collection Activities for Monitoring River Condition

Component	Tasks	Where data should be collected	Frequency of collection
Hydrology	Continuous time series stage height data	IFR Site 1, 2, 3, 4, 5, and 7 and outlets of Katse, Mohale and Matsoku structures	Continuous.
Habitat	Habitat mapping and characterisation	IFR Site 1, 2, 3, 4, 5, 6, 7 and 8. Reference IFR 9 and 10.	Every two years.
	Re-survey of cross-sections		Every two years.
	IHAS		Twice per year
Water quality	Routine monthly sampling of nutrients	IFR Site 1, 2, 3, 4, 5, 6,7 and 8. Reference IFR 9 and 10.	Monthly.
	WQ and temperature monitoring - using loggers - using hand-held field meters	 IFR Site 1, 2, 3, and 7 IFR sites 4, 5, 6 and 8; Reference sites 9 and 10	 Continuous Monthly
	Faecal coliforms	IFR Site 1, 2, 3, 4, 5, 6 7 and 8.	Monthly
	RBA	IFR Site 1, 2, 3, 4, 5, 6,7 and 8. Reference IFR 9 and 10.	Twice per year in spring and autumn
Riparian vegetation	Algae	IFR Site 1, 2, 3, 4, 5, 6,7 and 8. Reference IFR 9 and 10.	Monthly
	Zonation	IFR Site 1, 2, 3, 4, 5, 6,7 and 8. Reference IFR 9 and 10.	Once per annum in early autumn
	Braun-Blanquet		
Macro-invertebrates	RBA	*See Water Quality*	
	Visual assessments for simulids and snails	At all IFR sites and IFR Reference sites 9 and 10.	Twice per year in spring and autumn
Fish	Routine fish surveys.	IFR Site 1, 2, 3, 4, 6, 7 and 8. Reference IFR 9 and 10.	Twice per annum (summer and winter).

Source: Lesotho Highlands Development Authority: *IFR Procedures 3: Monitoring Programme*. www.lhwp.org.ls

10.1.2.5 Institutional Issues

Large water infrastructure projects affect many components of the biophysical and social environment and usually necessitate major monitoring programmes. Because of the range of topics requiring monitoring, there are usually many different agencies and institutions involved. It is essential that the project's EMP establishes clear roles and responsibilities for all monitoring associated with the project, especially reporting relationships.

A common question is: "How much should Government agencies do - and how much should the project do itself?" Government agencies provide institutional continuity but may be inadequately resourced, and responsibilities are fragmented. It is important to establish a central unit where all M&E information can be reviewed, so as to maintain an overview and facilitate management action based on monitoring results.

Monitoring generates large amounts of information and data, which requires quality control, analysis, storage, and easy retrieval over a period of at least five years, often more (**Figure 10-1**). This immediately runs into the question of skills, staffing, equipment and budgets.

Government entities are seldom resourced adequately, and project-specific M&E units are usually desirable.

Figure 10-1: Monitoring Sequence

Monitoring data

↓

Storage (data entry, cleaning, etc)

↓

Analysis

↓

Evaluation

↓

Management *action*

Monitoring requires significant resources (Figure 10-2).

Figure 10-2: Resources required for Monitoring

- **Staff**
- **Office / laboratory**
- **Sampling and measuring equipment**
- **Transport**
- **Computer systems**
- **Clear programme and responsibilities**
- **Standard operating procedures (SOPs)**
- **Regular budget**

If project owners or operators are responsible for monitoring, there is a need to ensure their objectivity (no falsification of data). This can be done by making sure all monitoring information is easily available to all stakeholders - **transparency** - and by using **independent monitors**, including NGOs. For example, during construction, the construction contractors will be carrying out monitoring of water and other topics; can their results be trusted? How can they be verified? Independent checks are essential to ensure the credibility of monitoring data.

