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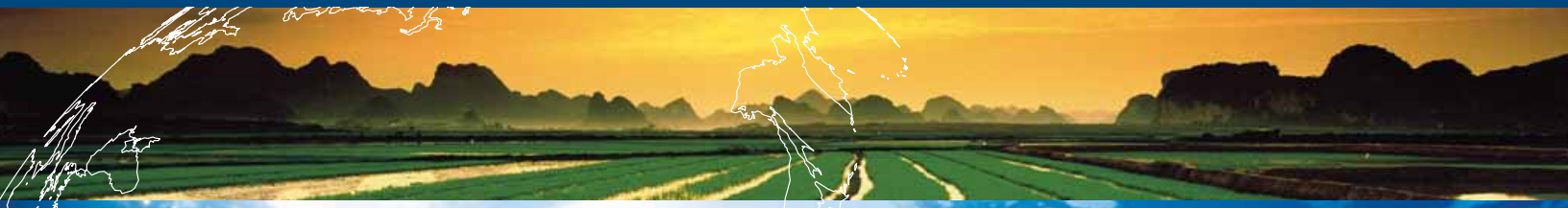
Global International Waters Assessment



UNEP

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Mekong River

GIWA Regional assessment 55

Snidvongs, Anond and Teng, Seng-Keh

Global International Waters Assessment

Regional assessments

Global International Waters Assessment

Regional assessment 55
Mekong River

GIWA report production
Series editor: Ulla Li Zweifel
Editorial assistance: Matthew Fortnam, Russell Arthurton, Kristin Bertilius
Maps & GIS: Rasmus Göransson
Design & graphics: Joakim Palmqvist

Global International Waters Assessment
Mekong River, GIWA Regional assessment 55

Published by the University of Kalmar on behalf of
United Nations Environment Programme

ISSN 1651-940X

United Nations Environment Programme
PO Box 30552,
Nairobi, Kenya

CITATIONS
When citing this report, please use:
UNEP, 2006. Snidvongs, A. and S-K. Teng. Mekong River, GIWA Regional assessment 55. University of Kalmar, Kalmar, Sweden.

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Publishing house: Kirjastusaktsiaselts MATS, Tallinn
Printed in Estonia by Tallinna Raamatutrükikoda, 2006

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Preface

This report presents the output of the Global International Waters Assessment for the Mekong River carried out by the Southeast Asia START Global Change Regional Center (SEA START RC), Environmental Research Institute of Chulalongkorn University, Bangkok, Thailand, in collaboration with the Global International Waters Assessment (GIWA) of the United Nations Environment Programme (UNEP). Assessment studies were undertaken in accordance with the methodology developed by GIWA (GIWA 2001) and by conducting Scaling and Scoping Workshops organised by GIWA in collaboration with the SEA START RC. The workshops were attended by specialists with diverse expertise (see Annex I for a list of workshop experts and other contributing authors to this report).

The boundaries as well as the main physical and socio-economic characteristics of the Mekong River region were deliberated by the regional experts in order to provide sufficient background information and to define the area within which the impact assessment studies were conducted. Environmental and socio-economic impacts of the region were studied, based on the GIWA Scaling and Scoping Methodology.

The aims of this report is to present, in a single document, the available information on environmental and socio-economic impacts in the Mekong River region.

Executive summary

The 4 900 km long Mekong River is an international water body having its source in China's Qinghai province from where it flows southwards through the Tibet Autonomous region and Yunnan province of China, the eastern portion of Myanmar and the four countries of the Southeast Asian peninsula. It discharges to the South China Sea through the Mekong Delta to the south of Ho Chi Minh City in Vietnam. The Mekong River and its network of tributaries form the Mekong River Basin (MRB), draining parts of six countries: Cambodia, China, Lao PDR, Myanmar, Thailand, and Vietnam. The boundary of this region includes the entire Mekong River Basin and the coastal area surrounding the Mekong Delta.

The part of the MRB in China and eastern Myanmar are known as the Lancang or Upper Mekong River Basin (UMRB), and the lower part, the Lower Mekong River Basin (LMRB). The LMRB covers about 70% of the entire MRB and is more important, both socio-economically and environmentally, than the UMRB. The terrain of the UMRB is largely mountainous while in the LMRB there are vast areas of lowland and floodplain. The coastline of the Mekong Delta extends to around 650 km, of which about 350 km flank the South China Sea, and 300 km the Gulf of Thailand. The associated coastal area is characterised by large estuaries, sand dunes, tidal marshes, and mangrove forests.

The climate of the region ranges from cold temperate and tundra in the UMRB to tropical, monsoonal in the LMRB. The southwest monsoon (May to October) provides the rainy season, and the northeast monsoon (November to March), the dry season. The total water catchment area of the region is 795 000 km^2. Surface water resources are abundant with run-off amounting to approximately 475 billion m^3 in the rainy season and 78.8 billion m^3 in the dry season. Flooding occurs almost every year, particularly in the LMRB, when heavy rainfall prevails. Groundwater is an important resource in the alluvial deposits of northeast Thailand and in the Delta. The total potential capacity of groundwater resources is estimated to be about 60 million m^3 per day. In the MRB as a whole, fish are the principal aquatic living resource. It is estimated that there are 1 200 to 2 000 fish species, the majority of them freshwater and many of them migratory species travelling far in search of food and spawning grounds. Other important natural resources include minerals and timber.

The population of the MRB in 2000 was estimated to be approximately 65 million people. About 80% of this population live in rural areas, the great majority being farmers and fishermen. Crop cultivation is the main livelihood, with rice and other food crops grown primarily for household consumption. There are 71 cities with populations in excess of 100 000 with Phnom Penh in Cambodia and Vientiane in Lao PDR being the two largest urban centres. The population density is generally low, about 59 person/km^2 in the UMRB and 88 person/km^2 in the LMRB. The MRB is home to more than 70 ethnic groups, most practicing subsistence agriculture.

Hydropower is the major energy resource in the MRB. Large amounts of surface water are utilised to irrigate rice cultivation. However, water resources are still under-exploited. Groundwater resources in the region are used mainly for domestic and industrial consumption, with some used for irrigation. Almost all sections of the Mekong River and its associated main tributaries are navigable during the rainy season with the exception of the Khone Falls in southern Laos PDR.

The GIWA Task team selected Freshwater shortage, Pollution, Habitat and community modification, and Unsustainable exploitation of fish and other living resources as the priority environmental concerns affecting the transboundary waters of the region. This decision was justified by the assessment of their impacts on environmental, economic, social and health issues both as currently reported and anticipated for the future.

Currently, freshwater shortage per se does not appear to be a significant problem for the region. However, the impact of the Modification of stream flow has been considered severe. This is evidenced by changes in the flow volume of the Mekong River and its tributaries caused not only by changes in rainfall but also by development activities, notably the construction of dams for hydropower development, the improvement of river navigation routes and the diversion of river water for irrigation. Economic development and population growth will increase water demand, and the extensive development of hydropower schemes will significantly alter the hydrological cycle.

The impacts of pollution due to suspended solids have been considered to be severe. Development activities during the past decade including deforestation, mining, grazing and urbanisation have caused extensive soil erosion in many parts of the MRB resulting in high contents of total suspended solids (mainly suspended sediment) in the Mekong River and its major tributaries. The suspended solids are transported through the basin, altering channels and habitats and accreting in the Mekong Delta. The impacts of the loss and/or modification of ecosystems, categorised under the GIWA concern of Habitat and community modification, have been considered to be severe and are becoming major issues in the region. Modification or loss of the ecosystems has been found to deplete the living resources on which the rural communities depend for their subsistence. The impacts of Overexploitation and Impact on biological and genetic diversity have been evaluated as severe. The fisheries resources in the region have shown evidence of overexploitation, indicated by declining catches per fisherman and the great increase in the number of fishermen. The increasing population of the region also adds to the fishery pressure causing overexploitation. As with loss of ecosystems, these issues also deplete the resources on which rural communities depend.

Habitat modification was selected by the GIWA Task team as the main priority concern for the Mekong River region. Changes in habitats and the modification of communities are being caused by changes in the fluxes of water and sediment, particularly suspended solids, by increased pollution from point and diffuse sources, and by the introduction of new species into the aquatic environment. The Causal chain analysis of the Mekong River region in this report focuses on two of the factors causing habitat modification, stream flow modification (Freshwater shortage) and suspended solids (Pollution).

The flow regime of the Mekong River and its tributaries has been modified by changes in precipitation patterns and by human activities, particularly the construction of dams for hydropower development, the modification of rivers to improve navigation, and the diversion of river water for irrigation, industrial development and human settlements. Deforestation in the catchments is the principal cause of increased rates of surface water run-off that is increasing the frequency and intensity of flooding. Locally, the built environment is also causing increased rates of run-off. The raising of embankments or levées along the Mekong River and its tributaries is resulting in a significant reduction in the volume of floodplain storage, causing increased rates of river discharge and high flood levels. The increased rates of surface water run-off resulting from deforestation and land clearance in upland areas of the MRB are causing increased soil erosion and the consequent entrainment of suspended and bed-load sediments into water courses. Except where they are trapped in reservoirs or deposited on floodplains and riverbeds, the sediments are transported through the basin to the Mekong Delta, where they are deposited in mangrove forests or discharged to the sea. Suspended sediments are also being introduced to water courses from land disturbance through mining or urbanisation, for example.

The principal root causes of the modification of the water and suspended solid flow regimes through the MRB are population and economic growth. The population has grown rapidly in the past decade, and, by the year 2010, it is expected to have increased to 75-90 million people. Population growth has led to deforestation, increasing erosion rates and surface run-off, thus modifying the sediment loads and flow volume of the region's rivers. Over the next 20-30 years, demand for water and the pressure on natural resources will continue to increase in parallel with rapid population growth. Economic growth is a key driver of the changes affecting river fluxes in the MRB. Urbanisation, human settlement and industrial development activities have substantially increased water demand, while agriculture is a dominant economic sector and the largest consumer of water. Demand for electricity has surged in the last two decades in response to the rapid economic development experienced in the riparian countries of the MRB and elsewhere in Southeast Asia. Although at present, per capita electricity consumption in the riparian countries of MRB is generally low except in Thailand, demand is increasing rapidly. The great hydropower potential in Lao PDR, Myanmar and Yunnan province of China, and the increasing market demand for electricity in neighbouring countries including Thailand, Vietnam, Malaysia and Singapore, are promoting the development of lucrative hydroelectricity schemes in the MRB. To date, only 11 hydropower facilities have been constructed in the MRB, representing just 5% of its estimated hydropower potential. Many more facilities are planned. Economic development has also led to deforestation for timber or fuelwood supplies, agricultural expansion and urban development, all contributing to increased erosion and, consequently, sediment loads in the aquatic environment.

The importance of governance in addressing the transboundary environmental issues of the region is now widely appreciated and major steps have been taken in this regard. Various institutions and government agencies are involved in addressing and managing the water-related environmental issues and problems. Over recent decades all the riparian countries of the MRB have developed strategies, policies, laws, legislation and action plans, while numerous national and international donors, funding agencies and NGOs have initiated study programmes and assessments to facilitate and support the management of the region. External support agencies have contributed significantly to this process, providing support for capacity building, human resource development and technical studies related to environmental management. One agency, the Mekong River Commission, is a regional body responsible for the overall management of the MRB with the participation of four LMRB riparian countries, Thailand, Cambodia, Lao PDR and Vietnam.

The main policy relevant conclusions of the GIWA Mekong River Task team highlight the transboundary nature of the concerns and issues affecting, and forecast to affect, the region. Some environmental issues imply direct impacts on communities across national borders. Others are associated with decisions made at the regional scale, such as the development of transport and energy networks. With appropriate regional cooperation among the riparian countries, the transboundary impact of hydropower and other water-use development in the MRB can be limited by adopting integrated, multi-objective planning in order to optimise the utilisation of the region's water and living resources. Protected areas have been identified as a practical measure for conserving sensitive habitats and maintaining essential ecological processes. The GIWA Task team has recommended developing strategic action programs or policies based on further investigation of the driving forces behind the environmental problems in the region.

Acknowledgements

The authors would like to acknowledge the following experts, scientists and specialists, as well as their affiliated institutions from the riparian countries of the Mekong River Basin, who have significantly contributed to the preparation of this report:

Chaiyuth Suksri and David Coates, Mekong River Commission; David Jezeph, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP); Hans Friederich, The World Conservation Union (IUCN); Ian Campbell, Mekong River Commission; Ing Try, Department of Fisheries, Cambodia; John Dore, World Resources Institute (WRI); Le Huu Ti, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP); Le Quang Minh, Can Tho University, Vietnam; Li Ge, Ministry of Water Resources, China; Nicholaas van Zalinge, Mekong River Commission, Cambodia; Sansanee Choowaew, Mahidol University, Thailand; Sein Mya, Mekong River Commission; Somrudee Nicro, Thailand Environmental Institute; Thavivongse Sriburi, Chulalongkorn University, Thailand; Wijarn Simachaya, Pollution Control Department, Thailand; and Ruud Corsel, Mekong River Commission.

The authors are also grateful to the Global International Waters Assessment (GIWA) of the United Nations Environment Programme (UNEP) for their financial and technical support in conducting the assessment of the Mekong River Basin and in the preparation of this report.

Abbreviations and acronyms

ADB	Asian Development Bank
AIRC	Asian International Rivers Center
AMRC	Australian Mekong Resource Centre
CIDA	Canadian International Development Agency
CPUE	Catch Per Unit Effort
DANIDA	Danish International Development Agency
DDT	dichlorodiphenyltrichloroethane
DWT	Deadweight Tonnes
EIA	Environmental Impact Assessment
ENSIC	Environmental Systems Information Center
ENSO	El Niño Southern Oscillation
ESA	External Support Agency
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIWA	Global International Waters Assessment
GWh	Giga Watt hour
HCMPC	Hydropower Construction Management Professional Committee
IUCN	The World Conservation Union
JICA	Japan International Cooperation Agency
LMRB	Lower Mekong River Basin
MOC	Ministry of Culture
MOSTE	Ministry of Science, Technology and Environment
MRB	Mekong River Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
MW	Mega Watt
NGO	Non-Governmental Organisation
SEA START RC	Southeast Asia START Regional Center
Sida	Swedish International Development Agency
START	global change SysTem for Analysis, Research and Training
TSS	Total Suspended Solids
UMRB	Upper Mekong River Basin
UN	United Nations
UNCED	United Nations Conference on Environment and Sustainable Development
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USD	United States Dollar
WRI	World Resource Institute

Regional definition

This section describes the boundaries and the main physical and socio-economic characteristics of the region in order to define the area considered in the regional GIWA Assessment and to provide sufficient background information to establish the context within which the assessment was conducted.

Boundaries of the Mekong River region

The Mekong River and its network of tributaries form the vast Mekong River Basin, draining parts of six riparian countries: Cambodia, China, Lao PDR, Myanmar, Thailand and Vietnam. The river is an international water body which flows from its source in the Tanggula mountain range in Qinghai province, China (MOC/China 2004) for 2 161 km through Qinghai province, the Tibet Autonomous region and Yunnan province of China, and another 2 719 km through countries of the Southeast Asian peninsula to the south of Ho Chi Minh City in Vietnam, where it discharges to the South China Sea (MRC 1997a). Its total length is about 4 900 km.

The boundary of the Mekong River region includes the entire Mekong River Basin (MRB) and the coastal area adjacent to the Mekong Delta (Figure 1). The total catchment area is about 795 000 km^2, producing a run-off of approximately 475 000 million^3 during the rainy season (MRC 1997a). The part of the MRB within China and the eastern end of Myanmar is known

Figure 1
Boundaries of the Mekong River region
(Source: Elevation based on USGS 2003)

as the Lancang or Upper Mekong River Basin (UMRB), and the lower part, the Lower Mekong River Basin (LMRB). The UMRB is predominantly mountainous, whereas lowlands and floodplains prevail in the LMRB. The LMRB covers about 70% of the whole basin and is its most important part both environmentally and economically. Its population is largely rural and employed mostly in agriculture or related activities, with rice as the major crop (Chu et al. 2003).

Physical characteristics

The Mekong River Basin comprises a large network of tributaries, forming many sub-basins. While the watersheds of the UMRB are contiguous (Figure 1), those of the LMRB are much more complex with around 125 small and large watersheds (MRC 1997a). Watersheds with areas of more than 10 000 km^2 are shown in Figure 2 and their areas listed in Table 1. The watersheds harbour large areas of forest, paddy fields, streams and creeks forming a complex, rich and diverse ecosystem supporting over 65 million people.

Figure 2 Major watersheds in the Lower Mekong River region
(Source: Redrawn from MRC 1997a, MRC 2004)

The Mekong River Basin is divided into six bio-geographical zones or landforms as shown in Figure 3 and Table 2:

- Lancang River Basin (UMRB) (parts of Qinghai province, the Tibet Autonomous region and Yunnan province in China);

Table 1 Areas of the major watersheds in the Mekong River region

Name of watershed	Area (km^2)	Name of watershed	Area (km^2)
Lancang River (Yunnan province)	89 320	Nam Mun	70 900
Nam Ou	25 830	Se Kong	28 710
Nam Mae Kok	10 780	St Sreng	10 380
Nam Ngum	17 170	Se San	18 710
Nam Cadinh	14 860	St. Mongkol Borey	11 350
Nam Songkhram	13 090	Sre Pok	31 11
Se Bang Fai	10 240	St. Sen	16 250
Nam Chi	49 100	Mekong Delta	49 520
Se Bang Hieng	19 340		

(Source: Hirsch & Cheong 1996, MRC 1997a, Puustjarvi 2004)

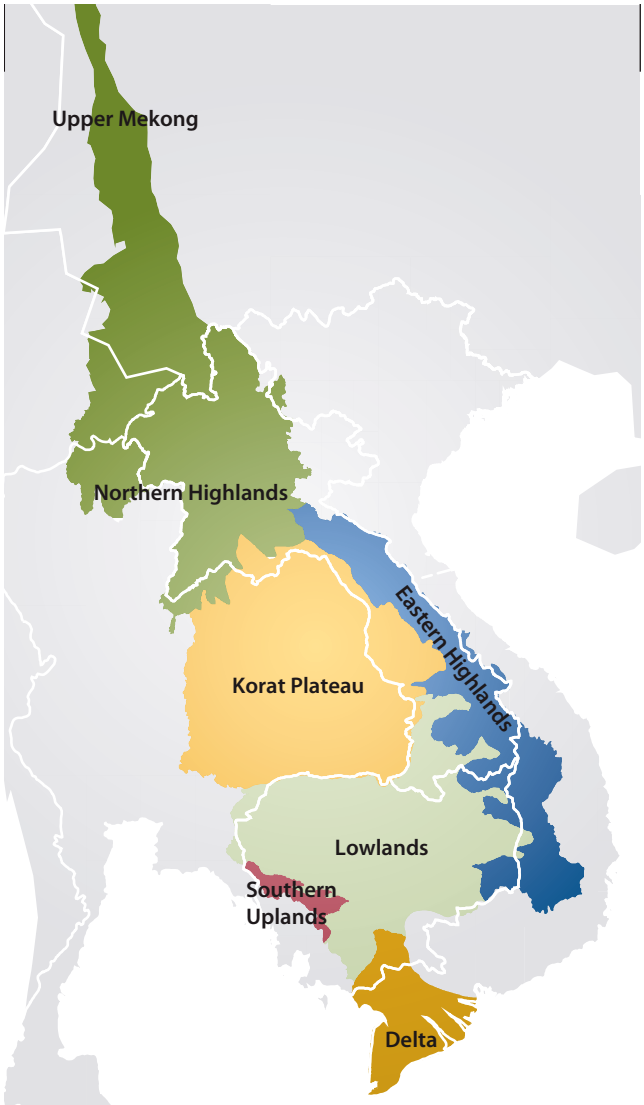

Figure 3 Bio-geographical zones of the Mekong River region
(Source: MRC 1997a, MRC 2004)

Table 2 General statistics relating to the Mekong River Basin

Basin (catchment) area (2004)	795 000 km^2
Area above 3 000 m altitude (2004)	62 000 km^2 (7.8% total basin area)
Mean annual run-off (2004)	560 mm
Discharge volume (2004): Rainy season Dry season	 475 000 million m^3 78 800 million m^3
Major cities in the MRB (2004)	Phnom Penh (Cambodia); Vientiane (Lao PDR); Luang Phrabang (Lao PDR); in Vietnam: Cao Tho, Nong Khai and Khon Khean
Loss of original forest area (up to 1998)	69%
Deforestation rate (1998)	16%
Eroded area (1998)	21% of total basin area
Large dams (>1 500 MW) in operation (2003): UMRB LMRB	 4 0
Small dams (<1 500 MW) in operation (2003): UMRB LMRB	 4 11
Wetlands (1998)	9% of total basin area
Protected areas (1998)	5% of total basin area
Population density (1998)	78 people per km^2 (average for entire MRB)

(Sources: ADB/UNEP 2004, WRI 2004)

- Northern Highlands (parts of Yunnan province in China, Lao PDR, Myanmar and Thailand);
- Korat-Sakon Plateau (parts of northern Thailand and southern Lao PDR);
- Eastern Highlands (parts of Lao PDR and Vietnam);
- Southern Uplands (part of Cambodia); and
- Lowlands (parts of Cambodia, Lao PDR and Vietnam including the Mekong Delta and its associated coastal area).

Lancang River Basin

The watershed of the Lancang River is typified by high mountains and deep gorges. The northern part of the river valley lies at some 2 000 m and is flanked by mountains of 3 500 to 5 000 m (MRC 1997a). The central part of the catchment comprises medium-sized mountains and wide, fertile valleys above 1 000 m. This is the most habitable and populated part where relatively large-scale agricultural, industrial and urban development has taken place. The southern part of the catchment is characterised by medium to low mountains and valleys below 1 000 m, with limited arable land and small population centres. The high flow relief of the Lancang River (average 6.5 m/km) provides potential for hydropower development (Hirsch & Cheong 1996, MRC 1997a).

Northern Highlands

The Northern Highlands cover parts of southern Yunnan in China, eastern Myanmar, northern Thailand and northern Lao PDR (Figures 1-3). The MRB here is characterised by high mountains with several peaks rising to over 2 000 m and valley floors more than 600 m below the mountain crests. The rough terrain is largely uninhabitable, thus human population is sparse. Agricultural activities are limited to rice production in the narrow valley floors and shift cultivation on the mountainsides. The greatest development potential of this area is for hydropower. Some large-scale hydropower schemes are already established in Myanmar, Thailand and Lao PDR (Hirsch & Cheong 1996).

Korat-Sakon Plateau

The Korat-Sakon Plateau extends over northern Thailand and the floodplains of southern Lao PDR. It is surrounded by the northern and eastern highlands in Lao PDR and the Petchabun and Phnom Dangrek mountain ranges in Thailand and northern Cambodia (MRC 1997a). The plateau is drained mainly by the Nam Mun, Nam Chi and Nam Songkhram rivers (tributaries of the Mekong River) in the north of Thailand (Figure 2). These rivers are generally incised several meters below the predominantly sandstone plateau. The Plateau is the driest part of the MRB. It has low rainfall and most of its soils have a poor capacity for moisture retention (Hirsch & Cheong 1996). Despite low soil fertility agriculture is extensive and there is potential for further agricultural development by installing flood controls, drainage and irrigation as well as taking measures to reduce salinsation (MRC 1997a).

Eastern Highlands

The Eastern Highlands cover the mountain ranges extending over eastern Lao PDR and central Vietnam, spanning an area of approximately 300 km long and 50 km wide (Hirsch & Cheong 1996, MRC 1997a). Networks of tributary rivers draining the Highlands are numerous, the large ones are the Nam Cadinh, Se Bang Fai, Se Bang Hieng, Se Kong, Se San and Sre Pok (Figure 2). Rainfall is the highest in the MRB with its tributaries contributing about two-fifths of the total water volume in the Mekong River (Hirsch & Cheong 1996). It is the most heavily forested area of the entire MRB and rich in biodiversity. Rotational farming is the commonest crop production method practiced by a wide range of indigenous communities in this area (Evans 1992). The upper part of the Highlands, generally of high relief, has a high potential for hydropower development; several large projects are already underway or imminent in the Laos and Vietnamese sections (Hirsch & Cheong 1996).

Southern Uplands

The Southern Uplands are extensions of the Northern Highlands and include the Cardamom and Elephant ranges in southeastern Cambodia (MRC 2003). They are drained by the Tonle Sap River which flows northward into the Tonle Sap, the great lake of Cambodia (see below), and by the Prek Thont River into the Basaac River (Hirsch & Cheong

1996). The uplands, including the mountain ranges, are still densely forested. They have low population densities and are considered significant areas for nature conservation.

Lowlands

The Lowlands cover a large part of the northern half of Cambodia and areas in southern Lao PDR, eastern Thailand and southern Vietnam, as well as the Mekong Delta and its associated coastal area (Figure 3). The Mekong River flows from the highlands of the Korat-Sakon Plateau to the northern part of this vast lowland area where it is broken by the Khone Falls (Figure 3), which form an obstruction to navigation. Surrounding habitats have great aquatic biodiversity significance (Hirsch & Cheong 1996). Two landforms of great importance in these Lowlands are the lake Tonle Sap on the floodplain in Cambodia and the Mekong Delta mainly in Vietnam. The Tonle Sap is the largest lake in Southeast Asia. It serves as a natural reservoir storing flood waters from the surrounding watersheds and regulating river flows in the dry season, thus helping to relieve droughts in southern Cambodia and the Mekong Delta (MRC 2003). The lake's area can increase from 250 000 to 300 000 ha in the dry season to as much as 1.3 million ha in the rainy season (MRC 1997a, MRC 2003).

The Mekong Delta is a triangular area at the southern tip of the Lowlands (Figure 3). It covers around 49 520 km^2 with 74% of this area in Vietnam and the rest in Cambodia (MRC 1997a). The Delta is historically the most densely populated area of the MRB with large areas of fertile agricultural lands (Snidvongs et al. 2003). It can be divided into three sections: upper, middle and lower. The upper section has strong natural levées – embankments built on either side of the river by accumulated deposits of silt. Behind the levées there are wide depressions. The middle section includes well drained arable land as well as poorly drained areas. The lower section is formed by the river distributaries and their associated sediments (Tuvy 2004). The coastline along the Delta is around 650 km in length of which around 350 km borders the South China Sea and the remaining 300 km flanks the Gulf of Thailand (MRC 1997a). The coastal area is characterised by large estuaries, sand dunes, tidal marshes and mangrove forest (MRC 1997a).

The Mekong Delta has three major water and land resource problems. Acute flooding occurs during the wet season when flood waters can rise more than four metres in much of southern Cambodia and the upper Delta (Hirsch & Cheong 1996). Another problem is the occurrence of acid sulphate soils in several areas, making them unsuitable for agriculture. Actual and potential acid sulphate soils, covering an area of about 1.6 million ha, occur mainly in the Dong Thap Muoi and Long Xuyen quadrangles (Cao 2004). The third problem is that of saline water intrusion. During the dry season, the river flows are so low that sea water intrudes the lower reaches; this produces brackish water conditions that are unsuitable for rice production (White et al. 2004).

The climate

The climate ranges from cold temperate and tundra in the UMRB to typically tropical monsoonal in the LMRB. In the UMRB, the peaks of the higher mountains in the catchment of the Tibet Plateau are almost permanently snow-capped. The climate is cold without any clear summer season and rainfall is generally low (Liu 2004). At lower elevations in Yunnan province, the climate is predominantly sub-tropical with higher rainfall (as high as 1 700 mm annually) and clearly demarcated seasons (Chu et al. 2003). Elsewhere in the LMRB, the climate is largely tropical monsoonal. The southwest monsoon usually begins in the latter half of May and continues to early October. The northeast monsoon starts in early November and continues to early March.

In the LMRB the southwest monsoon brings high rainfall resulting in the onset of the rainy or wet season while the northeast monsoon has low rainfall and forms the dry season. Air temperature is remarkably uniform due to the area's maritime influence and generally low elevation. High temperatures occur except during part of the northeast monsoon when

Table 3 Key characteristics of the various bio-geographical zones

Bio-geographical zone/landform	Rainfall (mm/year)	Type of vegetation & land	Population density (person/km^2)	Main economic activities	Environmental problems
Lancang River Basin (UMRB)	Variable: 600-2 700	Mountain brush, meadow, pine forest, mixed evergreen & broad-leaved; some arable land	Low to moderate: 7-145	Agriculture (frequently shifting)	Erosion, forest degradation and natural disasters
Northern Highlands	Wet: 2 000-2 800	Hill evergreen and mountain forest; grassland	Low: 8-15	Agriculture (frequently shifting)	Erosion and forest degradation
Korat-Sakon Plateau	Relatively dry: 1 000-1 600	Scrubs; grassland & arable land	Moderate: 80-160	Agriculture (irrigated and rain-fed)	Limited water resources, floods, drought, salinization and low soil fertility
Eastern Highlands	Wet: 2 000-3 200	Upland savannah & rain forest	Low: 6-33	Agriculture (shifting)	Erosion, soil degradation, forest degradation
Lowlands	Variable: 1 100-2 400	Arable lowland and dense upland	Moderate to dense in Lowlands: 10-570 Very low in Upland: less than 8	Agriculture in Lowlands (rice cultivation) Small development in Upland	Flooding, acid-sulphate soils, salinity intrusion, drought in lowland and forest degradation in upland

(Source: Snidvongs et al. 2003)

Figure 4 Precipitation in the Mekong River region
(Source: ESRI 1997)

cool winds blow from Central Asia. Lowest temperatures occur between November and February (MRC 2003). The hottest months are at the beginning of the dry season with average air temperatures of 30-38°C.

Precipitation in the region varies with location. Rainfall is low on the Tibet Plateau and increases southwards through the MRB, being the highest in the Mekong Delta (Figure 4). As indicated in Table 3, rainfall ranges from 600 to 3 200 mm per year. Cyclonic disturbances during the rainy season may cause widespread rainfall of long duration during July-September, resulting in flooding (Chu et al. 2003). With the onset of the southwest monsoon in May, the level of the Mekong River rises reaching its peak in mid-August or early September in the upper part of the LMRB, and in mid-September or early October in the Delta (MRC 2003). Flooding in the Cambodian and Vietnamese parts of the MRB is usually disastrous with up to 4 million ha of Cambodia's lowland areas and up to 1.8 million ha in the Delta inundated annually.

Water resources

The total water catchment area of the region is large (795 000 km^2). The Lao PDR catchment accounts for 25% of this total, Thailand 23%, Yunnan 21% and Cambodia 20%, while Vietnam accounts for 8% and Myanmar 3%. The region's catchment produces abundant surface water resources with discharge amounting to approximately 475 000 million m^3 in the rainy season and 78 800 million m^3 in the dry season (Table 4). About 17-19% of this discharge is contributed by the Cambodian catchments, 32-35% by Lao PDR's, only around 2% by Myanmar's, 15-17% by Thailand's, 10-11% by Vietnam's, and 16-25% by Yunnan's. Discharges in the dry season are 4 to 7 times lower than those in the rainy season (Table 4).

The availability of surface water resources in terms of the amount internally renewable annually also varies widely by country. Around 97% of the land area of Lao PDR and 86% of Cambodia as well as

Table 4 Contribution of discharges to Mekong River Basin

Description	Riparian country/province						MRB
	Yunnan, China	Myanmar	Lao PDR	Thailand	Cambodia	Vietnam	
Catchment							
Area (km^2)	165 000	24 000	202 000	184 000	155 000	65 000	795 000
Contribution to MRB total (%)	21	3	25	23	20	8	100
% of total area of country/province	38	4	97	36	86	20	
Average discharge (million m^3)							
In rainy season	76 128	9 416	166 195	80 732	90 193	52 350	475 014
In dry season	19 032	1 419	24 929	12 110	13 529	7 852	78 871
Average discharge as % of total MRB:							
Rainy season	16	2	35	17	19	11	100
Dry season	24.1	1.8	31.6	15.4	17.2	9.9	100

(Sources: ENSIC 1999, Ringler 2001, MRC 2003)

Table 5 Availability of water resources and withdrawals

Riparian country or province	Availability*			Withdrawal		Withdrawal to availability in 1995 (%)
	Total 1995 (m^3)	Per capita 1995 (m^3)	Estimated per capita 2020 (m^3)**	Total 1995 (m^3)	Per capita 1995 (m^3)	
Yunnan province, China	2 800 000	2 292	5 171	500 000	407	18
Myanmar	606 000	13 024	13 366	4 000	86	0.7
Lao PDR	270 000	55 305	20 345	1 000	205	0.4
Cambodia	88 000	8 585	4 811	1 000	98	1
Thailand	210 000	3 559	2 392	33 000	559	16
Vietnam	318 000	4 479	1 647	65 000	915	20

** Availability refers to the amount internally renewable annually (** Sokhem pers. comm.). (Source: ESCAP 1998)*

large areas of Thailand and Vietnam derive their water needs from the Mekong River Basin. In Yunnan province, China, the major source of supply comes from the MRB, but Myanmar is not dependent on basin waters (Table 5). As indicated in Table 5, in 1995 Lao PDR had the largest per capita availability of water resources while the availability in Yunnan province was the lowest. At the same time, Vietnam had the highest per capita withdrawal rate of the MRB's water resources, followed by Thailand and Yunnan province. Vietnam also has the highest ratio of withdrawals to availability, followed by Yunnan province, while low ratios were observed for Lao PDR, Myanmar and Cambodia (Table 5).

There are believed to be extensive groundwater resources in the region although these have not been adequately assessed (MRC 1997a). Aquifers of recent alluvium flank the mainstream Mekong River in northeast Thailand and the Mekong River Delta. These aquifers are recharged mainly through rainwater seepage. More than 6 000 groundwater wells are reported to have been drilled in these aquifers and in other parts of the MRB since 1980. Total potential capacity of the groundwater resources in the region is estimated to be around 60 million m^3/day (Chu et al. 2003).

Biodiversity, critical habitats and land cover

The Mekong River Basin possesses immense biodiversity of exceptional international significance, including many unique ecosystems and a wide array of globally-threatened species (GEF 2004). These include new genera of large mammals (*Pseudoryx, Megamuntiacus, Pseudonovibos*) discovered in the past decade and many bird species identified as globally threatened or globally near-threatened, including the famous Eastern saurus crane (*Grus antigone sharpii*), Giant ibis (*Pseudibis gigantea*), White-shouldered ibis (*Pseudibis davisoni)* and Bengal florican (*Eupodotis bengalensis*) (Friederich 2004). Aquatic biodiversity is also high. A recent study by IUCN lists the MRB as one of the nine richest habitats for fish biodiversity globally, with 298 recorded species, including the endemic Giant catfish (*Pangasianodon gigas*), the Giant Mekong barb (*Catlocarpio siamensis*) and several species of giant stingray (*Dasyatis* sp.). More recent estimates have raised this to over 480 species (Coates et al. 2003). The LMRB is considered a biodiversity hot-spot for molluscs, with 160 endemic species. The river also harbours an endangered population of Snubfin dolphins (*Orcaella brevirostris*) and the Siamese crocodile (*Crocodylus siamensis*).

Aquatic living resources represent significant biological value in terms of species composition and diversity (MRC 1997a). Fish represents the major aquatic living resource in the MRB with 1 200 to 2 000 species, the majority of which are freshwater species (Ringler 2001). Many of these are migratory and may travel far in search of food and spawning grounds. For instance, the Giant catfish (*Pangasianodon gigas*) (Figure 5) has been reported to migrate from Cambodia to its spawning grounds in Yunnan province (McElwee & Horowitz 1999).

The MRB's wetlands play a critical role as staging posts in the flyways for migratory birds. The Tram Chim National Park in Vietnam hosts almost the entire world population of Eastern sarus crane during the dry season. The freshwater wetlands are also important for migratory egrets and shorebirds, and the intertidal coastal areas, for shorebirds from northeast Asia (Friederich 2004). The total area of wetlands in the Cambodian part of the MRB is around 36 500 km^2, in Lao PDR 2 200 km^2 and in Thailand 2 000 km^2. The wetlands in the Mekong

Figure 5 Mekong Giant catfish.
(Photo: Suthep Kritsanavarin/U.S. Newswire Photography, 2005)

Table 6 Types and areas of land-cover in the Mekong River region

Type of land-cover	Area (km^2)		% of total MRB area	
	1992-1993	2003	1992-1993	2003
1. Forest land	340 620	242 475	42.8	30.5
2. Grassland, savanna & shrubland	140 754	136 740	17.7	17.2
3. Wetlands – rivers & lakes	11 643	69 165	1.5	8.7
4. Crop land or agricultural land Non-irrigated cropland Irrigated cropland	227 518	323 565 277 455 23 055	28.6	40.7
5. Dry land or semi-desert land	70 644	6 360	8.9	0.8
6. Urban & industrial centres	438	16 695	0.1	2.1
7. Tundra (treeless plain with frozen subsoil)	3 383	-	0.4	-
Total	795 000	795 000	100	100

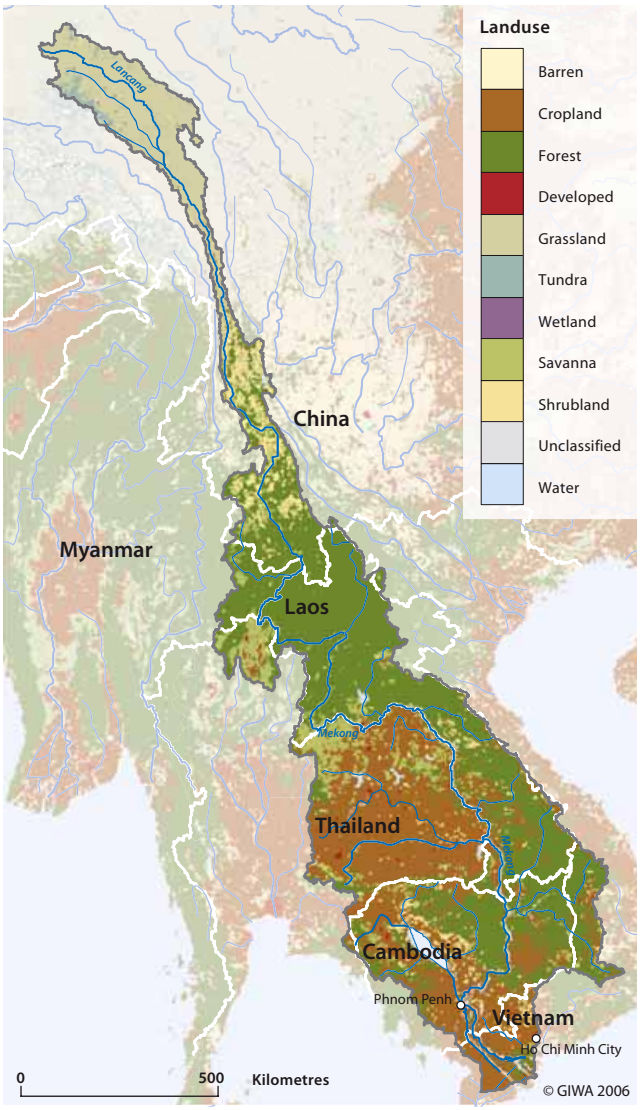

Figure 6 Land cover in the Mekong River region
(Source: IUCN 2004a)

Delta in Vietnam cover an area of 20 000 km^2. Within the UMRB, the largest known wetland is the 250 km^2 Er Hai lake in Yunnan province (ADB/UNEP 2004).