TRAINING AIDS	
Discussion topics	1) Discuss the merits of having independent monitors and auditors. Can the environmental authority (regulator) be the sole auditor? What role is there for stakeholders? 2) What is the latest stage in the project cycle when baselines can be established? Why? 3) Discuss the role of information technology in monitoring a large project. 4) How important is it to track each affected individual or family, as opposed to periodic surveys of samples of affected people?
Exercises	• For a large hydropower project, design a practical monitoring system for one of the following: - water quality - fisheries - watershed condition - river health - environmental flow releases Consider: purpose, indicators, sampling methods and frequency, baselines, organisation and staffing, reporting, resources, financing. • List some of the ways in which stakeholders can be involved in the monitoring process.
Additional reading and resources	1) EMP Report Case Study No. 9: *New Naga Hammadi Barrage & Hydropower Plant*. Paragraph 11.6. pp 116 - 117 2) EMP Report Case Study No. 4: *Coursier Dam*. Paragraph 11.5. pp 68 - 69. 3) World Bank. Environmental Sourcebook. Update No 11: *Environmental Auditing*. 1995. 4) World Bank. Environmental Sourcebook. Update No 14: *Environmental Performance Monitoring and Supervision*. 1996.

Case Studies

Case Study 1

The following case study from Egypt provides a summary of monitoring associated with a large water infrastructure project in the Nile Valley.

New Naga Hammadi Barrage and Hydropower Plant Project

The New Naga Hammadi Barrage and Hydropower Plant Project is a major infrastructure project on the Nile in Upper Egypt. The €325 million project involved replacing the original barrage, completed in 1930, with a new structure including a low-head hydropower plant, twin navigation locks, and a road bridge. Construction of the new barrage was financially supported by Germany's KfW and the EIB, and took six years (2002-2008).

The project was the first within the water ministry to undergo a detailed Environmental Impact Assessment (EIA) during its feasibility stage. The EIA identified two major categories of impacts that would require mitigation: (i) construction-related impacts, especially issues related to land and livelihoods, and (ii) operation related impacts, especially the direct and indirect consequences of raising the headpond and, in turn, regional groundwater levels.

In response, and again for the first time, the responsible ministry developed and implemented a comprehensive environmental and social management plan (ESMP) during the pre-construction (1999-2002), construction (2002-2008) and post-construction (2008-2010) phases. The EMP was organised into seven environmental programmes, each with two or more components comprising a variety of mitigation and/or monitoring measures.

ENVIRONMENTAL PROGRAMMES

1. **Communication and Coordination**
2. **Land Acquisition and Compensation**
3. **Engineering and Hydrology**
4. **Fisheries**
5. **Agriculture**

MONITORING PROGRAMMES

1. **Surface water quality**
2. **Groundwater levels and quality**
3. **Soil quality**
4. **Fisheries**
5. **Socio-economic conditions**

Environmental Monitoring

The project affected many aspects of the physical, biological and social environment. Consequently monitoring, organised into six monitoring programmes, was a very important project activity in all project phases.

- *Feasibility Study:* monitoring of groundwater levels was critical for project optimisation and the development of mitigation concepts.
- *Pre-construction:* physical, biological and socio-economic baselines (pre-project reference levels) were established by the environmental programmes before construction started; social information was used to design appropriate compensation and support measures for project-affected persons (PAPs). In parallel, photo and video monitoring took place for recording changes in the area during construction.

- *Construction:* both compliance and effects monitoring were undertaken:
    - on site, compliance monitoring (environmental construction supervision) was necessary to check that the contractors were operating in compliance with their approved Health and Safety and Environmental Protection Plans;
    - around the site, effects monitoring (through the environmental programmes) recorded the impact of construction on surface water quality, fisheries, PAPs' employment, and public health;
    - upstream, monitoring of groundwater levels and water and soil quality continued (through the environmental programmes) to improve the quality of the baselines prior to raising the headpond.
- *Operation:* effects monitoring continued for about a year after raising the headpond, except for:
    - fisheries, which continued to mid-2010;
    - groundwater levels (piezometer readings) which were necessary for another 2 to 3 years until 2012-2013, when all the infrastructure mitigation measures were expected to be operational.

Cost of Environmental Monitoring

Approximately €0.40 million was provided by the financing agency, as follows:

- Some €0.25 million as a grant for the installation of 165 piezometers to measure groundwater levels (installation campaigns in 1995, 1997, 2000, 2006);
- Some €0.15 million as a grant for the monitoring and survey equipment required for implementation of the environmental programmes.