Forest coverage in the MRB has declined from over 70% to below 30% in the past fifty years due to destruction by logging, uncontrolled shift cultivation, the encroachment of forest reserves for human settlements, uncontrolled farming and infrastructure development (MRC 1997a). Types of land-cover and changes over the period 1992/3-2003 are shown in Table 6 and Figure 6.

Socio-economic characteristics

Population and health

The Mekong River Basin had a population of approximately 65 million people in 2000, of whom about 55 million live in the LMRB. In 2000, the average proportion of the MRB's population living in urban areas was around 29%, an increase of about 6% over that in 1990. This proportion is likely to increase significantly due to rapid urbanisation over the next decades. The great majority of the MRB's inhabitants are farmers and fishermen, as illustrated in Figure 7 by the high population densities in arable lands. About 80% of the MRB's population live in rural areas. There are 71 large cities with populations in excess of 100 000 (IUCN 2004b). The average population density is generally low, around 59 person/km^2 for UMRB and 88 person/km^2 for LMRB. The density is highest (260 person/km^2) in the Vietnamese part and lowest in Lao PDR, around 24 person/km^2. In 1995, life expectancy, at 49-50 years, was lowest in the Cambodian and Lao PDR areas, but higher, at 64-67 years, in the Thai and Vietnamese areas.

The region is characterised by a rich cultural diversity with more than 70 ethnic groups living in localised communities and having their own languages and traditions. These ethnic groups use knowledge, traditions and land use systems that are closely interwoven with the surrounding local environment and natural resources to sustain their daily life (MRC 2003).

Health conditions for children and women are among the poorest in the world, particularly in less developed areas of the LMRB. In 1993, infant mortality rates in Cambodia and Lao PDR were high, about 3-4 times higher than those of Thailand and Vietnam. Due to economic growth in the 1990s, infant mortality rates fell in many parts of the LMRB and there will be further improvements in less developed areas if women have better access to education and health services (MRC 2003). In the MRB,

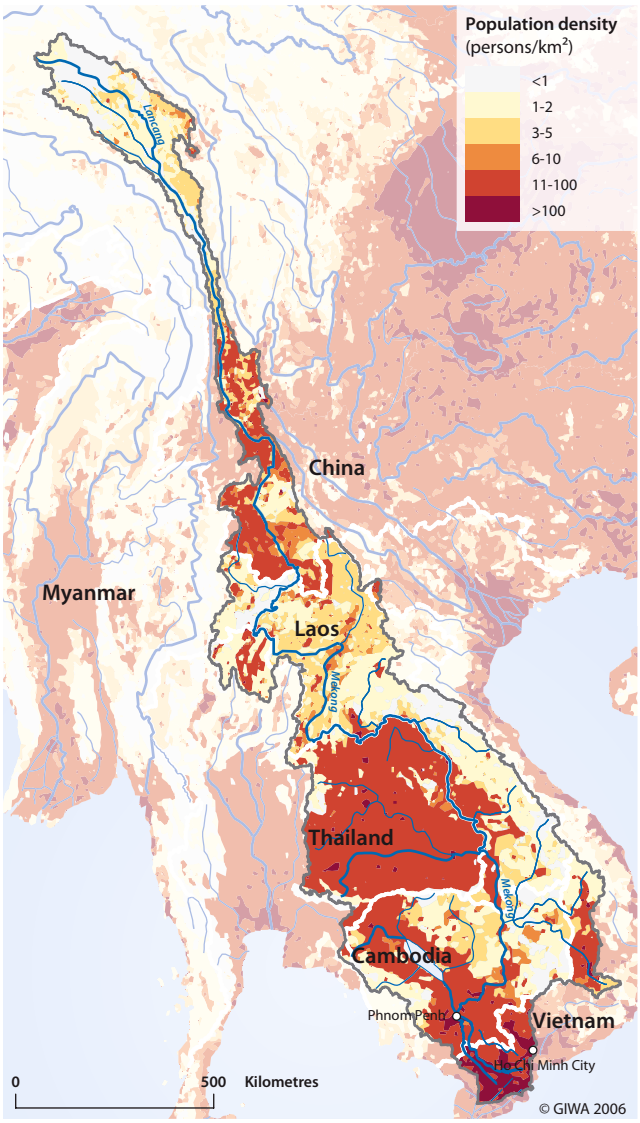

Figure 7 Population density in the Mekong River region.
(Source: data from ORNL 2003)

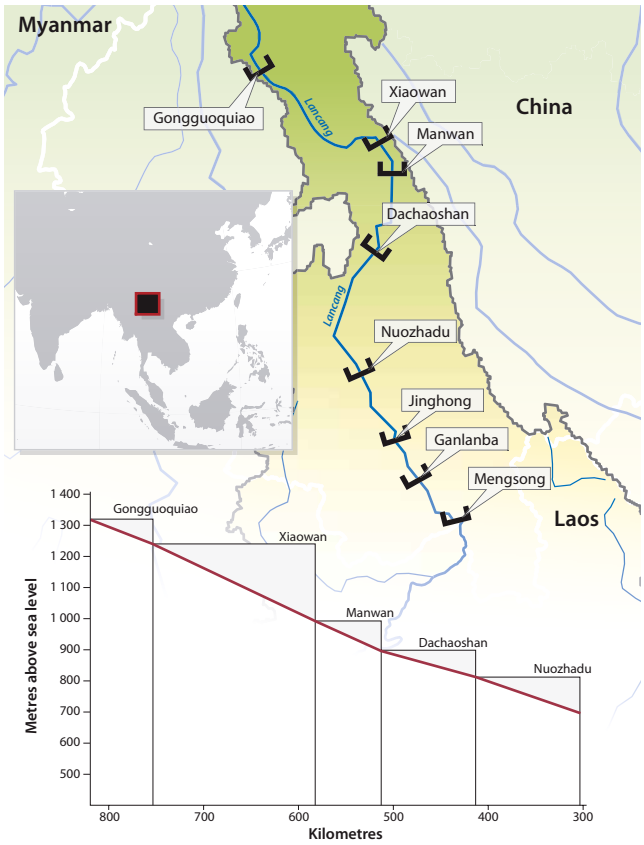

Figure 8 Location and elevation of the existing and proposed dams in Lancang River
(Source: McCormack 2000)

malaria and HIV/AIDS are the two leading public health problems. Cambodia has the highest and fastest growing rates of HIV/AIDS, although recent data suggest that the situation is stabilising. HIV/AIDS rates in Thailand have fallen due to the implementation of effective prevention programmes. However, women in the general population and their unborn children are also at risk because so many men migrate to urban centres in search of work (MRC 2003).

Hydropower

The region has a large potential for hydropower development, with some dams already in commission (AMRC 2003). Over the past ten years, more than 100 large dams have been proposed by, for example, the Asian Development Bank (ADB) and the Mekong River Commission (MRC). In the Lancang River Basin (UMRB), development is typified by the Lancang Cascade project which aims to construct and operate dams for hydropower development. The project is creating a cascade of dams, taking advantage of a 700 m elevation drop occurring over 750 m-stretch of the middle and lower reaches of Lancang River (Figure 8). Construction of the dams began in 1986 with the Manwan Dam followed ten years later by the Dachaoshan Dam. In 2000, a total of eight dams were reported as constructed or planned (Figure 8), and, according to a recent report from the Hydropower Construction Management Professional Committee (HCMPC) of China Hydropower Engineering Association, the number of dams along the Lancang River is to be increased to 15, with a total installed capacity of 25 605 MW, construction is expected to be completed by the year 2020 (Xu & Moller 2004).

In the LMRB, most of the planned dam projects are located on tributaries in Lao PDR. A concession agreement for the development of 23 hydropower projects, having a combined installed capacity of around 6 800 MW and with an annual generation capacity of 38 000 GWh, has been signed (MRCS 1997). No new hydropower

Figure 9 Location of the completed hydro-dams along the Mekong River region
(Source: MRC 2003)

projects have been planned in the Thai part of the MRB since the most suitable sites have been developed. Although the tributaries in Cambodia have considerable potential for hydropower development, no new projects have commenced since 2000. Vietnam has plans for several hydropower projects along tributaries in the Central Highlands. Among them, the Yali dam with a capacity of 720 MW has been completed for operation (Chu el al. 2003). In addition, the MRC has plans to develop up to 13 run-of-the-river hydropower projects in the LMRB including nine sites with a total capacity of 14 000 MW, which are considered to be priority projects by the MRC (MRCS 1994, MRCS 1995). The existing hydropower dams in the MRB are shown in Figure 9.

Agriculture and irrigation

Agriculture is a dominant economic sector in the Mekong River Basin. About 75% of the population in the MRB is dependent on agriculture and fisheries. In 1996, agriculture contributed 11% of Thailand's national income and 52% of Lao PDR's national income. During 1987 to 1997, growth in the agricultural GDP was largest in Vietnam at 5.4% per year and slowest in Cambodia at 3.6% per year. In 1996, at least one-third of the economically active population in the MRB was reported to be employed in agriculture. Cambodia has the largest share of labour employed in agriculture at 41% of basin's total labour force (Chu et al. 2003). For generations farmers in the MRB have used waters from the Mekong River and its tributaries to irrigate their crops. In 1999 in Cambodia, Vietnam and Lao PDR respectively about 7%, 30% and 40% of their total agricultural areas were irrigated by farmers using waters from the Mekong River and its tributaries (FAOSTAT 2004).

About 10% of the Korat-Sakon Plateau in northeast Thailand has been reported as irrigated, mainly supplementary wet season irrigation, with a total irrigated area estimated at 450 000 to 900 000 ha. In the dry season, less than 100 000 ha are irrigated by means of a series of reservoirs deriving water from the tributaries of the Mekong River (MRC 1997b). In Cambodia in 1993, the total irrigated agricultural area was estimated to be 390 500 ha, of which 70% were provided with fully or partially controlled irrigation, the remainder being used largely for floating rice production (FAO 1999). In the Mekong Delta of Vietnam, irrigation has been of particular importance in view of the rapid agricultural development in this area. The total cultivated area in 1990 was estimated to be around 2.4 million ha, of which about 1.0 million ha were irrigated. The introduction of fully or partially controlled irrigation has tripled food production, mainly of rice, from 4.5 million tonnes to 13 million tonnes between 1975 and 1995 (Phan 1996). In the Lowlands of the MRB, irrigation is increasingly used to enable a second, and even a third, rice crop as well as dry season or perennial cash-crops to expand rainy season production. The total irrigated area in the Chinese part of the UMRB in 1990 was estimated to be 291 000 ha, 90% of which were located in Yunnan province (Ringler 2001). Although large irrigation schemes have been constructed on the Chi and Mun watersheds of the MRB, local opposition to construction has slowed additional irrigation schemes. In the Central Highland areas of the MRB, irrigation is limited and used primarily for rice and coffee production (Ringler 2001).

Fisheries

Fish is the major source of low-cost and high quality protein for the people in the Mekong River Basin. Fisheries also provide income-earning opportunities for the unemployed and under-employed local communities. The Mekong River and its associated tributaries and wetland habitats provide 70-80% of fish and other aquatic animals consumed by the LMRB's inhabitants (Hortle & Bush In prep.). The MRB, mostly the LMRB, supports one of the richest river fisheries in the world. Catches from the capture fisheries constitute around 90% of the total fish production in LMRB. In 1998, total production of the capture fisheries from the MRB as a whole was around 1.16 million tonnes. Aqua-culture production comes mainly from the LMRB (Coates et al. 2003),

where there are at least 2 million rural households involved in culturing fish. Total freshwater aquaculture production in the LMRB rose from 60 000 tonnes in 1990 to 255 000 tonnes, valued at 244.6 million USD per year in 2001 (MRC 2003).

Navigation

Inland water transport by boats and vessels navigating the Mekong River and its tributaries is an important mode of transport particularly for bulk cargo. The Mekong River is navigable in various sections from Nandeba, in Yunnan province, to the Mekong Delta and into the South China Sea. Almost all sections of the Mekong River and its associated tributaries are navigable during the rainy season when the river water level is high, with the exception of a 14 km-long section which contains the impassable barrier of the Khone Falls, just north of the border between Cambodia and Lao PDR (MRC 2003). Water transport in the MRB, particularly the LMRB, has traditionally been the principal means of travel for much of the population, especially for those in remote areas (Chu et al. 2003). It has been estimated that some 1.4 million Cambodians depend totally on inland waterways for transport, while in Lao PDR around 320 000 people depend on water transportation for most of the year. In Vietnam about 73% of the country's cargo tonnage and 27% of its passengers travel by water, while Thailand makes the least use of water transport because the country has the benefit of extensive all-season roads (MRC 2003).

Urbanisation and industrial development

Urban centres and industries in the Mekong River Basin depend very much on the Mekong River and its tributaries for their water supply. For example, around 60% and 30% of the population respectively of Phnom Penh in Cambodia and Vientiane in Lao PDR are connected to public water supply systems which draw waters from the Mekong River and its tributaries. The total water demand per capita and domestic-industrial water demands in 1990 and 2020 are presented in Table 7.

Table 7 Total water demand per capita and domestic-industrial demand in the Mekong River region

Riparian country or province	Total demand per capita (m^3)	Domestic-industrial demand (million m^3)	
	1990	1990	2020
Yunnan province, China	250	121	328
Thailand	350	725	1 467
Lao PDR	280	70	168
Cambodia	150	78	187
Vietnam	550	899	1 994
Total		1 893	4 144

(Source: Ringler 2001)

Minerals and energy

There are high geological and economic potentials for the development of mineral commodities in the region (ADB/UNEP 2004). Mineral resources include gemstones, alluvial gold, alluvial cassiterite, silica, bauxite, calcite and construction materials. In addition to hydropower, energy resources include fuelwood, oil, natural gas, coal and lignite. Oil, natural gas and coal occur in Myanmar, Cambodia and Yunnan province. The reserves are probably sufficient to meet future domestic needs (MRC 1997a, ADB/UNEP 2004). Fuelwood is a vital resource in most areas of the MRB and is used in 80-90% of the households in Cambodia (Sokhem pers. comm.).

Legal and institutional frameworks

Various institutions and government agencies in the region are involved in addressing and managing water-related environmental issues and problems. The functions and activities of these institutions/agencies are illustrated in Annex III. Over recent decades, all the riparian countries of the MRB have developed strategies, policies, laws, legislation and action plans (Table 8), while numerous national and international donors, funding agencies and NGOs have initiated study programmes and assessments to facilitate and support the management of the region. The programmes and initiatives as well as specific laws and legislation related to the environmental management of the region are provided in Annex IV. These initiatives form a strong legal and institutional framework playing vital roles in ensuring the environmental well-being of the region.

Table 8 National initiatives for managing the environment of the Mekong River region

Riparian country/ province	State of environment report	UNCED national report	National conservation strategy	National environmental action plan	Sector action plans for			
					Protected areas	Biodiversity	Tropical forestry	Wetlands
Cambodia	1995			1995				1995
Lao PDR	1995	1992		1993	1993	1995	1995	
Myanmar	1995	1992		Under Prep.				
Yunnan	1995	1991	1990	1995				
Thailand	1995	1992	Under prep.					
Vietnam	1995	1991	1985	1995		1993	1991	

(Source: MRC 1997a)

Regional cooperation and external support agencies

External support agencies (ESAs) have contributed significantly to environmental management in the MRB, through supporting bilateral and multilateral assistance in environmental management

or assessment programmes (MRC 1997a). These programmes provide very significant inflows of foreign capital for capacity building, human resource development and technical studies related to environmental management, totalling more than 800 million USD in 1995. They provide not only funding but also technical expertise. Multilateral programmes are delivered by UN agencies, the World Bank, ADB, international NGOs and others. Bilateral programs are often facilitated through government international assistance agencies such as CIDA, DANIDA, JICA, Sida and USAID. ESAs have funded environmental activities for almost 40 years. Recently, ADB has funded projects for strengthening environmental institutions in the areas of training, NGO support, establishing legislation and regional standards and EIA. Some ESAs promote interest in technologies and services while others promote development initiatives such as infrastructure and energy development (MRC 1997a, Chu et al. 2003).

The MRC is a regional agency responsible for the overall management of the MRB with the participation of four LMRB riparian countries – Thailand, Cambodia, Lao PDR and Vietnam. The MRC has the vision of promoting "an economically prosperous, socially just and environmentally sound Mekong River Basin" with a mission to "promote and coordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well being by implementing strategic programs and activities and providing scientific information and policy advice" (MRC 2003).

Transboundary issues and implications in managing the Mekong River Basin

The Mekong River is a transboundary international waterway that traverses six countries. The land, water, forest and fish resources are shared in a number of senses and at a number of scales among the riparian countries in the region (Hirsch 2004). Thus, water used by an upstream country may become unavailable to a downstream country on a temporary, seasonal or even permanent basis. Many transboundary environmental issues, such as the upstream-downstream watershed dynamics of water quantity, quality and timing, the trade in timber and non-timber forest products, and air pollution, have begun to receive attention as regional issues. Similarly, some actors and decision-makers in the region have begun to consider issues such as livestock movements, labour migration and public health as being of importance to the regional environment.

Assessment

Table 9 Scoring table for the Mekong River region.

Assessment of GIWA concerns and issues according to scoring criteria (see Methodology chapter)

IMPACT 0 No known impacts
IMPACT 1 Slight impacts
IMPACT 2 Moderate impacts
IMPACT 3 Severe impacts

The arrow indicates the likely direction of future changes.

↗ Increased impact
→ No changes
↘ Decreased impact

Mekong River	Environmental impacts	Economic impacts	Health impacts	Other community impacts	Overall Score**	Priority***
Freshwater shortage	2* ↗	1 →	1 ↗	2 ↘	1.7	3
Modification of stream flow	3					
Pollution of existing supplies	1					
Changes in the water table	1					
Pollution	2* ↗	1 ↘	2 ↗	2 →	1.8	4
Microbiological pollution	1					
Eutrophication	2					
Chemical	1					
Suspended solids	3					
Solid wastes	0					
Thermal	0					
Radionuclides	0					
Spills	1					
Habitat and community modification	3* ↗	3 ↘	1 ↘	2 →	2	1
Loss of ecosystems	3					
Modification of ecosystems	3					
Unsustainable exploitation of fish	3* ↗	3 ↘	0 ↘	2 ↘	2.3	2
Overexploitation	3					
Excessive by-catch and discards	1					
Destructive fishing practices	2					
Decreased viability of stock	ND					
Impact on biological and genetic diversity	3					
Global change	ND →	ND →	ND →	ND →	ND	5
Changes in hydrological cycle	ND					
Sea level change	ND					
Increased UV-B radiation	ND					
Changes in ocean CO_2 source/sink function	ND					

* This value represents an average weighted score of the environmental issues associated to the concern.

** This value represents the overall score including environmental, socio-economic and likely future impacts.

*** Priority refers to the ranking of GIWA concerns.

This section presents the results of the assessment of the impacts of each of the five predefined GIWA concerns i.e. Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, Global change, and their constituent issues and the priorities identified during this process. The evaluation of severity of each issue adheres to a set of predefined criteria as provided in the chapter describing the GIWA methodology. In this section, the scoring of GIWA concerns and issues is presented in Table 9.

IMPACT Freshwater shortage

Modification of stream flow

The flow volume of the Mekong River and its tributaries has been modified by changes in precipitation patterns and development activities, such as the construction of dams for hydropower, the improvement of river navigation, and the diversion of river water for irrigation, industrial development and human settlements.

Urbanisation, human settlement and industrial development activities are increasing the water demand in the basin. Ringler (2001) estimated that domestic and industrial water demand would increase more than two-fold from 1.89 billion m^3 in 1990 to 4.1 billion m^3 in 2020. The majority of this demand will be met using water from the Mekong River and its major tributaries, with groundwater supplying a smaller proportion.

In terms of the ratio of withdrawal to availability of water resources, Vietnam has the highest ratio followed by the Yunnan province of China while low ratios are observed for Lao PDR, Myanmar and Cambodia. Although water resources in the MRB are currently considered to be

under-exploited, per capita water availability is expected to decrease considerably in all of the riparian countries by 2020, except in Yunnan province and Myanmar (Table 5).

The largest user of water is irrigated agriculture. It is estimated that water withdrawals for irrigated agriculture account for 94% of total withdrawals in Cambodia, 82% in Lao PDR, 91% in Thailand and 86% in Vietnam (Chu et al. 2003). Over the past decade, the expansion of agriculture and the development of medium- and large-scale irrigation schemes in the region has led to the increased diversion of river water to meet the demand. Urban centres and industries depend mainly on the Mekong River and its tributaries for their supply. Total water supply to Phnom Penh in Cambodia and Vientiane in Lao PDR is expected to have increased from 155 000 m^3/day in 1993 to 272 000 m^3/day by 2010 (Chea 1998). Water withdrawals for industrial and agricultural uses in Yunnan province, Thailand, and Vietnam are close to 20% of total annual internally renewable resources. All these development activities have been found to greatly modify the hydrological cycle, thus the flow volume of the Mekong River and its tributaries (MRC 1997a).

The construction of dams for hydropower development in the region has also altered the flow regime in the basin. Hydropower development in the Lancang River Basin (UMRB) is typified by the Lancang Cascade project. By 2020, up to 15 hydro-electric dams will be constructed along the Lancang River with a total installed capacity of 25 605 MW (Xu & Moller 2004). In the LMRB, most of the planned dam projects are located on the Mekong River's tributaries in Lao PDR.

The Lancang Cascade project is enhancing economic development in the region by providing cheap electricity. It is also helping to relieve the severity of droughts and floods by regulating the river flow whilst providing a sufficient volume of water for downstream hydropower schemes (Chapman & He 2004, Liu 2004, He & Chen 2004). However, the current and planned dam construction and water diversion schemes along the Mekong River and its tributaries, together with the flood control schemes in the Mekong Delta, are likely to substantially modify the annual floods and dry season flow levels in the future (MRC 1997a, MRC 2003).

Since the completion of the Manwan and Dachaoshan dams, the Mekong River's flow pattern has changed, sediments are trapped behind the dams and there have been a number of associated environmental impacts, including the degradation of wetlands (Roberts 2001, Snidvongs et al. 2003). The reduction in suspended sediment concentrations resulting from sediment being trapped behind the Manwan Dam is apparent as far downstream as Pakse in southern Lao PDR. Modification of the flow regime by dams and weirs has disrupted fish migration and spawning, resulting in a reduction in the productivity of the fisheries (Sverdrup-Jensen 2002, MRC 2003, ADB/UNEP 2004). The next two dam projects, Xiaowan and Nuozhadu, will have much larger reservoirs and could further change river flow on a seasonal basis (MRC 2003).

Improvements to navigational routes will also permanently modify the course and volume of water flow in the Mekong River Basin (Sverdrup-Jensen 2002). In the UMRB, 11 major rapids and shoals and 10 scattered reefs are being removed to allow the navigation of large vessels up to 300 DWT. This will not only destroy important habitats, and spawning and feeding grounds for fish, but will also modify downstream habitats due to changes in the flow regime and increased riverbank erosion (Sverdrup-Jensen 2002). This will negatively affect fisheries production in the region (MRC 2003, ADB/UNEP 2004). The increasing number of embankments in the basin is reducing the volume of floodplain storage. This is likely to result in increased discharge and high flood levels, both in the upstream and downstream parts of the basin (MRC 2003).

Further, deforestation and land clearance in upland areas is increasing the volume and speed of surface run-off which, in turn, is likely to increase the intensity and frequency of floods. The rapid expansion of urban settlements and infrastructure which replaces natural vegetation with sealed surfaced structures including roads and buildings, could: (i) reduce the time that intense rainfall takes to reach the streams, resulting in greater peak flows and a higher risk of sudden floods; and (ii) contribute to flooding if they impede natural drainage patterns (MRC 2003).

Pollution of existing supplies

In general, water throughout the Mekong River Basin is of good quality and well oxygenated. However, irrigation, the extraction of rock salt, and poor drainage has caused salinisation of the topsoil leading to the deterioration of ground and surface water quality, in addition to reducing agricultural productivity and degrading the soil (MRC 1997a, Chu et al. 2003).

Although groundwater quality is generally good, in some areas it may be contaminated by acids, mineral salts, nutrients (such as nitrates and nitrites) and toxic chemicals due to the intrusion of saline water, and leaching from soils and pit latrines. While in northeast Thailand the groundwater salinity is often high due to the presence of rock salt, in the Vietnamese Mekong Delta the groundwater is contaminated by salt water intrusion from the coastal sea, acid sulphate leaching from soils, and the infiltration of agricultural run-off (Chu et al. 2003). There are 750 000 ha of arable agricultural land in the Vietnamese part of the

Delta affected by saltwater intrusion during the dry season, rendering the area unsuitable for crop production. Efforts have been made to control saltwater intrusion by blocking seawater using sea dikes and water-gate systems. Although these measures have facilitated the expansion of agricultural land, they have also led to adverse impacts, such as a deterioration in the quality of freshwater used for domestic consumption and animal husbandry (MRC 1997a, Chu et al. 2003).

Even though the impact of this GIWA issue was considered to be slight, the expansion of development activities will increase pollution levels in the water supplies of the basin (MRC 1997a).

Changes in the water table

Overextraction of groundwater for use in the production of high-value crops, such as coffee, has led to a severe drop in groundwater levels in many areas of the Vietnamese highlands. Over the past decade, groundwater has been extensively abstracted for domestic consumption and agricultural use in the Cambodian part of the basin. The rate of extraction has increased from 120 000 m^3/day in 1997 to 290 000 m^3/day in 2000 (Chu et al. 2003). However, the current rate of groundwater extraction has not caused any significant lowering of the water table in the majority of the basin (Chu et al. 2003). The impact is therefore considered slight. Although total potential capacity of the groundwater resources in the region is high (60 million m^3/day), the intensification of agricultural activities in the highland areas of the MRB may result in the overextraction of groundwater for crop production, which is likely to deplete groundwater resources in the future (Chu et al. 2003).

Socio-economic impacts

Currently, freshwater shortage *per se* does not appear to pose any significant socio-economic problems to the region. However, economic development and population growth will increase water demand, and the extensive development of hydropower schemes will significantly alter the hydrological cycle.

Negative socio-economic effects of changes in the flow regime caused by hydropower development include: (i) a reduction in alluvial deposition causing a decline in agricultural productivity unless substituted with chemical fertiliser and increased irrigation; and (ii) a decrease in fisheries productivity due to water level fluctuations, the deterioration of water quality, and the impediment of migratory fish (MRC 1997a). Navigation improvements may result in loss of environmental aesthetics due to the disappearance of rocks and rapids.

The Plain of Reeds, the north-western extension of the Mekong Delta, is generally productive in agriculture, forestry and fisheries. Apart from

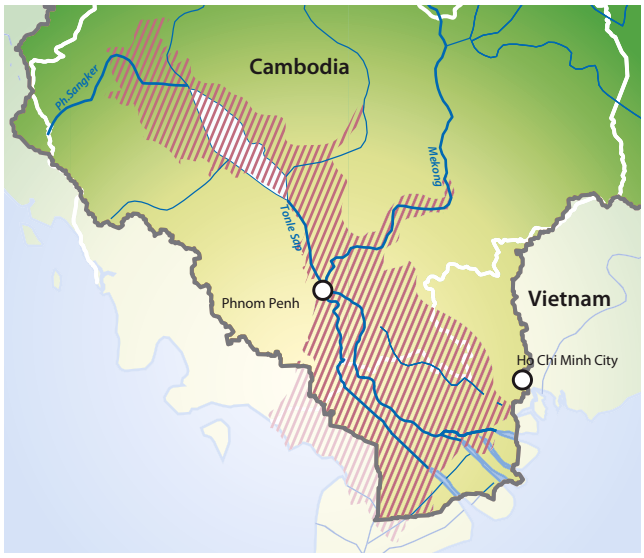

Figure 10 Extent of flooding in Cambodia and Mekong Delta
(Source: MRC 2003)

the problem of acid sulphate soils, limited freshwater supply during the dry season is a constraint for agricultural and aquacultural development in the Plain. A Mekong Delta Master Plan which aims to address the acid sulphate soil and limited freshwater supply problems has been prepared by the MRC (MRC 1997a, MRC 2003).

The heavy rainfall that predominates during the rainy season usually causes flooding in the lowland areas of the basin, resulting in negative socio-economic impacts. The recurrent floods cause varying degrees of damage to agricultural production, rural infrastructure and human settlements, and loss of life and property. They also disrupt people's social and economic activities throughout the basin (FAO 1999, MRC 2003). For instance, a severe flood that occurred in 2000 (Figure 10) affected (i) 22 of the 24 provinces of Cambodia involving over 3.4 million people with a death toll of 347, 80% of them being children, and causing physical damage totalling 161 million USD; (ii) 1 200 villages in seven provinces of Lao PDR involving 395 600 people, causing widespread damage to irrigation systems, rural road infrastructure and large parts of provincial towns, as well as the loss of around 10% of the wet rice production totalling 20 million USD; and (iii) 5 million people in the Delta in Vietnam, with over 500 deaths, 825 000 homes and thousands of kilometres of national and provincial roads damaged or destroyed, where the total cost of flood damage amounted to 285 million USD. In 2001, the flood in the LMRB inundated about 47 350 km^2 of farmland, affected the livelihoods of 2.8 million people and damaged 5 300 km of roads. Flood management and mitigation has thus become a priority issue at the national and regional levels, especially in the aftermath of the disastrous floods which occurred in 2000 and 2001 (MRC 2003).

Pollution

Microbiological

In water, faecal micro-organism indicators reach medium to high levels in all the surface waters of the Mekong River as well as in its tributaries, canals and ponds. Surveys showed that 98.5% of dug-well water samples were contaminated. Consequently, there is a high prevalence of diarrhoea and intestinal parasites in densely populated parts of the basin. Generally, the major urban centres have limited sewage treatment services, resulting in the discharge of raw or inadequately-treated sewage (ADB/UNEP 2004). The situation of microbiological pollution in the region is, however, still localised and insignificant (Fedra et al. 2004). The impact of this GIWA issue is considered slight. Although the situation is unlikely to change much in the future, the implementation of the Mekong Basin Development Plan (MBDP) by the MRC may improve sanitary conditions in the forthcoming decade (MRC 2003).

Eutrophication

With increasing population densities and the intensification of agricultural crop production, increasing amounts of domestic wastewater and agricultural run-off with a high nutrient content have been discharged into the Mekong River and its tributaries during the past two decades. Tributaries in northeastern Thailand have shown signs of eutrophication. In the Mekong Delta, where population density is the highest, eutrophication events occur every year (Fedra et al. 2004). Although eutrophication of the water bodies in the region is common, its occurrence is still localised. The impact is considered to be moderate. Unless effective measures are taken to control the excessive use of agricultural fertilisers, particularly those with a high phosphate content, and the discharge of untreated or inadequately treated domestic and industrial wastes from urban centres, eutrophication will become more frequent and widespread.

Chemical

Chemical pollution in the region mainly originates from agricultural run-off containing the residual contents of pesticides and chemical fertilisers. The Mekong Delta and the lake Tonle Sap are hot spots where chemical pollution often occurs. Agricultural activities are extensive in these two areas. In the Delta, chemical fertilisers are extensively used to enhance rice production. The Vietnam Ministry of Agriculture and Rural Development estimated that the quantity of agrochemicals used by farmers in the Delta has increased three-fold between the late 1980s and mid-1990s (Petersen 2003). Promotion of the cultivation of more cash crops and intensive farming methods by the governments of the riparian countries has led to the increased use of agro-chemicals. This campaign of agricultural intensification will increasingly contaminate surface and ground waters in the basin with agro-chemicals (MRC 1997a, Chu et al. 2003).

The soil on around 1.6 million ha of land in the Plain of Reeds, Long Xuyen Quadrangle, and the Ca Mau peninsula in Vietnam are highly acidic, have high levels of potentially toxic aluminium and iron sulphide, and low levels of phosphorous. Run-off from land with acid sulphate soils which have been converted for agriculture (e.g., rice fields) has harmed aquatic life, including fish cultured in the converted rice fields. Although farmers can mitigate the problem of acid sulphate soils by using more water and fertilisers in their crop production, the method increases water consumption and nutrient build-up which is unlikely to be environmentally sustainable (MRC 2003).

Mining activities, such as gemstone mining in Thailand and Myanmar, copper mining in Yunnan province of China, lignite mining in Lao PDR, as well as the paper factories in Thailand and around Phnom Penh, also contribute to chemical pollution in localised areas of the region (MRC 1997a, MRC 2003, Li 2004). However, the toxic contamination of water and fish does not appear to have reached critical levels (Try pers. comm.). The situation is unlikely to change significantly in the foreseeable future as mining activity in the region is unlikely to expand. In addition, measures are being taken by the Vietnamese government and MRC to restrict and effectively manage the use of chemical fertilisers by farmers in the Delta as well as in other areas of the basin (MRC 2003), this may help to alleviate future chemical pollution in these areas. The impact of chemical pollution is considered to be slight.

Suspended solids

In the past decade, development activities, such as deforestation, mining, grazing and urbanisation, have caused extensive erosion in

Table 10 Total suspended solid loads in the mainstream and tributaries of Mekong River

Monitoring stations	**Total suspended solid** (tonnes/km^2)
(A) Mainstream Mekong River	
Chiang Saem	356
Vientiane	221
Nakhon Phanom	183
Pakse	249
Average for mainstream Mekong River	252.2
(B) Tributaries of Mekong River	
Nam Mae Kok	77
Nam Karn	15
Nam Ngum	72
Nam Mun	14
Se Done	249
Average for Mekong River tributaries	85.4

(Source: MRC 1997, Chu et al. 2003)

many parts of the basin, resulting in high loads of total suspended solids. This is indicated by high turbidity levels in the mainstream and tributaries of the Mekong River (Table 10). For instance, in the upland steep slopes of Cambodia and Yunnan province as well as in the shoals of lake Tonle Sap's river system, the turbidity has exceeded 1 000 mg/l, while in the mainstream of the Mekong River it has exceeded 400 mg/l. In Cambodia, at the merging point of the Tonle Sap River and the Mekong River there are high Total Suspended Solid (TSS) loads and the same is true in the Delta, at the confluence of the Bassac River and the Mekong River. Poor management of land in the Yunnan highlands, where the average slope is 33%, has caused significant erosion in about 29% of the Lancang River Basin (MRC 2003).

The average turbidity of the Mekong River (294 mg/l) is considered to be high but not as high as that of the Irrawaddy River (607 mg/l) and Ganges River (1.13 mg/l) (MRC 1997a). The impact of this GIWA issue was considered to be severe.

All countries in the basin contribute to the sediment loads of the Mekong River. Deforestation for timber or fuelwood supplies, and the conversion of the basin's forestland to agricultural use and human settlements is leading to increased erosion and higher suspended solid concentrations in the freshwater environment.

Shift cultivation for economic crops is widely practiced in the upland areas of the basin. It can be sustainable but population growth and increased food demand has led to more farmers in the upland areas practicing this method, resulting in the shortening of the fallow period and the clearance of more forest. This has led in turn to forest degradation and soil erosion which contributes further sediment into the aquatic environment (MRC 1997a, Chu et al. 2003).

The sediment trapping dynamics of the river system are different in the two types of hydro-dams – the storage dams and run-of-the-river dams proposed or already built in the basin. The storage dams have a potential to trap large amounts of sediment as compared to the run-of-the-river dams. Such sediment trapping could disrupt the biodiversity and productivity of downstream river ecosystems (MRC 1997a). The productivity of the lake Tonle Sap and its river system in Cambodia is threatened by the changes in sediment transport caused by upstream dam construction, deforestation, gem mining, land conversion and improper irrigation development (MRC 2003).

Although mining activities in the basin are relatively limited, some of these operations have caused erosion and reduced water quality in parts of northeast Thailand and western Cambodia (MRC 1997a). Critical habitats for fish spawning and feeding have been altered as a result of increased siltation. This has affected the productivity of the fisheries. Efforts by the riparian countries to enhance reforestation and protect ecosystems in the region are likely to make some progress in controlling erosion in the future (MRC 2003).

Solid wastes

Solid waste pollution resulting from tourism development and the proliferation of urban centres in the basin is mainly localised and the issue is still insignificant (MRC 2003, Leksakundilok 2004) and it is considered to have no transboundary consequences. The situation may deteriorate with the increased generation of solid wastes as a consequence of higher living standards, increased urbanisation and enhanced tourism development. However, increased public awareness of the need for environmental protection, combined with efforts taken by the governments of the riparian countries to develop sanitary landfills, recycle wastes and to develop waste incineration plants in urban centres and tourist areas, may avert any future threats from the increased generation of solid wastes (MRC 2003).

Thermal

Thermal pollution due to discharges from nuclear power plants or other turbine energy generation plants is insignificant, as most of the power supply within the region comes from hydropower generation (Chu et al. 2003). The issue is considered to have no impact and this is unlikely to change much in the future. Although demand for energy in the region is expected to increase with economic development, the region has a high hydropower development potential (Chu et al. 2003).

Radionuclides

This GIWA issue is considered to have no environmental impact at the moment, as there is no nuclear power plant in the region (Chu et al. 2003). Future developments are unknown.

Spills

The impact of spills is considered to be slight as some oil spills do occur in the Mekong Delta area where there is busy shipping traffic. Otherwise, the situation is currently insignificant in the basin. No chemical spills have been recorded (Petersen 2003, Fedra et al. 2004). The risks of spills may increase if improvements to the navigation routes in the mainstream of the Mekong River, particularly along its upper reaches, lead to increased shipping traffic (Fedra et al. 2004).

Socio-economic impacts

Pollution from non-point sources, including the run-off from agriculture, mining, logging and land-clearing as well as residential and commercial

development, has adversely affected the habitats of economically important fish species. The consequential reduction in fisheries production has decreased the income of the local communities who depend on these fisheries for their livelihood.

There has been an increasing incidence of gastro-intestinal diseases due to the consumption of polluted water from the Mekong River during the past decade (ADB 2004). Diarrhoea is prevalent throughout Lao PDR, Cambodia and Vietnam, especially in the densely populated Mekong Delta where the sanitary standards are low.

Because water pollution can exert profound impacts on the economic, social and health aspects of communities, it has generated wide interest and concern amongst the governments and public of the region. Efforts aimed at combating pollution problems are being made by the riparian countries and the MRC (MRC 2003).