10.2 Compliance

Key aspects	• Ensuring public trust requires that developers meet all commitments and standards. • A comprehensive Compliance Plan is a standard management tool for major water infrastructure projects. • Environmental compliance is an aspect of good governance and requires transparency to be effective. • Environmental auditing is an important activity within Quality Assurance processes such as Environmental Management Systems (EMS).

TRAINING AIDS	
Purpose of session	To review the need for, purpose and scope of compliance plans; to introduce the topic of environmental auditing.
Learning objectives	• To understand the importance of compliance monitoring to achieving sustainability by ensuring public trust. • To understand the role of environmental auditing.
Key readings	1) WCD report Chap. 6: *Decision-Making, Planning and Compliance,* Chap. 8: *Strategic Priorities* and Chap. 9: *Criteria and Guidelines*

10.2.1 Compliance Monitoring

10.2.1.1 Overview

Environmental and social compliance monitoring is a process of oversight, designed to determine conformity with environmental regulations, permits, and conditions of project approval. The standards may be determined by national legislation or may be project-specific. Conditions of approval include the environmental and social mitigation measures in project EMPs and ESMPs. They also include conditions included in contractual agreements relating to the project, such as financing agreements and construction contracts.

Dam projects are expected to comply with the legal framework and guidelines of the country and the organisations involved in financing and constructing the dam. The World Commission on Dams (WCD) found that where environmental and social problems occurred, the principle cause was the lack of legal requirements for particular standards at the outset—or a lack of appropriate recourse mechanisms to adequately reflect people's rights in the face of a powerful national decision. Regulatory frameworks were often weak, and the necessary provisions were not made in project planning documents. Even when they were present, governments and donors alike ignored them all too frequently. Reasons for this included:

- incompleteness, incoherence, and ambiguity of national legal and regulatory frameworks;
- difficulties of accurately defining social and environmental requirements and integration of these components into project implementation agreements and schedules;
- lack of transparency and accountability, frequently with opportunities for corruption at key points in the decision-making process;
- lack of meaningful participation at key points in the decision-making process
- low levels of internal and external monitoring that reduce feedback into decision-making;
- weak or non-existent legal recourse and appeals mechanisms to an independent judiciary, particularly for negatively affected and vulnerable groups; and
- lack of human, financial and organisational capacity.

As a result, the WCD developed a strategic priority in relation to compliance (**Figure 10-3**). **Ensuring Compliance** is WCD Strategic Priority 6, with two applicable WCD Guidelines: No. 21 Compliance Plans, and No. 22 Independent Review Panels for Social and Environmental Matters.

Figure 10-3: Ensuring Compliance: Key Message from WCD Report (2000)

Key Message

Ensuring public trust and confidence requires that governments, developers, regulators and operators meet all commitments made for the planning, implementation and operation of dams. Compliance with applicable regulations, criteria and guidelines, and project-specific negotiated agreements is secured at all critical stages in project planning and implementation. A set of mutually reinforcing incentives and mechanisms is required for social, environmental and technical measures. These should involve an appropriate mix of regulatory and non-regulatory measures, incorporating incentives and sanctions. Regulatory and compliance frameworks use incentives and sanctions to ensure effectiveness where flexibility is needed to accommodate changing circumstances.

Effective implementation of this strategic priority depends on applying these policy principles:

6.1 A clear, consistent and common set of criteria and guidelines to ensure compliance is adopted by sponsoring, contracting and financing institutions and compliance is subject to independent and transparent review.

6.2 A Compliance Plan is prepared for each project prior to commencement, spelling out how compliance will be achieved with relevant criteria and guidelines and specifying binding arrangements for project-specific technical, social and environmental commitments.

6.3 Costs for establishing compliance mechanisms and related institutional capacity, and their effective application, are built into the project budget.

6.4 Corrupt practices are avoided through enforcement of legislation, voluntary integrity pacts, debarment and other instruments.

6.5 Incentives that reward project proponents for abiding by criteria and guidelines are developed by public and private financial institutions.

The WCD's key message is that ensuring public trust and confidence requires governments, developers, regulators and operators meet all commitments made for the planning, implementation and operation of dams. Compliance with applicable regulations, criteria and guidelines, and project-specific negotiated agreements must be secured at all critical stages in project planning and implementation.