Habitat and community modification

Loss of ecosystems or ecotones

Numerous critical habitats in the MRB have been lost over the past decades, due primarily to increased development activities. The spraying of defoliants and napalm during the Vietnam War of the late 1960s and the development of paddy fields has reduced the total area of the *Melaleuca* Forest from 174 000 ha in 1972 to 110 000 ha in 1985. The area increased slightly to 120 000 ha at the beginning of the 1990s following some rehabilitation (Le 2004). In the province of An Giang in the Delta area, the extent of the *Melaleuca* forest is reported to have declined from 40 000 ha to 4 000 ha, from about 16% to 1.6% of the provincial area, since the 1980s (MRC 1997a). Apart from its commercial value of providing valuable timber for construction, the forest also plays an important role in maintaining the well-being of the Mekong Delta's ecosystem (MRC 1997a) by:

- Preventing acidification of the topsoil and surface water;
- Storing freshwater for human and wildlife uses;
- Reducing water velocity during the flooding season, thus minimising flood damage;
- Helping in sedimentation and storage of silt, thus enriching soil fertility;
- Providing suitable nursery and breeding grounds for fish; and
- Supporting high biodiversity and other benefits similar to those provided by mangrove forest.

A recent study by MRC indicated that this deforestation rate means that much of the forest cover in the MRB is likely to be lost over the next century (MRC 2003). With the population growing quickly, the demand for wood products is likely to increase, accelerating the rate of deforestation.

Large areas of mangrove forest, a critical coastal habitat, have been destroyed during the past two to four decades due to wartime hostilities and post-war agricultural expansion, as well as conversion to shrimp ponds. Nowadays, the total area of mangrove forest in the Mekong Delta amounts to only 120 000 ha (Snidvongs et al. 2003).

Considerable areas (over 10 000 ha) of the following habitats were reported to be lost to development over the last two decades: peat bogs and marshlands in the Mekong Delta; running-water wetlands in parts of the MRB in Thailand, Lao PDR, Yunnan province, Cambodia and Vietnam; flooded forests in the Cambodian part of the MRB; and estuaries around the Mekong Delta (Torell et al. 2001, Snidvongs et al. 2003, Friederich 2004). Widespread destruction of mangrove wetlands has caused numerous adverse environmental impacts such as excessive sediment transport, shoreline erosion and the destruction of nursery and breeding grounds for fish and shrimps (MRC 1997a). Uncontrolled deforestation in the MRB is resulting in a loss of biodiversity and critical habitats (MRC 2003, ADB/UNEP 2004). Shoreline development, such as port development, and navigation improvements could result in the loss of habitats for terrestrial wildlife. The impact of the loss of ecosystems or ecotones is considered to be severe.

Governments of the riparian countries in the MRB are aware of the implications of unsustainable logging and the associated loss of forestland. Regulatory measures to control logging and timber trades have thus been imposed by the riparian governments to curtail the effects of a previously uncontrolled timber industry (Oxfam 2004). These measures may help to arrest the loss of forestlands in the future. The situation for other types of habitat in the region may slightly improve as a result of efforts being made by the MRC, NGOs, donor agencies and the governments of the riparian countries (MRC 2003).

Modification of ecosystems or ecotones, including community structure and/or species composition

Several ecosystems or habitats in the region have been modified or degraded resulting in various degrees of change in biodiversity, species composition and community structure. The degradation of the ecosystems, thus the critical habitats therein, has become one of the main concerns in recent years. For instance, millions of hectares of

valuable forests have been degraded to inferior scrub, grasslands or savannah, or have been encroached upon by subsistence agriculture. As a result, soil conditions have deteriorated, with increased water discharge and erosion (Fedra et al. 2004). In the Lancang River Basin (UMRB) in Yunnan province about 70% (3.5 million ha) of the total grassland area has been degraded by the spread of inferior shrubs or bushes due to development activities (Zhou 1999).

Wetlands in the MRB face many threats including: aquaculture and the increased practice of destructive fishing methods; introduced fish species; deforestation; weed infestation (e.g. by *Mimosa pigra*); use of DDT and other persistent organochlorine pesticides; saline intrusion and pollution; acid sulphate soils; loss of wetland wildlife from hunting and habitat destruction; reclamation schemes, drainage, dredging and filling; irrigation leading to salinisation; sedimentation and erosion; and flood control and hydropower development.

In the Tri Ton area of the Mekong Delta, more than 350 000 ha of *Melaleuca* wetlands have been degraded with extensive outgrowth of inferior shrubs (Le 2004). It has also been reported that large areas of (i) peat bogs and marshlands in Vietnam and Cambodia have been altered due to infestation by bugs; (ii) flood forests around the lake Tonle Sap have been severely modified by outgrowth of a shrub, *Mimosa*; (iii) rice fields have been substantially modified by the farming of different varieties of rice or other economic crops; (iv) Alpine wetlands in Yunnan province have been greatly modified by the extensive grazing of farmed animals; and (v) mangrove swamps around the Mekong Delta have changed where pollution has promoted colonisation by different species of mangrove (Lacoursiere et al. 1998, Torell et al. 2001, Friederich 2004).

In recent years, the water quality of the lake Er Hai has deteriorated mainly because of the mismanagement of waste from the wood pulp factories and sedimentation from timber harvesting, as well as the impact of marble quarrying. Increases in non-point run-off from agriculture, animal husbandry and fish farming have further degraded the lake's water quality over the past 10 to 15 years (ADB/UNEP 2004).

The increased reclamation of floodplains and wetlands has decreased their water storage capacity, thus increasing the intensity of floods. Some unusually severe floods (e.g., those of 2000) have also greatly modified several aquatic habitats in the region, changes which may be irreversible (MRC 2003, Chu et al. 2003).

Threats to the aquatic biodiversity of the MRB arise from two main sources: the impacts of fisheries activities themselves and impacts arising from outside the fisheries sector. Fisheries activities that can impose direct threats to aquatic biodiversity include: (i) the use of destructive fishing methods such as explosives, poisons and electrocution; (ii) exploitation of fish at vulnerable stages, such as at spawning times; and (iii) fishing in sensitive areas such as spawning grounds. Impacts on aquatic biodiversity arising from outside the fisheries sector involve changes in the environment and habitats of rivers resulting from development, including:

- Destruction of local spawning grounds or dry season refuges as a result of stream-bed dredging, removal or alteration of vegetation, and bank modification;
- Local changes in the quality (e.g. pollution) and quantity of water available as a result of storage in dams and abstraction for irrigation; and
- Construction of barriers (dams, weirs, diversions) which, apart from creating local environmental disturbances, act as physical barriers to fish migration.

The impacts may significantly reduce aquatic productivity and biodiversity. Industrialisation and urbanisation in the MRB are currently relatively limited, and so far have had little environmental impact, except locally. But as populations grow and development pressures increase, aquatic life is likely to be affected. Also, the negative consequences of deforestation, inappropriate agriculture, road construction, hydropower and other forms of development are already evident (Coates et al. 2003).

The introduction of alien species to the MRB was undertaken for four major purposes: aquaculture, stocking of lakes and reservoirs, pest control (e.g., mosquito) and the aquarium trade (Welcomme & Vidthayanom 2003). Annex VI provides a table listing the species that have been introduced to the region and describes the status of their introduction. Many of these species have now become established in the ecosystems and some have even become the major aquaculture species. Welcomme & Vidthayanom (2003) have reported that about seventeen of the species introduced into the MRB have either formed established populations or have strong possibilities of doing so, and a large number of species are also moving within the MRB as part of the aquarium fish trade.

Currently, the impacts of introduced species appear to be relatively minor and the positive impacts of the introductions have far outweighed any negative effects (Welcomme & Vidthayanom 2003). Table 11 gives some examples of introduced alien species and describes some of their benefits and negative effects. Established species such as Nile tilapia (*Oreochromis niloticus*), Black sucker catfish (*Hypostomus plecostomus*),

Table 11 Examples of alien species introduced to the Mekong River Basin

Introduced/exotic species	Description of the introduction
African catfish *(Clarias gariepinus)*	The African catfish was first introduced into Vietnam from the Central African Republic in 1974 for aquaculture, and into other riparian countries by internal transfer. A wild population of the fish has established itself throughout the MRB. The fish and its hybrids are highly tolerant of poor water quality and deoxygenated conditions. This tolerance gives the species and the hybrid a competitive advantage over native clariid catfish.
Grass carp *(Ctenopharyngodon idella)*	It was introduced from China and Hong Kong to Thailand in 1932, to Vietnam in 1958 and to Lao PDR at an undetermined date. It has been used to stock reservoirs, ditches and canals as a control for invasive aquatic vegetation. The species does not breed naturally in any part of MRB.
Common carp *(Cyprinus carpio)*	The species was introduced into Thailand from China, Japan, Israel and Germany from 1913 onwards, into Lao PDR from Thailand and India in 1977, and into Vietnam from Hungary during the period 1969–1975. The Common carp has been the keystone species of many aquaculture development projects in the MRB. The species complex is widely established in the wild and in many areas is regarded as a permanent element of the fauna. Common carp are notorious for the way their populations rapidly increase following environmental disturbances by dams. Their habit of digging around in the bottom and muddying the water can seriously alter the environment to the detriment of other species. Given that the species is now firmly established, there seems little that can be done to eradicate this potentially troublesome fish.
Mosquito fish *(Gambusia affinis)*	The species was introduced into drainage ditches throughout the MRB at an unknown date for mosquito control, escaping later into the main tributaries of the Mekong River. It is now found at the margins of most water bodies including rice fields and floodplain lakes. The species is tolerant of high salinity and it is not regarded as detrimental although its habit of eating eggs and larvae of other fish may do some damage to fish stocks.
Nile tilapia *(Oreochromis niloticus)*	This introduced species is one of the most popular for aquaculture and for stocking into dams and reservoirs. It was introduced into Thailand from Japan in 1965, into Vietnam in 1973 and 1994 from Taiwan, the Philippines and Thailand, and into Lao PDR and Cambodia at an unknown date. The species is not known to have any detrimental environmental impact throughout its introduced range. It is one of the few species that can readily digest blue green algae and as such is of value in the control of eutrophication.
Apple snails *(Pomacea canaliculatus, P. gagas)*	These species have been introduced from various sources into Thailand for aquaculture from 1988 onwards. Apple snails have now established in the wild and have had a major impact on aquatic habitats, including rice fields, because they destroy the bases of growing aquatic plants, causing enormous economic losses for rice farmers and the degradation of natural wetland habitats by stripping vegetation. In addition, the introduced snails compete with endemic species of snails, such as Pila spp., which are relatively benign in their effect, since they feed only on moribund plants. Apple snails are tolerant of salinity and are thus able to penetrate coastal habitats.

(Welcomme & Vidthayanom 2003)

Guppy (*Poecilia reticulate*) and Mosquito fish (*Gambusia affinis*) appear to have no notable adverse consequences. However, some impacts to the environment of the MRB have been reported. For instance, there are some suggestions that hybrid African catfish (*Clarias gariepinus*) are contributing to the decline in native Catfish (*Clarias batrachus*) and that established populations of Rohu carp (*Labeo rohita*) may damage native species of the same genus (Welcomme & Vidthayanom 2003). Aquaculture in the MRB relies heavily on the introduced species and will probably continue to do so unless satisfactory alternatives are found among the native species.

The impact of the modification of ecosystems or ecotones is considered to be severe. The damaged ecosystems in the MRB are unlikely to be restored in the next two to three decades. Instead, they may deteriorate further due to increased pressure on ecosystems from economic development and population growth.

Socio-economic impacts

A number of human and development activities (e.g., population growth, deforestation, urbanisation, dam construction, irrigation) have threatened the existence of wetlands and their critical habitats in the MRB which, subsequently, have greatly impacted the social and economic well-being of local communities. The livelihood of many inhabitants in the MRB depends on wetland resources (Snidvongs et al. 2003). The socio-economic impacts include (Fedra et al. 2004):

- Economic losses of rural communities who subsist on the services or output of habitats such as rice fields, rivers and mangroves; for instance, Cambodia used to export large amounts of fish but nowadays local consumption for certain species of fish has to be met by imports;
- Economic losses in tourism due to habitat disturbance through loss or modification, and the costs inflicted by coastal erosion resulting from reduced shoreline protection from the loss of mangrove, grasslands, forestland, etc;
- Impact on the food security of rural communities who have to find alternative food sources due to the loss or modification of habitats; for instance, 85% of the rural communities of Cambodia rely on fish as their main source of food nutrition and, therefore, a shift in the type of food they consume (due to decreased fish catch) to other less nutritious foods would cause malnutrition;
- Loss or modification of habitats would force the rural communities to change their livelihood which may disrupt their social structure and social coherence, and result in migration to urban areas in search of employment; and
- Loss of cultural heritage sites may affect the social integrity of rural communities.

Ecosystems are likely to be degraded further in the future. Due to the reliance of the inhabitants of the MRB on the natural environment, this will exacerbate the negative socio-economic impacts highlighted above.

Unsustainable exploitation of fish and other living resources

Overexploitation

Studies show that catches per fisherman have declined by about 44% between the 1940s and 1995. But over the same period, the total fish yield in the lake Tonle Sap area has increased by 84% from

125 000 tonnes to 230 000 tonnes. Catches per fisherman have declined because the number of fishermen has greatly increased. Population growth has also increased demand for fish products and has, thus, intensified fishing effort (MRC 2003). Destructive fishing practices and the steady loss of flooded forests have had an negative effect on the abundance of fisheries resources, which has led to middle-scale and family fishermen in the region complaining about decreasing Catch Per Unit Effort (CPUE) (van Zalinge et al. 1998). According to Sverdrup-Jensen (2002) the changes in the species composition and the decline in the abundance of larger, slower growing species indicates that the present exploitation rate is too high. Future increases in annual catches in heavily exploited areas would be unsustainable. In less exploited areas, there is some scope for modest catch increases. Other living resources are also extensively hunted and traded in all the MRB countries by many vendors, middlemen and international dealers. There is significant cross-border trade in wildlife (MRC 1997a).

The impact of overexploitation is considered to be severe. The situation may improve as result of the Fisheries management programme of the MRC and the governments of the riparian countries strengthening capture fisheries management (Sverdrup-Jensen 2002).

Excessive by-catch and discards

The by-catch and discards of fish are insignificant in the region because almost all fish caught, no matter how small, are either consumed or sold in the markets (Sverdrup-Jensen 2002). Discards of small and low-value fish are rare. The impact of this issue is slight and the situation is unlikely to change in the future.

Destructive fishing practices

The most common destructive fishing practices employed in the region include the use of fine-mesh nets to capture Catfish fry for raising in cages and ponds (such nets also capture the fry of 160 species unwanted for aquaculture), and the use of electricity, poison and explosives to kill fish (MRC 2003). Such practices extensively destroy fish spawning grounds and decrease fish recruitment, thus affecting the overall productivity of the fisheries. The use of destructive practices has become increasingly common over the last decade (Sverdrup-Jensen 2002).

The impact of this issue is considered to be moderate. Regulatory measures to control the destructive fishing practices in the region are being, or will be, implemented by the riparian countries (MRC 2003). With sound enforcement of the regulatory measures, the situation may gradually improve.

Decreased viability of stock through pollution and disease

There is no conclusive evidence or sufficient data to demonstrate that the viability of fish stocks has decreased because of pollution and diseases. The pollution load of the aquatic environment has increased due to urbanisation, industrialisation and greater agricultural production. Although water pollution is currently not believed to be a threat to the fisheries, pollution from agricultural run-off and industrial/domestic wastes high in nutrients and other harmful pollutants could become a concern in the future as governments promote the commercialisation of agriculture and industrialisation (Sverdrup-Jensen 2002, MRC 2003, ADB/UNEP 2004).

Impact on biological and genetic diversity

The introduction of foreign or alien species for aquaculture, biological pest control and the aquarium trade has become a common practice in the region since the early 1960s (Welcomme & Vidthayanom 2003). Alien species such as Mrigal (*Cirrhinus cirrhosus*), North African catfish (*Clarias gariepinus*), Mosquitofish (*Gambusia affinis*), Albino strain (*Helostoma temminki*), Rohu (*Labeo rohita*), Mozambique tilapia (*Oreochromis mossambicus*), Nile tilapia (*Oreochromis niloticus*), Guppy (*Poecilia reticulate*), Suckermouth catfish (*Pterygoplichthys plecostomus*) (more than one species may be present) seem to have established breeding populations in much of the MRB. Other introduced species such as the Grass carp (*Ctenopharyngodon idella*), Catla (*Gilbelion catla*) and numerous aquarium species are used widely for aquaculture but have not shown any evidence of having become established (Welcomme & Vidthayanom 2003). The practice of introducing alien species for aquaculture and other purposes has substantially replaced indigenous fish species, reduced biodiversity, introduced disease and parasites as well as resulting in hybridisation and loss of genetic diversity (MRC 2003).

Given the chaotic nature of current practices for species introductions and species movements within the MRB, the risk of spreading diseases within the aquaculture sector and degrading the genetic quality of wild and aquaculture stocks is becoming a concern (Welcomme & Vidthayanom 2003). The impact of this GIWA issue is considered to be severe.

Socio-economic impacts

Many people are employed in the capture fisheries sector in the MRB, especially at the small-scale and household level. Virtually all farming households fish part-time or on a seasonal basis, and captured fish make a significant contribution to their food security. According to the Lao PDR 1998 agricultural census, 71% of all the country's farm households were engaged in fishing, equivalent to 2.9 million people dependent to varying degrees on the fisheries. Statistics from the northeast Thai

part of the MRB show even higher levels of participation. Throughout the LMRB at least 40 million rural dwellers are active in the fishery and for most rural households fish are important for family nutrition and income generation (Sverdrup-Jensen 2002). Reduced catches as a result of the overexploitation of stocks has affected the income, health and overall livelihood of rural communities. Consequently, there has been increased migration from rural populations to urban centres. This has disrupted the economic and social well-being of rural communities (Sverdrup-Jensen 2002). In the next two decades, fish stocks will continue to decline and this will increase rural unemployment and the severity of associated social problems (Sverdrup-Jensen 2002).

Global change

The workshop participants unanimously agreed that the overall impact of global change is far reaching, affecting every ecosystem in the region. Presently, there is insufficient data to demonstrate conclusively the current impacts of this concern. Thus, the environmental and socio-economic impacts of this concern have been scoped as unknown.

Some studies have made theoretical predictions of the likely impacts that could be expected for the region. For instance, Chinvanno (2004) and Snidvongs et al. (2003) projected using a prediction model, based on the assumption that CO_2 will rise to twice today's level (from 350 ppm to 700 ppm), that the future impacts of global climate change will be as follows:

- The daily maximum temperature will be higher by 1-3°C in January-May and lower by 1-3°C in the last four months of the year;
- The seasons will shift and change their pattern with the dry season being dryer and longer and the rainy season starting one month later in June and lasting until November with a short break in August;
- The hydrology of the Mekong River and its tributaries will not be significantly changed except for the discharge of the UMRB which may be reduced;
- More severe floods may be expected in areas such as the Korat-Sakon Plateau and the Southern Lowlands of the MRB;
- None of the natural wetlands may be significantly affected except for the Melaleuca forests in Mekong Delta which may be further degraded; and
- Crop production, especially rain-fed rice cultivation, will be strongly affected. The varieties of rice and other crops currently grown in each area may not be suitable in future due to the effects of a shorter and more intense rainy season.

Chu et al. (2003) reported the predicted global climate impacts in the region based on other prediction models:

- As a result of the seasonal shifts in weather, the MRB will experience more annual floods, droughts, and tropical cyclones;
- Geographically, the effects of the El Niño Southern Oscillation (ENSO) phenomenon will be much more extensive. The ENSO has an especially important influence on the weather and inter-annual variability of climate and sea level, particularly in the western Pacific Ocean and the South China Sea adjoining the MRB;
- There will be significant effects on agriculture in many parts of the MRB, particularly impacting low-income populations that depend on isolated agricultural systems; and
- Water shortages in Thailand's part of the MRB and salinity intrusion in the Mekong Delta will be exacerbated.