The fundamental principles of compliance monitoring are (i) **independence**, and (ii) **transparency**.

In large projects, mechanisms to ensure compliance are required at many different levels: between financing agencies and governments, between employers and contractors, between regulators and project operators, between project owners and local residents (

Figure 10-4). To achieve this, compliance monitoring procedures are usually laid out in a high-level **Compliance Plan**, as recommended by the WCD. At lower levels, such as on-site, similar plans establish the requirements for compliance, with agreed standards, such as water and air quality.

One type of document, which is becoming more common, is a **Register of Commitments**, typically prepared by the project owner or proponent and listing all the measures and activities, which have been agreed (see **Box 9-14**). This becomes binding—referred to, for example, in the project approval, conditionality.

Figure 10-4: Levels of Compliance – Typical Hydropower Project

Party 1	Contract or Agreement	Party 2
	COMPLIANCE MONITOR	
FUNDING AGENCY	***Funding agency***	**GOVERNMENT**
FINANCE MINISTRY	***Finance ministry***	**ENERGY MINISTRY**
ENERGY MINISTRY	***Energy ministry***	**OTHER MINISTRIES**
ENERGY MINISTRY	***Energy ministry***	**POWER COMPANY**
POWER COMPANY	***Environmental regulator*** ***Panel of experts*** ***NGOs***	**LOCAL RESIDENTS**
POWER COMPANY	***Environmental regulator*** ***Auditors***	**CONSTRUCTION CONTRAC-TORS**
ENVIRONMENTAL REGULA-TOR	***Environmental regulator***	**POWER COMPANY**

Another illustration of compliance monitoring relationships is given in

Table 10-2.

Table 10-2: Compliance: Examples of Monitoring Roles

Who monitors whom? Examples …	
Funding agency (IFI)	Government ("the borrower")
Environmental Regulator	Proponent
Employer (via the Engineer)	Contractor
Panel of Experts	Engineer and others
Certified Auditor	EMS (applied by, e.g. the Contractor)
Monitoring Committee or NGO	RAP implementation, PAP conditions

10.2.1.2 Compliance Incentives and Enforcement

The primary legal framework governing all projects is the national legislation in the country concerned. In major internationally funded projects there are two additional entry points often used to provide leverage to back up desired environmental and social performance. These are:

- Financing agreements.
- Contract documentation for internationally-tendered construction contracts.

Financing agreements provide the highest level of leverage. In the case of under-performance in country, the inclusion of environmental and social conditionality gives the project's international funding agencies essential tools to ensure that their in-house safe-guard policies are met. This is best done by specifying deliverables and milestones directly linked to disbursement (for example, successful relocation of affected people). Because of project dynamics once construction has commenced, it is best to front-load the conditionality (i.e. to achieve as much as possible before disbursement of the first tranche of the loan or grant).

With respect to the mitigation of direct impacts during construction, **construction contracts** form the only source of control over the contractors active on site (apart from national legis-lation and regulations). It is essential that resources are devoted to incorporating appropriate environmental and social provisions in the tender documents: the standard FIDIC docu-ments168, used on many large projects, require extensive modification to adequately cater to most developing-country situations. In addition, the bidders' environmental protection,

[168] FIDIC: International Federation of Consulting Engineers, which has prepared standard contract documents in various forms widely used for construction. The version referred to above is the FIDIC 'Red Book" 4th Edition of 1987 (Conditions of Contract for Works of Civil Engineering Construction) of 1987, now supplemented and for some purposes superseded by various other FIDIC products. Visit http://www1.fidic.org/bookshop/ for further information.

social performance, and health and safety skills should be assessed during bid evaluation (including the award of, say, 5% in total of points, depending on the sensitivity of the project).

Environmental and social performance on site will remain low unless attention is given to the following factors:

- Contractors must be financially rewarded for health, safety and environmental activities (HSE). If important tasks, such as the provision of personal protective equipment or site clean-up, are made part of the general overheads, unsatisfactory performance is guaranteed. Making health, safety, water treatment, erosion control and similar tasks pay items in the Bill of Quantities (with associated Specifications) reduces the excuses for under-performance.
- The Employer/Engineer must be given the ability to penalise the contractor financially for unsatisfactory HSE performance. (I.e. The contract documents must include provisions for the withholding of payments if inadequate quality is identified and persists.)
- The Employer must provide leadership by articulating and demonstrating commitment to high HSE standards.

The Engineer (supervising consultant), if included in the project organisation, must be given clear directions in his Terms of Reference as to the importance of HSE and should be resourced accordingly.

10.2.1.3 Disputes and Conflicts

All compliance plans require clear dispute resolution mechanisms. Things will *always* go wrong, and people will *always* complain. Project implementation is invariably smoother when effective mechanisms are in place to deal with complaints. The requirements for an effective system are shown in **Box 10-5**, and the steps involved in a typical system are shown in Box 10-6.

Box 10-5: Features of Effective Complaints Mechanisms

- Agreed process (negotiated with stakeholders, especially PAPs
- Public awareness of both the process and the point of contact with the project
- Accessible office location(s)
- Dedicated, trained staff with necessary authority
- Hard copy and soft copy record keeping and complaint tracking system

Box 10-6: Typical Steps in Addressing Complaints

- A single, known point of contact (e.g. the project office, on site)
- Process for receiving a complaint (trained staff on duty)
- If complaint is verbal, is a quick discussion with project staff enough?
- If not, register a formal complaint.
- Receive and register written complaints (as letters, etc.)

- Determine the responsible authority. (In many cases, it is not the project.)
- If project-related, assess the validity of the complaint and appropriate project action.
- Discuss with complainant.
- If no agreement, take to arbitration panel or local equivalent.
- If still no agreement, revert to legal system.
- Track this process (using a database).

An example of a grievance redress mechanism established for a major project in Lao PDR is given in

Figure 9-5.

Some approaches to promote compliance are listed in **Box 10-7**; similarly, sanction and dispute resolution mechanisms are listed in

Box 10-8. Compliance mechanisms and approaches are discussed in more detail in the DDP Compendium and in the corresponding background report.

Box 10-7: Compliance – Incentives and Facilitative Approaches

Incentives	Facilitative Approaches
Economic Incentives Access to Markets Certification Access to Credit/Equity Cross-compliance to be eligible for subsidies Green Taxes Financial Assurance Performance Bonds Insurance ***License Renewal*** Joint Relicensing ***Awards***	***Detailed Terms and Conditions in Contracts/Licenses*** ***Adaptive Management*** ***License Amendments*** ***Capacity Building*** ***Awareness Raising*** ***Public Participation*** Participatory Processes Stakeholder Involvement NGOs as Watchdogs ***Integrity Pact*** ***Trust Funds*** ***Ownership Structure*** ***Implementation/Management Plan*** ***Environmental Management System*** ***Compliance Report*** ***Self-Monitoring*** In-house Compliance Officer ***Independent Monitoring*** Community Monitoring Implementation Committee Advisory Committee External Review Body /Mechanism Monitoring Plan Panel of Experts ***Transparency*** Information to Facilitate Compliance ***Technological Innovation***
Source: Carl Bruch *et al.* 2006. Compendium of Relevant Practices on Improved Decision Making, Planning and Management of Dams and Their Alternatives - *Compliance Theme*. UNEP-DDP.	

Box 10-8: Compliance – Sanctions and Dispute Resolution

Approaches to Compel Compliance	
Disincentives	***Enforcement***
Sanctions	Administrative Enforcement
Debarment	Compliance Orders
Blacklisting	Civil Enforcement
Fines	Criminal Enforcement
Negative Publicity/Shame/Peer Pressure	Courts
Dispute Resolution	Access to Justice
Independent Review Mechanisms	Transboundary Access to Courts
Ombudsman	Intervention by NGOs/Public Interest Litigation
Mediation and Arbitration	National Courts
	International Courts
Source: Carl Bruch *et al.* 2006. Compendium of Relevant Practices on Improved Decision Making, Planning and Management of Dams and Their Alternatives - *Compliance Theme*. UNEP-DDP.	