Priority GIWA concerns/issues and their transboundary implications

Priority GIWA concerns/issues

Based on the impact assessment results, the GIWA concerns and issues which were assessed as having severe impacts in the region are:

GIWA Concern	GIWA Issue
I. Freshwater shortage	Modification of stream flow
II. Pollution	Suspended solids
III. Habitat and community modification	Loss of ecosystems Modification of ecosystems
IV. Unsustainable exploitation of fish & other living resources	Overexploitation Impact on biological and resources genetic diversity

The environmental and socio-economic impacts of these priority GIWA concerns and issues, and the possible causes of these impacts are presented in Annex V. The interrelationships of the five GIWA concerns are illustrated in Figure 11.

Based on the results of the assessment and the network diagram shown in Figure 11, ranking of the five GIWA concerns has been concluded as follows:

Priority 1: Habitat and community modification

Priority 2: Unsustainable exploitation of fish and other living resources

Priority 3: Freshwater shortage

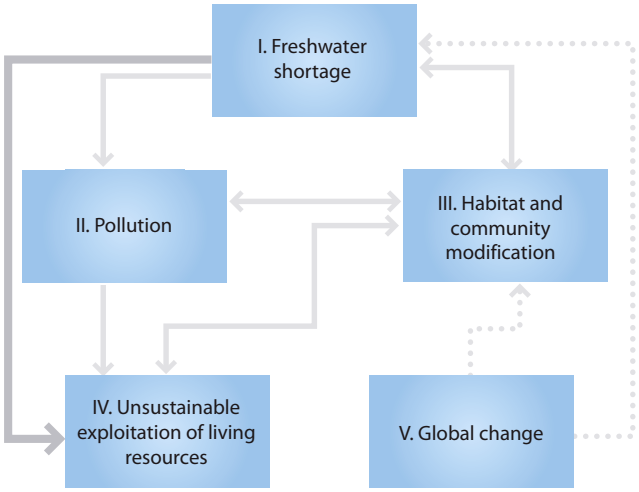

Figure 11 Network diagram showing the interrelationships between the five GIWA concerns

Priority 4: Pollution

Priority 5: Global change (possible relationship indicated by dotted lines in Figure 11)

The figure also indicates that the Unsustainable exploitation of fish and other living resources has a close relationship with the concern of Freshwater shortage, particularly the issue of stream flow modification. Modification of the hydrological cycle or flow volume and pattern of the Mekong River and its tributaries is likely to influence the availability of aquatic living resources and their subsequent status of exploitation in the MRB.

The transboundary issues of the region arising from human and development activities are related to:

- Utilisation of water resources for hydropower development;
- Pollution in association with the increased use of agricultural chemicals;
- Cross-border trade of logs and timber related to the utilisation of forest resources; and
- Exploitation of fisheries in various parts of the MRB.

These issues closely resemble the priority GIWA issues that were assessed as having severe impacts. Almost all the priority GIWA concerns and issues for the region have transboundary implications.

Causal chain analysis

This section aims to identify the root causes of the environmental and socio-economic impacts resulting from those issues and concerns that were prioritised during the assessment, so that appropriate policy interventions can be developed and focused where they will yield the greatest benefits for the region. In order to achieve this aim, the analysis involved a step-by-step process that identified the most important causal links between the environmental and socio-economic impacts, their immediate causes, the human activities and economic sectors responsible and, finally, the root causes that determine the behaviour of those sectors. The GIWA Causal chain analysis recognises that, within each region, there is often enormous variation in capacity and great social, cultural, political and environmental diversity. The Causal chain analysis uses a relatively simple and practical analytical model. For further details on the methodology, please refer to the GIWA methodology chapter.

Habitat modification was identified as a priority concern for the GIWA Mekong River region. Changes in habitats and the modification of communities are being caused by changes in the fluxes of water and sediment, particularly suspended solids, by increased pollution from diffuse and point sources, and by the introduction of new species into the aquatic environment. The Causal chain analysis of the Mekong River region focuses on two of the prioritised GIWA issues which have caused habitat modification in the MRB - stream flow modification (Freshwater shortage) and suspended solids (Pollution). For details of the environmental and socio-economic impacts of these prioritised issues, please refer to the Assessment section, and for background information on the sectors responsible for the immediate causes, please refer to the Regional definition.

Stream flow modification (Freshwater shortage) and suspended solids (Pollution)

Immediate causes

The flow regime of the Mekong River and its tributaries has been modified by changes in precipitation patterns and by human activities, particularly the construction of dams for hydropower development, the modification of rivers to improve navigation, and the diversion of river water for irrigation, industrial development and human settlements. The raising of embankments or levées along the mainstream and tributaries of the Mekong River is resulting in a significant reduction in the volume of floodplain storage, causing increased rates of river discharge and high flood levels.

Deforestation in the catchments is the principal cause of increased rates of surface water run-off that may increase the frequency and intensity of flooding in the basin. Locally, the built environment of urbanisation is also causing increased rates of run-off. The increased erosion caused by deforestation and land clearance in upland areas of the MRB is causing the entrainment of suspended and bed-load sediments into water courses. Except where they are trapped in reservoirs or deposited on floodplains and riverbeds, the sediments are transported through the basin to the Delta, where they are deposited in mangrove forests or discharged to the sea.

Root causes

Population growth

The population of the MRB has experienced rapid growth in the past decade, ranging from 1.4% per year in Myanmar's Shan state (a Myanmar state that lies within the MRB) to 2.8% per year in Cambodia, with growth averaging about 2% per year. By the year 2010, the population in MRB is expected to increase to 75-90 million people (MRC 1997a, MRC 2003). A growing population uses more drinking

water and consumes more food which, in turn, requires larger volumes of water. Population growth has led to the colonisation of forests, which has increased erosion rates and surface run-off, thus modifying the sediment loads and flow volume of the region's rivers. Over the next 20-30 years, demand for water and the pressure on natural resources will continue to increase in parallel with rapid population growth, despite the fact that birth rates are falling.

Economic development

Urbanisation, human settlement and industrial development activities have substantially increased water demand in the MRB. Ringler (2001) estimated that domestic and industrial water demand in the MRB would double from 1.89 billion m^3 in 1990 to 4.1 billion m^3 in 2020. Agriculture is a dominant economic sector and the largest consumer of water in the MRB. In the economic development strategies of the riparian countries agriculture is always considered as one of the key sectors and therefore is allocated increasing quantities of water.

Demand for electricity has surged in the past two decades in response to the rapid economic development experienced in the riparian countries of the MRB and elsewhere in Southeast Asia. Although at present, per capita electricity consumption in the riparian countries of MRB is generally low, except for Thailand, demand is increasing rapidly. In the Thai portion of the MRB, demand is expected to reach about 411 300 GWh per year by 2020, representing more than a six-fold increase over its 1993 level. Demand in parts of the MRB in Vietnam and Yunnan province is expected to increase to 72 300-93 000 GWh per year in 2020 but in Cambodia and Lao PDR demand is likely to remain low at around 1 800-4 900 GWh per year.

Lao PDR, Myanmar and Yunnan province, China, are planning to harness their great hydropower potential by developing hydroelectricity schemes to meet the increasing market demand for electricity in neighbouring countries including Thailand, Vietnam, Malaysia and Singapore (Crousillat 1998). To date, only 11 hydropower facilities have been constructed in the MRB, representing only 5% of the hydropower potential. An additional 240 000 GWh per year could be exploited to meet the increasing demand.

Economic development has also led to deforestation for timber or fuelwood supplies, agricultural expansion and urban development, all contributing to increased erosion and, consequently, sediment loads in the aquatic environment. Forest reserves and agricultural lands occupied by illegal squatters create environmental problems such as forest destruction and land degradation, (MRC 1997a, Chu et al. 2003). The lack of alternative energy supplies for rural communities results in the excessive use of fuelwood contributing to deforestation and further watershed degradation.

Technical

Currently the irrigation schemes in the MRB face some technical problems. Irrigation reservoirs are 3-5 times larger than necessary due to the overuse of water by farmers, and there is currently a lack of efficient mechanisms to control and measure water use by farmers (MRC 2003). Because most irrigation systems were designed for rice production, switching their use for the production of less water-intensive crops is difficult (MRC 2003). In the Mekong Delta of Vietnam there is extensive irrigated agriculture. Despite more than half of the land in the delta being flooded during the rainy season, farmers are unable to store water for intensive rice cropping after the floods recede (Ringler 2001).

Governance

Even though all the riparian countries in the MRB develop strategies and action plans for environmental management, the development goals differ between countries. In the past, the needs of civil society groups were rarely incorporated into governmental policy. The impact on the human well-being of communities downstream of hydropower schemes was often not considered during the planning process. However, the MRC has recognised that, in the planning of policies, strategies and development plans for managing the MRB, it is necessary to involve all stakeholders. Consequently, the Basin Development Plan project as developed by MRC is a recent initiative that is working to develop an inclusive planning process (MRC 2003).

Government institutions and agencies often lack the institutional capacity to control water use and effectively manage the rivers of the MRB. For example, in Thailand, the Ministry of Science, Technology and Environment has to share the implementation of environmental management policies with other agencies, such as the Ministry of Industry and Ministry of Interior. This dilutes its power of implementation. The current sectoral approaches of the riparian governments hinder cross-sectoral integration, as does the lack of coordination between donors. Further, ecosystem protection measures aimed at controlling erosion in the region appear to be relatively weak.

Generally, cooperation between government agencies and NGOs is limited. In the Lao PDR, Yunnan province in China, and Vietnam, apart from international NGOs which are increasing rapidly in number, there are very few national NGOs that are clearly independent from the government. Instead, there are some parastatal or mass organisations which are more or less attached to the government, such as the Women's Union in Vietnam. However, increasingly they provide opportunities

for cooperation on environmental management initiatives as trust has been fostered between these organisations and their governments.

Lack of public awareness

Public awareness of environmental issues and the willingness to address them varies between the riparian countries of the MRB. Environmental awareness is relatively high in Thailand as a result of public information campaigns at all levels of society throughout the country (MRC 1997a). In other riparian countries of the MRB, public engagement is limited, particularly in environmental assessment activities.

Economic

The utilisation of water resources for hydropower is a key transboundary issue in the MRB. In terms of cross-border trade in energy, vast energy resources (mainly from hydropower development) in Yunnan province, Lao PDR and Myanmar can be developed for export, with Thailand being the most likely importer. Many hydropower projects in these riparian countries are being planned expressly for this purpose. In exchange for the economic benefits they receive, the exporting countries suffer from the impacts associated with the development of hydropower projects, such as the resettlement of people, the inundation of land and reduced fisheries productivity (ADB/UNEP 2004).

Prices, subsidies and taxes often inadvertently discourage efficient water use. Fees charged for irrigation water are too low to encourage efficiency or to generate sufficient revenues to invest in new, and maintain existing, water distribution and irrigation systems (MRC 2003). In Thailand, water management is dominated by command-and-control instruments with limited use of market-based incentives to encourage water efficiency. The current legal framework in Vietnam also lacks economic incentives to encourage compliance with environmental regulations.

Policy relevant conclusions

The GIWA Mekong River region is a large river basin with distinct physical characteristics and complex socio-economic conditions. The Mekong River and its network of tributaries drain parts of six riparian countries – China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. The region is vulnerable to environmental changes arising from human and development activities, as well as climatic fluctuations. The major aquatic concerns studied by the GIWA Task team were found to be highly inter-connected.

Habitat and community modification was considered to be the most severe water-related problem, but it is mainly the consequence of the other transboundary issues studied by GIWA, such as stream flow modification, changes in the sediment flux, and diffuse and point sources of pollution, as well as the introduction of alien species. The loss of habitat has depleted the living resources which the rural communities in the region depend on for their subsistence. Currently, freshwater shortage does not appear to impose any significant socio-economic and environmental problems on the region. In the future, the extensive hydropower development, and flood control and water diversion schemes may provide significant benefits for humans but will transform the hydrological cycle in the region when altering the nature of annual flooding and dry season low flow levels. These impacts have substantial transboundary implications in that they are affecting most of the region's riparian countries.

Heavy rainfall during the rainy season results in flooding in the lowland areas of the Mekong River Basin. The frequency and intensity of flooding is exacerbated by increased rates of surface water run-off caused mainly by deforestation and the increased extent of man-made impermeable surfaces in the Basin. Embankments or levées along the mainstream and tributaries of the Mekong River are resulting in a significant reduction in the volume of floodplain storage, causing increased rates of river discharge and high flood levels. The recurrent flooding events causes varying degrees of damage to agricultural production, rural infrastructure and human settlements, as well as a loss of human life throughout the MRB each year. Flood management and mitigation has thus become a priority issue at national and regional levels in the MRB.

Although pollution is becoming increasingly prevalent, it is generally not at critical levels. However, development activities, such as deforestation, mining, grazing and urbanisation, have caused extensive erosion in many parts of the MRB resulting in high concentrations of total suspended solids in the mainstream and tributaries of the Mekong River. The suspended solids are blocking channels, destroying or modifying habitats and forming deltas at the river mouths. This has profound environmental and socio-economic impacts, both detrimental and beneficial.

There is evidence that the fisheries resources of the region have been overexploited in recent years. Increasing numbers of fishermen, the widespread use of destructive fishing practices and the steady loss of flooded forests have negatively affected the abundance of fisheries resources. Middle-scale and family fishermen are concerned about their decreasing catches. The chaotic and uncontrolled nature of species introductions and movements within the MRB has increased the risk of the spread of disease within the aquaculture sector and the degradation of the genetic quality of wild and aquaculture stocks.

Migratory fish constitute a significant proportion of the 1 200 to 2 000 species of icthyofauna that inhabit the MRB. Therefore, if spawning habitats are destroyed by the clearing of flooded forests in one country, or if migration routes are obstructed by a dam in another, fish are less abundant elsewhere in the Mekong River Basin. Thus, the management of these shared resources requires holistic approaches that transcend both national and resource sector boundaries.

The transboundary aquatic concerns can be traced back to a number of root causes that will continue to present many challenges to the Mekong River Basin in the future. The region is experiencing rapid economic development and population growth, which are increasing demand for water, energy, and fisheries and agricultural products. The population in the LMRB alone is expected to increase to 120 million by 2025. This will increase the demand for energy and food, necessitating more hydro-dams and the intensification of agricultural production. Industrial development is being stimulated by increasing foreign investment in several parts of the MRB. Although these demographic and economic trends will create employment and income opportunities, thereby making an important contribution to poverty alleviation, it is likely to increase the pressure on the ecosystems of the Mekong River Basin.

Hydropower is seen as a cheap means of meeting surging electricity demand in Southeast Asia, and will provide valuable cross-border trade for countries exporting the electricity. However, the environmental and socio-economic cost of such schemes on downstream communities could be substantial. Water is used inefficiently, particularly in the irrigated agriculture sector, due to both technical constraints and inappropriate water prices. Public awareness of environmental issues and the willingness to address them varies between the riparian countries of the MRB, and civil society groups are seldom consulted during the decision-making process. Government agencies often lack the institutional capacity to control water use and manage the rivers of the MRB effectively.

Some environmental issues imply direct impacts on communities across national borders, such as changes in the hydrological cycle of the Mekong River Basin. Others are associated with development decisions made at the regional scale, such as the development of transport and energy networks, and may result in localised impacts across the region. To address these transboundary concerns regional cooperation is required. With appropriate regional cooperation among the riparian countries, the impact of hydropower development in the MRB can be limited by adopting integrated, multi-objective planning in order to optimise the utilisation of the region's water resources. The risks arising from introduced species can be reduced by establishing harmonised policies among the MRB countries and adopting effective measures for controlling the introduction and transfer of these species. In order to implement regional and integrated water management, the capacity of national institutions should be strengthened.

The creation of protected areas can conserve sensitive habitats. The wetlands of the MRB are commonly outside of protected areas as they are often intensively developed and there is little appreciation of their economic value. The environmental benefits of protected areas are the maintenance of essential ecological processes; the provision of economically and non-economically valuable resources; the conservation of species; and the preservation of cultural and spiritual heritage.

There is a need to ensure that environmental management issues receive prominent attention at the highest levels of political decision-making within the riparian countries. This report, which has prioritised environmental and socio-economic issues facing the region, can be used for this purpose. The root causes of these priority issues require further investigation so that strategic action programs or policies can be formulated to address the emerging transboundary water-related problems of the MRB.

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Annexes

Annex I
List of contributing authors and organisations

Name	Institutional affiliation	Country	Field of work
Anond Snidvongs (Task Team Leader)	Southeast Asia START Regional Center	Thailand	Oceanography; Global Climate Change
Seng-Keh Teng	Life Science Bio-Technology Ventures	Singapore	Fisheries
Chaiyuth Suksri	Mekong River Commission	Cambodia	Environmental governance
David Coates	Mekong River Commission	Lao PDR	Biodiversity, fisheries management
David Jezeph	Economic and Social Commission for Asia and The Pacific, UN	Thailand	Water resources management, policies and strategies
Hans Friedrich	Regional Wetlands and Water Resources Programme, IUCN	Thailand	Water resources management
Ian Campbell	Mekong River Commission	Cambodia	Ecology
Ing Try	Department of Fisheries	Cambodia	Fisheries biology and management
John Dore	Social Research Institute	Thailand	Environmental governance, political economy
Huu Ti Le	Economic and Social Commission for Asia and The Pacific, UN	Thailand	Hydrology
Quang Minh Le	Can Tho University	Vietnam	Water resources management
Ge Li	Department of International Cooperation, Ministry of Science and Technology	China	Water resources management
Nicholaas van Zalinge	Mekong River Commission	Cambodia	Fisheries
Sansanee Choowaew	Faculty of Environment & Resource Studies, Mahidol University	Thailand	Environmental planning, wetland conservation & management, social & economic aspects of fisheries
Sein Mya	Mekong River Commission	Cambodia	Environmental information management
Somrudee Nicro	Urbanisation and Environment Program, Thailand Environment Institute	Thailand	Sociology
Thavivongse Sriburi	Environmental Research Institute, Chulalongkorn University	Thailand	Water resources planning and management
Wijarn Simachaya	Pollution Control department	Thailand	Coastal/freshwater quality management
Ruud Corsel	Mekong River Commission	Cambodia	Water utilisation

Annex II
Detailed scoring tables

I: Freshwater shortage

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
1. Modification of stream flow	3	60	Freshwater shortage	2.2
2. Pollution of existing supplies	1	20		
3. Changes in the water table	1	20		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		N/a	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		N/a	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		N/a	

N/a=Not applied

II: Pollution

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
4. Microbiological	1	15	Pollution	2.0
5. Eutrophication	2	20		
6. Chemical	1	15		
7. Suspended solids	3	40		
8. Solid wastes	0	0		
9. Thermal	0	0		
10. Radionuclides	0	0		
11. Spills	1	10		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		N/a	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		N/a	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		N/a	

N/a=Not applied

III: Habitat and community modification

Environmental issues	Score	Weight	Environmental concern	Weight averaged score
12. Loss of ecosystems	3		Habitat and community modification	3
13. Modification of ecosystems or ecotones, including community structure and/or species composition	3			

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		N/a	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		N/a	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		N/a	

N/a=Not applied

IV: Unsustainable exploitation of fish and other living resources

Environmental issues	Score	Weight %	Environmental concern	Weight averaged score
14. Overexploitation	3	50	Unsustainable exploitation of fish	2.7
15. Excessive by-catch and discards	1	5		
16. Destructive fishing practices	2	20		
17. Decreased viability of stock through pollution and disease	N/a	N/a		
18. Impact on biological and genetic diversity	3	25		

Criteria for Economics impacts	Raw score	Score	Weight %
Size of economic or public sectors affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of impact (cost, output changes etc.)	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Economic impacts		N/a	
Criteria for Health impacts	**Raw score**	**Score**	**Weight %**
Number of people affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Health impacts		N/a	
Criteria for Other social and community impacts	**Raw score**	**Score**	**Weight %**
Number and/or size of community affected	Very small – Very large 0 1 2 3	N/a	N/a
Degree of severity	Minimum – Severe 0 1 2 3	N/a	N/a
Frequency/Duration	Occasion/Short – Continuous 0 1 2 3	N/a	N/a
Weight average score for Other social and community impacts		N/a	

N/a=Not applied

Presently, there is insufficient data to demonstrate conclusively the current impacts of Global Change.

Comparative environmental and socio-economic impacts of each GIWA concern

Concern	Types of impacts								Overall score	Rank
	Environmental score		Economic score		Human health score		Social and community score			
	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)	Present (a)	Future (b)		
Freshwater shortage	2	3	1	0	1	2	2	1	1.71	3
Pollution	2	2	1	1	2	2	2	2	1.75	4
Habitat and community modification	3	2	3	2	1	1	2	2	2.00	1
Unsustainable exploitation of fish and other living resources	3	3	3	2	0	0	2	1	2.33	2
Global change	N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a	N/a	5

N/a=Not applied

Annex III
Functions and activities of the regional institutions and agencies involved in addressing and managing water-related environmental issues and problems in the GIWA Mekong River region

Asian International Rivers Center (AIRC)

AIRC was established in October, 2000 and headed by Professor He Daming. The Center is primarily engaged in basic and applied research, information development and capacity building related to the study of international rivers in China and Asia. It is located in the campus of Yunnan University in Kunming City, Yunnan province, China. The AIRC provides necessary research for addressing issues related to the conservation of natural resources and is meeting the growing demand for high quality information and analysis on which environmental management decisions should be based. Studies related to the well-being of ecosystems in the Upper Mekong River Basin, or the Lancang River Basin, are undertaken by the program entitled "Ecosystem Changes in Longitudinal Range-Gorge Region and Transboundary Ecological Security in Southwest China, 2004-2008".

Australian Mekong Resource Centre (AMRC)

AMRC is a resource centre established in 1997 and based at the School of Geosciences, University of Sydney, Australia. AMRC defines the Mekong Region into two levels, the first level is the Mekong Basin proper, i.e. the catchment of the Mekong River and its tributaries, covering an area of 795 000 km^2 and providing home to 65 million people in six different countries; the second level has a broader geographical framework including what has become known as the Greater Mekong Subregion (GMS). GMS comprises an area that is home to some 250 million people and is based on five of the countries through which the Mekong River flows – Myanmar, Thailand, Lao PDR, Cambodia and Vietnam - plus Yunnan province in southern China. The Centre promotes research, discussion and debate on development and environmental issues in the Mekong Region, focusing on the role that Australia plays in the region as a near neighbour, donor and major trading partner. The Centre is a focal point for information, dialogue and activities in support of an equitable and sustainable development path for the Region. By fostering a deeper and wider understanding of contemporary changes in the Mekong Region, the AMRC aims to support development paths that maintain the integrity, diversity and symbiosis of local livelihoods, cultures and ecosystems.

Association of Southeast Asian Nations (ASEAN)

ASEAN was established on 8 August 1967 in Bangkok by the five original Member Countries: Indonesia, Malaysia, Philippines, Singapore, and Thailand. Brunei Darussalam joined on 8 January 1984, Vietnam on 28 July 1995, Laos and Myanmar on 23 July 1997, and Cambodia on 30 April 1999. The ASEAN region has a population of about 500 million, a total area of 4.5 million km^2, a combined gross domestic product of 737 billion USD, and a total trade of 720 billion USD. ASEAN functions in accordance to the ASEAN Declaration as the guiding principles. The Declaration states that the aims and purposes of the Association are: (i) to accelerate the economic growth, social progress and cultural development in the region through joint endeavours in the spirit of equality and partnership in order to strengthen the foundation for a prosperous and peaceful community of Southeast Asian nations; and (ii) to promote regional peace and stability through abiding respect for justice and the rule of law in the relationship among countries in the region and adherence to the principles of the United Nations Charter.

Greater Mekong Subregion Academic and Research Network (GMSARN)

GMSARN carries out activities related to human resources development, joint research, and dissemination of information and intellectual assets generated in the Greater Mekong Subregion (GMS). The Network seeks to ensure that the holistic intellectual knowledge and assets generated, developed and maintained are shared by organisations within the region. Primary emphasis is placed on complementary linkages between technological and socio-economic development issues. An agreement among the founding GMS country institutions was signed on 26 January 2001, based on resolutions reached at the Greater Mekong Subregional Development Workshop convened earlier. The GMSARN member institutions are the Asian Institute of Technology; the Institute of Technology of Cambodia; the Kunming University of Science and Technology, Yunnan province, China; the National University of Laos; the Yangon Technological University, Myanmar; the Khon Kaen University, Thailand; Thammasat University, Thailand; the Hanoi University of Technology, Vietnam, and the Ho Chi Minh City University of Technology as well as the Royal University of Phnom Penh in Cambodia and Yunnan University in Yunnan province, China. The agreement commenced on the date of signing and will remain in effect for four years, subject to extension by the GMSARN member institutions. Objectives of the GMSARN are (i) To enhance the roles and functions of regional academics in project evaluation and development planning in order to achieve the region's truly self-reliant and sustainable development; (ii) to foster multi-disciplinary research and academic development within and among academic and research institutions in the GMS through relevant joint activities; (iii) to formulate and resolve, scientifically and objectively, complex problems covering both cross-border issues and issues that are common to GMS countries; and (iv) to take stock of intellectual assets developed for the GMS so as to ensure transparently accessible reference and utilisation among the GMS countries.

Greater Mekong Subregion Program of the Asian Development Bank

The Program was created by the Asian Development Bank (ADB) in 1992 to enhance economic cooperation among the Greater Mekong Subregion (GMS) countries including Cambodia, Lao PDR, Myanmar, Thailand, Vietnam, and Yunnan province in China. The Program has contributed to the development of infrastructure to enable the development and sharing of

the resource base, and promote the freer flow of goods and people in the subregion. It has also led to the international recognition of the subregion as a growth area. In addition, the Program has produced a comprehensive "Atlas of the Environment" for the GMS that describes in detail the profile, environmental and natural resources, people and environment, sustainable development, remote sensing images of ecoregions and information resources of the subregion.

International Rivers Network (IRN)

IRN is an international non-governmental organisation (NGO) that supports local communities working to protect their rivers and watersheds. Efforts of IRN are to halt destructive river development projects, and to encourage equitable and sustainable methods of meeting needs for water, energy and flood management. IRN also seeks a world in which rivers and their watersheds are valued as living systems and are protected and nurtured for the benefit of the human and biological communities that depend on them. Overall vision of IRN is to develop worldwide understanding of the importance of rivers and their essential place in the struggle for environmental integrity, social justice, and human rights. Its mission is to halt and reverse the degradation of river systems; to support local communities in protecting and restoring the well-being of the people, cultures and ecosystems that depend on rivers; to promote sustainable, environmentally sound alternatives to damming and channelling rivers; to foster greater understanding, awareness and respect for rivers; to support the worldwide struggle for environmental integrity, social justice and human rights; and to ensure that our work is exemplary of responsible and effective global action on environmental issues. IRN has initiated a Mekong Campaign project that watches over the development activities for instance, the hydropower development, improvement of the navigation routes, etc., which could induce adverse impacts on the ecosystems of the Mekong River Basin.

Mekong River Commission

The Mekong River Commission (MRC) was founded under the "Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin" signed by Cambodia, the Lao PDR, Thailand and Vietnam on the 5th of April 1995 in replacement of the Committee for Coordination of Investigation of the Lower Mekong Basin (the Mekong Committee) and the Interim Mekong Committee, which were established earlier in 1957 and 1978, respectively. The purpose of the 1995 Agreement is to optimise the use and minimise the waste of the Basin's water resources. The MRC also holds an official dialogue with the two other states of the Mekong River Basin, China and Myanmar, which are not signatories of the 1995 Agreement. The MRC enjoys the status of an international body and it has signed several agreements and holds obligations with the donors and the international community. There are three permanent bodies in the MRC: Council, Joint Committee and Secretariat. Acting as focal points for the Commission in each of the member countries are the National Mekong Committees (NMCs). The MRC is the lead agency which deals with every aspect (from environment and natural resources to socio-economic management) relating to the management of the Mekong River Basin. The MRC Secretariat is the executive arm of the MRC with its headquarters in Phnom Penh, Cambodia. The Commission has formal agreements for cooperation with regional and international organisations, e.g. ADB, AIT, and ICLARM. Current programs carried out by MRC include: Water Utilisation Programme (WUP); Basin Development Plan (BDP); Environment Programme (EP); Integrated Capacity Building Programme; Fisheries Programme; Agriculture, Irrigation and Forestry Programme; Water Resources Management Programme; Flood Management Programme; and Navigation Programme.

Oxfam International

Oxfam International is an international non-governmental organisation (NGO) which seeks increased worldwide public understanding that economic and social justices are crucial to sustainable development. It strives to be a global campaigning force promoting the awareness and motivation that comes with global citizenship whilst seeking to shift public opinion in order to make equity the same priority as economic growth. Oxfam's goal is to enable people to exercise their rights and manage their own lives. From long-term programmes to short-term emergency relief and immediate campaign action, Oxfam believes in empowering people. Oxfam strives to work with local partners and takes a rights based approach to development work. Oxfam International has conducted several projects relating to the impacts of hydropower development on the environment and ecosystems of the Mekong River Basin over the past decade.

Partnership in Environmental Management for the Seas of East Asia (PEMSEA)

PEMSEA is a GEF project which aims to build partnership within and among governments as well as with the public and private sectors of the East Asian Seas region in environmental management and to reduce or remove barriers to effective environmental management such as inadequate or inappropriate policies, disparate institutional and technical capabilities and limited investment in environmental facilities and services. PEMSEA is based on two management frameworks, namely, the integrated coastal management (ICM) framework for coastal area management and the risk assessment/management framework for assessing the impacts of human activities on marine ecosystems in sub-regional sea areas. Six ICM demonstration sites (one in each of Vietnam, Cambodia, Indonesia, Thailand, DPR Korea and Malaysia) and two sub-regional sea environmental management demonstration sites, in the Gulf of Thailand and the Bohai Sea, were established to test and validate the implementation of PEMSEA's environmental management frameworks. The ICM demonstration sites in Cambodia and Vietnam established by PEMSEA also conduct studies that have some direct relation with the Mekong River Basin.

Southeast Asia START Regional Center (SEA START RC)

Southeast Asia START Regional Center is one of the regional research nodes of the Southeast Asia Regional Committee for START (SARC). Southeast Asia is one of eight regions in the Global Change SysTem for Analysis, Research and Training (START) network, initiated jointly by the International Geosphere-Biosphere Programme (IGBP), the International Human Dimension Programme (IHDP), and the World Climate Research Programme (WCRP). START is a global network aimed at encouraging multidisciplinary research on the interactions of humans and the environment which are affecting and being affected by global changes. The START regional networks cover areas in Pan-Africa, Southeast Asia, South Asia, Temperate East Asia, Mediterranean, and Oceania. SEA START RC represents geographically: Australia, Brunei Darussalam, Cambodia, China-Taipei, Indonesia, Lao, Malaysia, Philippines, Singapore, Thailand and Vietnam.

SEA START RC was established in 1996 under a Memorandum of Understanding among Chulalongkorn University (CU), National Research Council of Thailand (NRCT), and International START. The Center is located on the Chulalongkorn Campus in Bangkok, Thailand. Its operational objectives are:

1. To develop integrated scientific and socio-economic approaches to reduce uncertainties of forecasting and assessing impacts of environmental change in the Southeast Asia region;
2. To provide recommendations and expert advise to governments and the private sector on coping with long-term environmental changes;
3. To encourage and support the sharing and exchange of environmental data and information within and between regions , and;
4. To promote public awareness on global environmental issues

Strategic environmental framework (SEF) for the Greater Mekong Subregion (GMS)

The Strategic Environmental Framework (SEF) Project was created to help the Asian Development Bank (ADB) make funding decisions about infrastructure projects in the Greater Mekong Subregion (GMS) which includes Cambodia, Lao PDR, Myanmar, China (Yunnan province), Thailand and Vietnam. The Project was implemented with consulting inputs from the Stockholm Environment Institute (SEI), in collaboration with the UNEP Regional Resource Centre for Asia and the Pacific (UNEP RCC AP) and the Mekong River Commission (MRC). The project employs analytical, participatory and policy oriented processes to develop a strategic environmental framework for guiding investment decisions in the transport, water resources development and environmental sectors in the GMS. Its ultimate goal is to ensure these investments are environmentally and socially sustainable, and that environmental and social aspects, as well as cumulative impacts, are considered at an earlier stage in the planning process than currently takes place. It involved four broad phases: 1. Inception Phase (November 1998 - September 1999); 2. Analysis Phase (October 1999 - July 2000); 3. Production Phase (August 2000 - December 2000); and 4. Communication Phase (January 2001- April 2001). These phases involved a broad range of consultations with a spectrum of stakeholders and decision-makers in the region. The project has been completed and a final report of the project prepared.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP)

The regional arm of the United Nations Secretariat for the Asian and Pacific region is the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The functions of UNESCAP have been defined by the Secretary General as follows:

1. Promoting economic and social development through regional and subregional cooperation and integration;
2. Serving as the main economic and social development forum within the United Nations system for the UNESCAP region;
3. Formulating and promoting development assistance activities and projects commensurate with the needs and priorities of the region while acting as an executing agency for relevant operational projects;
4. Providing substantive and secretariat services and documentation for the Commission and its subsidiary bodies;
5. Carrying out studies, research and other activities within the terms of reference of the Commission;
6. Providing advisory services to governments at their request;
7. Developing and executing programmes of technical cooperation;
8. Coordinating UNESCAP activities with those of the major departments/offices of the United Nations at Headquarters and specialised agencies and intergovernmental organisations.

Water-related activities in Asia and the Pacific Region are carried out under ESCAP's Water Resources Programme in the Environment and Natural Resources Development Division. The UNESCAP organises seminars and workshops in tackling various issues including those related to: (a) Water resources assessment; (b) Integrated water resources development and management; (c) Protection of water resources, water quality and aquatic ecosystems; (d) River basin development and management; (e) Promotion of infrastructure development and investment for drinking water supply and sanitation; (f) Water pricing and promotion of private investment in the water sector; (g) Water demand management, water saving and economic use of water; and (h) Mitigation of water-related natural disasters, particularly flood loss reduction. UNESCAP also undertakes studies relating to the environment and sustainable development, and provides a statistical database for the riparian countries of the Mekong River Basin.

UNEP Regional Office for Asia and the Pacific (ROAP)

ROAP reports directly to the Division of Regional Cooperation and Representation of UNEP's headquarters in Nairobi. It was established to adopt global environmental policies to meet the regional priorities and needs, putting particular emphasis on building partnerships with regional and sub-regional and intergovernmental agencies, other UN agencies, national governments, NGOs, the private sector, academic and research institutions, civil society and the media. ROAP also acts as a catalyst, coordinator, facilitator and mobiliser of resources to support these activities.

World Resources Institute (WRI)

WRI is an independent non-profit organisation based in Washington D.C., United States. The organisation has more than 100 scientists, economists, policy experts, business analysts, statistical analysts, mapmakers and communicators working to protect the Earth and improve people's lives. Studies on the biodiversity, protected areas and watersheds of the Mekong River Basin are being undertaken by two of its core programs: Biodiversity and Protected Areas and Water Resources and Freshwater Ecosystems.

Annex IV
List of conventions and specific laws that affect water use in the GIWA Mekong River region

(A) List of Convention, Treaties and Agreements

Conventions/Treaties/Agreements	Year
(1) Cambodia	
- Ramsar Convention	1999
- International Trade of Endangered Species of Wild Flora and Fauna	1997
- Framework Convention on Climate Change	1996
- Convention on the Prevention of Marine Pollution	1996
- Convention on Biological Diversity	1995
- Coordinate Body of Southeast Asia Seas Agreement	1996
- International Convention for the Prevention of Pollution from Ships	1995
- International Convention on Civil Liability for Oil Pollution Damage	1995
- International Tropical Timber Agreement	1994
- Convention on the Protection of World Heritage	1993
- Plant Protection Agreement for Asia and the Pacific Region	1969
- Convention on the Fishing and Conservation of the Living Resources of the High Seas	1966
- Convention on Road Traffic	1956
- International Plant Protection Convention	1952
(2) Yunnan province of China	
- United Nations Convention on the Law of the Sea	1996
- Framework Convention on Climate Change	1994
- International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL) Annex III (Optional): Hazardous Substances Carried in Packaged Form	1994
- Convention on Biological Diversity	1993
- Agreement for the Establishment of the Asia Pacific Fishery Commission	1993
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat	1992
- Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	1992
- Montreal Protocol for CFC Control	1991
- Plant Protection Agreement for Asia and the Pacific Region	1990
- Agreement for the Establishment of Network of Aquaculture Centers in Asia and the Pacific	1990
- Convention for the Protection of the Ozone Layer	1989
- Protocol to the International Convention on Civil Liability for Oil Pollution Damage	1986
- Convention on Protection of World Heritage	1986
- International Tropical Timber Agreement	1986
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	1985
- Amendments to the Annexes to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	1985
- International Convention for the Prevention of Pollution from Ships (as modified by the Protocol of 1978)	1983
- Convention on International Trade of Endangered Species of Wild Flora and Fauna	1981
- International Convention on Civil Liability for Oil Pollution Damage	1980
- Convention on Road Traffic	1957
(3) Lao PDR	
- Convention for the Protection of the Ozone Layer	1998
- United Nations Convention on the Law of the Sea	1998
- Montreal Protocol for CFC Control	1998
- Convention on Biological Diversity	1996
- Framework Convention on Climate Change	1995
- Agreement on Cooperation for the Sustainable Development of the Mekong River Basin	1995
- Convention on the Protection of World Heritage	1987
- Convention on Road Traffic	1959
- Plant Protection Agreement for Asia and the Pacific Region	1950
- International Plant Protection Convention	1955

(Source: ADB/UNEP 2004)