10.2.2 Auditing

Auditing is a specialised monitoring procedure that systematically checks an organisation's compliance with specific requirements, such as operational procedures and standards. One definition is *"Environmental auditing is a process whereby an organisation's environmental performance is tested against its environmental policies and objectives*."[169]

UNEP's description of the objectives of the audit process are given in

[169] South African Department of Environmental Affairs and Tourism. 2004. *Environmental Auditing*, Integrated Environmental Management, Information Series 14. p4.

Box 10-9.

Box 10-9: Environmental Audit

Audit is the term, taken from financial accounting, to infer the notion of verification of practice and certification of data. In terms of environmental management, the objectives of audit include:

- The **organisation and interpretation** of the environmental monitoring data to establish a record of change associated with the implementation of a project or the operation of an organisation;
- The process of **verification** that all or selected parameters measured by an environmental monitoring programme are in compliance with regulatory requirements, internal policies and standards, and established environmental quality performance limits;
- The **comparison** of project impact predictions with actual impacts for the purpose of assessing the accuracy of predictions;
- The **assessment of the effectiveness** of the environmental management systems, practices and procedures; and
- The **determination of the degree and scope of any necessary remedial or control measures** in case of non-compliance or in the event that the organisation's environmental objectives are not achieved.

Two audit documents normally required are a **compliance audit**, prepared during the implementation and operation of a project; and a **post-project audit**, prepared after implementation and commissioning of a project.

Source: UNEP. *Environmental Impact Assessment: Training Resource Manual* -Second Edition. Topic 11.

Environmental (and social) audits can be carried out during project implementation to check that agreed measures are being implemented on time and effectively. They can also be carried out after project completion (“post-project audit”) in order to correct deficiencies and provide lessons for future projects.

Audits are also an essential component of quality assurance (QA) systems, including formal Environmental Management Systems (EMS). Periodic independent audits are required to obtain and maintain EMS certification and build public confidence. They may also be required as part of due diligence when a proposal exists to take over a company, or to ensure that there are no overlooked environmental liabilities such as groundwater contamination.

Environmental auditing is normally carried out by certified auditors, who have received specialised training.

TRAINING AIDS	
Discussion topics	1) Should compliance plans themselves be legally binding? How can this be achieved? 2) In your country and culture, how can conflict resolution be made fair, given the difference in power between the state and affected residents? 3) Should construction contractors or project operators be required to implement an EMS? Would this help to ensure high standards?
Exercises	• For a hydropower project you know, make a diagram of the monitoring relationships. How could this system be improved? Is there a role for NGOs? • For a large hydropower project, design a practical grievance / complaints mechanism.
Additional reading and resources	4) World Bank. 1995. Environmental Assessment Sourcebook Update 11 *Environmental Auditing*.

11 MRC-GIZ COOPERATION PROGRAMME BACKGROUND

GIZ is supporting the Mekong River Commission (MRC) in its work in poverty-alleviation and environmentally friendly hydropower development, as well as in protecting the population from the negative impacts of climate change in the Lower Mekong Basin. GIZ is directly supporting experts and managers from the MRC Secretariat, the National Mekong Committees, and the Ministries for water, energy and environment in the member countries. The GIZ programme aims to achieve long-term, sustainable improvement to the livelihoods of more than 60 million people in the Lower Mekong Basin.

The GIZ programme comprises the following components (http://www.giz.de/themen/en/30306.htm):

- Supporting the Mekong River Commission in organisational reform
- Supporting the MRC in pro-poor sustainable hydropower development
- Supporting the MRC in Adaptation to Climate Change in the Mekong region
- Adaptation to climate change through climate-sensitive flood management

Supporting the MRC in pro-poor sustainable hydropower development

GIZ is advising the Mekong River Commission (MRC) on developing and implementing instruments for testing and improving the sustainability of hydropower projects. For example, this includes for example instruments for analysing the impacts of hydropower development in catchment areas as well as approaches for establishing benefit-sharing mechanisms within water catchment areas and beyond borders. In addition, GIZ is promoting the exchange of experiences between various river basin commissions involved in sustainable hydropower development. The project is also developing basic and advanced training measures on sustainable hydropower.

Network on Sustainable Hydropower Development in the Mekong Countries (NSHD-M)

The NSHD-M is integrated in the project 'supporting the MRC in pro-poor sustainable hydropower development' of the Mekong River Commission (MRC) - GIZ Co-operation programme. The Network was established in October 2012 by universities and research institutions in the Mekong countries Cambodia, China, Laos, Thailand and Vietnam. The network aims to

- enhance knowledge and skills on sustainable hydropower development (SHD) at academic and research institutions,
- share knowledge and experiences on SHD in the Mekong countries,
- increase awareness on SHD at all levels of decision making,
- strengthen the capacity of stakeholders, including planners and decision makers, to cope with the challenges of SHD.

The network and its activities in the Mekong River Basin are supported by GIZ on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ).

Further information on NSHD-M goals, activities and partners: www.cdri.org.kh/index.php/nshdmekong.

Contacts: klaus.sattler@giz.de and thomas.petermann@giz.de

About the authors and GIZ programme managers

James Ramsay is an independent consultant, working in the environmental sector. He has tertiary qualifications in geography, agricultural engineering, and forestry; is registered in Canada as a Professional Agrologist, and in the United Kingdom as an Incorporated Engineer and Chartered Environmentalist; and is a Fellow of the Royal Geographical Society. He has specialized in the environmental management of infrastructure projects—especially in the transport sector (roads) and the water sector (hydropower and irrigation). This technical focus is complemented by a continuing involvement in the conservation sector and long-term membership of IUCN's World Commission on Protected Areas.

Brian Hollingworth is an independent consultant, working at the intersection of water resources and the law. He has tertiary education qualifications in engineering, business, and the law; is registered in South Africa as a Professional Engineer; and is a Fellow of the Association of Arbitrators (Southern Africa). For 18 years (until 2004), he worked in the Development Bank of Southern Africa in a number of capacities, including financing of infrastructure projects (such as dams, hydropower development), and, most recently, as a water specialist. In this position his task was to guide the DBSA's project programme towards best international practice. He gained wide experience in development financing institutions and approaches to key issues, such as project and contract administration, environmental sustainability, institutional analysis, economic justification of projects, and public private partnerships.

Phouvin Phousavanh is a PhD lecturer at the Faculty of Agriculture, National University of Laos, with a specialisation in management of fisheries and aquatic resources, and aquatic biodiversity. He is involved in several studies on fish-behaviour and fish management for various hydropower dams in Laos.

Wanpen Wironajagud is an Associate Professor at Thailand's Khon Kaen University, Faculty of Engineering. With a background in environmental engineering—particularly environmental health engineering—her key working areas are: Environmental Management, Environmental Impact Assessment, and Strategic Environmental Assessment.

Ha Thanh Lan is an engineer, specialised in R&D and commercial projects, in the fields of water and environment engineering. Ha Thanh Lan works in Vietnam and internationally. Currently, he is based at the **Institute of Water Resources Planning (IWRP)** in Hanoi, Vietnam, working in the Division of Science and Technology on mapping and analysis, multi-reservoir optimisation, hydrological models, urban hydrology, integrated water resources management, climate change impact—among other projects.

Try Thuon is a professional researcher with over a decade of experience in Cambodia and neighbouring countries, working on natural resource governance (land, forest, water, fisheries), rural livelihood systems and agrarian changes, irrigation and water resource management, climate change adaptation and mitigation, REDD, and carbon trading.

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Mekong River Commission - GIZ Cooperation Programme
P.O. Box 9233
Vientiane, Lao PDR
T ++856 21 263263 ext 3061
mrc@giz.de

HCD subcomponent Sustainable Hydropower Development Network:
Network for Sustainable Hydropower Development in the Mekong countries (NSHD-Mekong)
www.cdri.org.kh/nshdmekong
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Responsible
Dr. Philipp Magiera (philipp.magiera@giz.de)

Editors
Thomas Petermann (thomas.petermann@giz.de)
Klaus Sattler (klaus.sattler@giz.de)

Authors
James Ramsay (Canada), lead author
Brian Hollingworth (South Africa)
Phouvin Phousavanh (Laos)
Wanpen Wironajagud (Thailand)
Ha Thanh Lan (Vietnam)
Try Thuon (Cambodia)

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