Conventions/Treaties/Agreements	Year
(4) Myanmar	
- United Nations Convention on the Law of the Sea	1996
- Framework Convention on Climate Change	1995
- Convention for the Protection of the Ozone Layer	1994
- Montreal Protocol for CFC Control	1994
- Convention on Biological Diversity	1995
- Convention on the Protection of World Heritage	1994
- International Tropical Timber Agreement	1994
- Agreement for the Establishment of Network of Aquaculture Centers in Asia and the Pacific	1990
- International Convention for the Prevention of Pollution from Ships	1988
- Statutes of the International Center for the Study of the Preservation and Restoration of Cultural Property	1987
- Convention on the International Maritime Organisation	1963
- Agreement for the Establishment of the Asia Pacific Fishery Commission	1949
(5) Thailand	
- Framework Convention on Climate Change	1995
- Convention for the Protection of the Ozone Layer	1989
- Protocol on Substances that Deplete the Ozone Layer	1989
- Montreal Protocol for CFC Control	1989
- International Tropical Timber Agreement	1997
- Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin	1995
- Agreement for the Establishment of Network of Aquaculture Centers in Asia and the Pacific	1994
- Agreement for the Establishment of the Asia Pacific Fishery Commission	1948
- Convention on the Protection of World Heritage	1987
- Convention on International Trade of Endangered Species of Wild Flora and Fauna	1983
- International Plant Protection Convention	1978
- Convention on the International Maritime Organisation	1973
- Convention on the Fishing and Conservation of the Living Resources of the High Seas	1968
- Agreement on Establishing the Southeast Asian Fisheries Development Center	1967
- Statutes of the International Center for the Study of the Preservation and Restoration of Cultural Property	1967
- Convention on Road Traffic	1962
- Plant Protection Agreement for Asia and the Pacific Region	1956
- Convention on Biological Diversity	1989
(6) Vietnam	
- Framework Convention on Climate Change	1995
- Convention for the Protection of the Ozone Layer	1994
- Montreal Protocol for CFC Control	1994
- United Nations Convention on the Law of the Sea	1994
- Convention on Biological Diversity	1995
- Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	1995
- Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin	1995
- Convention on International Trade of Endangered Species of Wild Flora and Fauna	1994
- Amendment to the Convention on International Trade of Endangered Species of Wild Flora and Fauna (Art XI)	1994
- International Convention for the Prevention of Pollution from Ships	1991
- Agreement for the Establishment of Network of Aquaculture Centers in Asia and the Pacific	1990
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat	1989
- Convention on the Protection of World Heritage	1988
- Convention on the International Maritime Organisation	1984
- Statutes of the International Center for the Study of the Preservation and Restoration of Cultural Property	1972
- Agreement on Establishing the Southeast Asian Fisheries Development Center	1968
- Plant Protection Agreement for Asia and the Pacific Region	1956
- Agreement for the Establishment of the Asia Pacific Fishery Commission	1951

(Source: ADB/UNEP 2004)

(B) List of Policies, Laws, Decrees, Rules and Regulations

Policy/Law/Decree/Rule/Regulation	Year
(1) Cambodia	
1.1. Policies	
- Natural Environmental Action Plan	1998 - 2003
1.2. Laws, Decrees, Rules & Regulations	
- Sub-Decree on Water Pollution Control	1999
- Sub-Decree on Solid Waste Management	1999
- Sub-Decree on Environmental Impact Assessment (EIA)	1999
- Law on Environmental Protection and Natural Resources Management	1996
- Royal Decree on Protected Areas	1993
(2) Yunnan province of China	
2.1. Policies	
- 9th 5-Year Plan and Long-term Environmental Protection Plan for 2010 for Yunnan province	1996-2010
2.2. Laws, Decrees, Rules & Regulations	
- Forestry Law of the People's Republic of China	1998
- Law of the People's Republic of China on Conserving Energy	1997
- Flood Control Law of the People's Republic of China	1997
- Mineral Resources Law of the People's Republic of China	1996
- Law of the People's Republic of China on the Coal Industry	1996
- Law of the People's Republic of China on Prevention and Control of Water Pollution	1996
- Law of the People's Republic of China on Prevention and Control of Environmental Pollution by Solid Waste	1995
- Law of the People's Republic of China on Water and Soil Conservation	1991
- Law of the People's Republic of China on the Protection of Wildlife	1988
- Environmental Protection Law of the People's Republic of China	1989
- Water Law of the People's Republic of China	1988
- Fisheries Law of the People's Republic of China	1986
- Grassland Law of the People's Republic of China	1985
- Law of the People's Republic of China on the Protection of Cultural Relics	1982
- Circular on Strengthening Environmental Protection in the Tourism Area	1995
- Regulation on Examining an Environmental Protection Facility along with Construction Projects	1994
- Regulation on Environmental Pollution Prevention from the Electrical Facility and Wastes involved with PCBs	1991
- Ordinance on Radioactive Safeguards for Radioactive Isotope and Radiation	1989
- Regulation on Undertaking an Environmental Impact Assessment for the Construction Project	1989
- Circular on Strengthening the Supervision to the Wastewater Discharge from Pesticide Production	1997
- Provisional Regulations on Environmental Control for Economic Zones Open to Foreigners	1986
- Regulations on Management of the Environmental Protection Standards	1983
(3) Lao PDR	
3.1. Policies	
- Environmental Action Plan	1993
3.2. Laws, Decrees, Rules & Regulations	
- Prime Minister's Decree on Vientiane Urban Development and Administration Authority	2000
- Formalised Environmental Impact Assessment (EIA)	2000
- Environmental Protection Law	1999
- President's Decree on Urban Planning Law	1999
- Mining Law	1997
- President's Decree on Historical, Cultural and National Heritage Protection	1997
- Prime Minister's Decree on Urban Development and Administration Authority (UDAA)	1997
- Prime Minister's Decree on Management and Use of Forest and Forestland	1993
- Water and Water Resources Law	1996
- Land Law	1997
- Forest Law	1996
- Prime Minister's Decree on the Protection of Sites and Buildings of National Importance	1994
- Decree on Logging Ban	1991
- Decree on Adoption of Tropical Forest Programme	1991
- Decree on Wild Animals, Fisheries, Hunting and Fishing	1989
- Provisions on Discharge of Wastewater from Factories	1994
- Regulations of Environmental Assessment in Lao PDR	2000

Policy/Law/Decree/Rule/Regulation	Year
(4) Thailand	
4.1. Policies	
- Policy and Prospective Plan for National Environmental Quality Enhancement and Protection	1997 – 2017
- Environmental Quality Management Plan	1999 - 2006
4.2. Laws, Decrees, Rules & Regulations	
- National Environmental Quality Enhancement and Protection Act	1992
- Factories Act	1992
- Public Health Act	1992
- Cleanliness and Orderliness of the Country Act	1992
- Hazardous Substances Act	1992
- Poisonous Substances Act	1967
- Energy Conservation Promotions Act	1992
- Wildlife Conservation and Protection Act	1992
- Forest Plantation Act	1992
- Forest Reserve Act	1964
- National Park Act	1961
- Forestry Act	1947
- Conservation of Wild Elephants Act	1921
- Fishery Act	1945
- Mineral Act	1967
- Groundwater Act No. 2	1992
- Prevention of Ships Collision Act	1979
- Groundwater Act	1977
- Navigation in Thai Waterways Act	1913
(5) Myanmar	
5.1. Policies	
- Myanmar Agenda 21	1997
- National Environmental Policy	1994
- Forest Policy	1995
5.2. Laws, Decrees, Rules & Regulations	
- Draft Environmental Law	2000
- Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law	1994
- Mines Law	1994
- Plant Pest Quarantine Law	1993
-Forestry Law	1992
- Freshwater Fisheries Law	1991
- Pesticide Law	1990
- Law on Aquaculture	1989
- Law on Fishing Rights of Foreign Fishing Vessels	1989
- Irrigation Laws and Regulations	1982
- Factory Act	1950
(6) Vietnam	
6.1. Policies	
- National Plan for Environmental and Sustainable Development	1991 - 2000
- Draft National Strategy for Environment Protection	2001 - 2010
6.2. Laws, Decrees, Rules & Regulations	
- Instruction No. 490/1998/TT-BKHCNMT on Environmental Impact Assessments	1998
- Decree No. 28/CP on Sanctions against Administrative Violations on Environmental Protection	1996
- Law on Minerals	1996
- Decree No. 02/CP on Toxic Chemicals and Radioactive Substances	1995
- Instruction No.1420/QD-MTg for Guiding Environmental Impact Assessment to the Operating Units	1994
- Decree 09/CP of the Government on Organising and Managing the Tourist Enterprise	1994
- Law on Environmental Protection	1993
- Law on Land	1993
- Decree 14/CP on Administrative Fines in the Management and Protection of Forests	1992
- Precious and Rare Wild Plants and Animals Regulating their Management and Protection	1992
- Law on Forest Protection and Development	1991
- Vietname Maritime Code	1990
- Law on the Protection of People's Health	1989
- Law on Fisheries (draft)	
- Law on Water Resources (draft)	
- Vietnam Standards, Water Quality – Maximum Allowable Pesticide Residues in the Soil, TCVN 5941	1995
- Vietnam Standards, Water Quality – Surface Water Quality Standard, TCVN 5942	1995
- Vietnam Standards, Water Quality – Coastal Water Quality Standard, TCVN 5943	1995
- Vietnam Standards, Water Quality – Ground Water Quality Standard, TCVN 5944	1995
- Vietnam Standards, Water Quality – Discharge Standard, TCVN 5945	1995

(Source: ADB/UNEP 2004)

Annex V
Impact Assessment for GIWA Mekong River region:

Environmental & socio-economic impact statements and causes of priority GIWA concerns and environmental issues

Priority GIWA Concern			Priority GIWA Environmental Issue		Impact Statement (environmental & socio-economic)	Possible Causes
Concern	**Overall Environmental Impact Score**	**Socio-economic Impact Scores***	**Issue**	**Overall Score**		
III. Habitat and community modification	3	2-3-1	**12. Loss of ecosystems**	3	1) The area of forestland decreased by 98 145 km^2 between 1993 and 2003; a loss of around 12% of the total forestland area.	1) The loss was largely due to excessive logging, uncontrolled shift cultivation, encroachment of forest reserves by human settlements, and uncontrolled farming and infrastructure development, as well as the increasing use of wood fuel and inappropriate land occupation.
					2) Large areas of mangrove forests around the Mekong Delta have been destroyed over the past 2-3 decades; around 120 000 ha remain today.	2) The loss was due to wartime hostilities and post-war agricultural expansion as well as the conversion of mangroves to shrimp ponds.
					3) The livelihood of the population in the MRB has been affected by the loss of forestland and mangrove forests.	3) Because the rural communities in the region depend on the natural resources of the ecosystems to subsist, the loss of ecosystems will reduce their income and quality of life.
					4) The loss of ecosystems in the region has substantial transboundary implications.	4) Most of the fish species in the MRB are migratory; the destruction of spawning or breeding habitats in one riparian country affects the recruitment and harvest of fish in other riparian countries.
			13. Modification of ecosystems	3	1) Millions of hectares of valuable forestland in the region have been degraded to inferior shrub, grassland or savannah.	1) The degradation is caused by unsustainable human and development activities, e.g. population growth, deforestation, urbanisation, dam construction, irrigation, etc.
					2) The aesthetic and recreational values of the habitats have been greatly reduced.	2) The modification of habitats has reduced the number of goods and services that they provide.
					3) Cost of controlling alien species and restoring ecosystems.	3) The introduction of alien species for aquaculture, the stocking of lakes and reservoirs and the aquarium trade.
					4) Employment opportunities, particularly in the fisheries sector, have substantially declined.	4) Modifications or loss of habitats indirectly influences fisheries production which, in turn, changes the employment opportunities for fishers.
					5) Modification of ecosystems, e.g. the Melaleuca forest land, has substantial transboundary implications for environmental management.	5) Some of these forests are transboundary in that they cover more than one territory.
IV. Unsustainable exploitation of fish & other living resources	3	2-3-0	**14. Overexploitation**	3	1) Catches per fisheman have declined by approximately 44% between the 1940s and 1995.	1) The number of fishermen has greatly increased and the larger population places additional pressure on the fisheries.
					2) The abundance of fish resources in the region has declined over the past decade.	2) The building and operation of dams and weirs has disrupted fish migration and spawning, thus reducing fisheries productivity; habitat loss and deforestation have modified or destroyed habitats that fish require for spawning and feeding; the use of destructive fishing practices has reduced fish recruitment.
					3) Employment opportunities in the fisheries sector have decreased.	3) Overexploitation has led to a reduced catch per unit effort, which has affected employment opportunities in the fisheries sector.
					4) The livelihood strategies of local communities have significantly changed.	4) The loss of commercially valuable fish species and the destruction of habitats has forced fishers to seek alternative livelihoods.
					5) Competition among fishermen from different countries due to them fishing the same migratory stocks.	5) Migratory fish constitute a significant proportion of the some 1 500 species of ichtyofauna in the MRB. Conflicts arise from foreign fishers operating in the fishing grounds of their neighbouring country.

** Scores for: Social & Community – Economic – Human Health, respectively.*

Priority GIWA Concern			Priority GIWA Environmental Issue		Impact Statement (environmental & socio-economic)	Possible Causes
Concern	**Overall Environmental Impact Score**	**Socio-economic Impact Scores***	**Issue**	**Overall Score**		
IV. Unsustainable exploitation of fish & other living resources *- continued*	3	2-3-0	**18. Impact on biological & genetic diversity**	3	1) Current practices used for the introduction and movement of alien fish in the MRB have resulted in the degradation of the genetic quality of wild stocks. 2) The degradation of the genetic quality of fish stocks has transboundary implications for fisheries management.	1) Such practices are chaotic and uncontrolled, particularly in the aquaculture sector; alien fish species that are established in the local environment have replaced endemic species and reduced the biodiversity of wild stocks. 2) Most of the fish species in the region are migratory species. There is evidence that the biological and genetic diversity of some of these species has changed as a result of overexploitation.
II. Pollution	2	2-1-2	**7. Suspended solids**	3	1) High TSS loads in the mainstream and the tributaries of Mekong. 2) High TSS loads in the Mekong River system have affected the well-being of the population in the MRB. 3) TSS pollution has transboundary implications for management.	1) Development activities such as deforestation, mining, grazing and urbanisation have caused extensive erosion in many parts of the MRB. 2) High TSS loads destroy or modify critical habitats, particularly spawning and breeding grounds of fish, resulting in a reduction in ecosystem products and services. 3) Suspended solids are carried from one part of the MRB to another, from upstream to downstream of the Mekong River, blocking channels, destroying or modifying habitats and forming deltas at the river mouths.
I. Freshwater shortage	2	2-1-1	**1. Modification of stream flow**	3	1) The hydrological cycle of the Mekong River and its tributaries is altered periodically. 2) The course and flow volume of the Mekong River and its tributaries has changed. 3) Changes in the hydrological cycle and the flow volume of the Mekong River and its tributaries have imposed substantial transboundary implications for environmental management. 4) The well-being of the population in the MRB has been affected by changes in the course and flow volume of the Mekong River and its tributaries.	1) Heavy rainfall during the rainy season results in the flooding of lowland areas in the MRB. 2) Human and development activities, such as the construction of dams, improvement of river navigation routes, diversion of river water for irrigation etc., have greatly modified the flow regime of the Mekong River and its tributaries. 3) The Mekong River is an international river that traverses six countries. The upstream modification of stream flow affects downstream environmental conditions. 4) Flooding causes varying degrees of damage to agricultural production, rural infrastructure and human settlements, as well as causing a loss of life.

** Scores for: Social & Community – Economic – Human Health, respectively.*

Annex VI
Alien species introduced to the Mekong River Basin

(Source: Welcomme & Vidthayanom 2003)

Introduced/alien species	Description of the introduction
1. Arapaima (*Arapaima gigas*)	This species has been introduced to the MRB through the aquarium fish trade. Some experiments have been made for its aquaculture development. Escaped individuals have occasionally been found in natural waters in central Thailand. The species is long-lived and can grow to a very large size. It is a voracious predator and a mouth brooder.
2. Goldfish (*Carassius auratus*)	It has been introduced to Thailand as an ornamental fish from China around 1300 AD and to Vietnam at an unknown date. The species reproduces naturally in captivity but does not apparently do so in the natural waters of Thailand. More recently, a variety of this species was recorded in the MRB; these are probably escapees from the Red River Basin in Vietnam and from the river network in Lao PDR, and they are presumed to be breeding naturally. Goldfish is a generalised feeder and sticks its spawned eggs onto aquatic plants.
3. Mrigal carp (*Cirrhinus cirrhinus*)	This species is one of the Indian major carps introduced from India into Lao PDR (1977) and Thailand (1979), and later from Lao PDR into Vietnam (1984) for aquaculture. The species is also used for stocking dams. It is thought to be breeding naturally within the basin, since its fry have been found in the mainstream of the Mekong River in northeast Thailand. There are two native or endemic species of *Cirrhinus,* which have better eating qualities, but do not respond well to culture in ponds. The species is used for aquaculture throughout the MRB, where it is regarded as generally beneficial. The Mrigal carp lays demersal eggs and feeds on detritus and periphyton.
4. African catfish *(Clarias gariepinus)*	The African catfish was first introduced into Vietnam from the Central African Republic in 1974 for aquaculture. It has since been introduced into other riparian countries of the MRB by internal transfer. It has been widely used for aquaculture and has been hybridised with the native *Clarias macrocephalus* (C. gariepinus male x C. macrocephalus female). A wild population of the fish has been reported to be established throughout the MRB. However, no immediate detrimental environmental effects have been noted in the MRB or in other areas to which the species has been introduced. The species has a wide range of feeding habits from predation to generalised benthic feeders, and migrates to shallow flooded areas to spawn large quantities of adhesive eggs. The fish and its hybrids are highly tolerant of poor water quality and deoxygenated conditions. This tolerance gives the species and the hybrid a competitive advantage over native clariid catfish.
5. Grass carp (*Ctenopharyngodon idella*)	It is one of the first species introduced to the MRB. It was introduced from China and Hong Kong to Thailand in 1932, to Vietnam in 1958 and to Lao PDR at an undetermined date. The species is used for aquaculture throughout the MRB and is highly appreciated by consumers. It has also been stocked in reservoirs, ditches and canals to control invasive aquatic vegetation. The species does not breed naturally in any part of the MRB and its aquaculture is normally maintained by artificial reproduction and continuous stocking. As its name suggests, the grass carp is one of the few fish to feed primarily on higher vegetation.
6. Common carp (*Cyprinus carpio*)	The species was introduced into Thailand from China, Japan, Israel and Germany from 1913 onwards, into Lao PDR from Thailand and India in 1977, and into Vietnam from Hungary during the period 1969-1975. A complex of variant species has established themselves since the introduction of the species to the MRB. They can be differentiated into two groups: the silver varieties originating from southern China and northern Vietnam, and the yellow varieties originating from eastern Europe. The Common carp has been the keystone species for many aquaculture development projects in the MRB. The species complex is widely established in the wild and in many areas, and is now regarded as a permanent element of the fauna in the MRB. Common carp are notorious for the way their populations rapidly increase following environmental disturbances by dams. Their habit of digging around in the bottom and muddying the water can seriously alter the environment to the detriment of other species. Given that the species is now firmly established, there seems little that can be done to eradicate this potentially troublesome fish. Common carp are basically detritus and mud feeders. They breed on the vegetated margins of lakes and rivers where they deposit their adhesive eggs on submerged vegetation.
7. Mosquito fish (*Gambusia affinis*)	The species was introduced into drainage ditches throughout the MRB at an unknown date for mosquito control, escaping later into the main tributaries of the Mekong River. It is now found at the margins of most water bodies including rice fields and floodplain lakes. The species is tolerant of high salinity and it is not regarded as detrimental although its habit of eating eggs and larvae of other fish may do some damage to fish stocks. The species feeds on surface-living insects and other particulate matter falling on the surface, and it is a live-bearer.
8. Catla carp (*Catla catla*)	The species was introduced into Lao PDR from India in 1977 and Thailand in 1979. Subsequently, some of Lao PDR's stock was introduced to Vietnam for aquaculture in 1984. It is also used for stocking dams and has been recorded as breeding naturally within the waters of MRB but no natural stocks have been reported. Due to its slow growth rate, culture of this species has been largely abandoned in Thailand and Vietnam. The Catla carp feeds on phytoplankton and detritus and normally lays demersal eggs in the mainstream of a river.
9. Silver carp (*Hypothalmichythys molitrix*)	The species was introduced from China into Thailand in 1913 and Vietnam in 1958 for aquaculture. It is widely used for aquaculture throughout the MRB and is artificially bred for this purpose. The species is recorded as having established itself in the Saigon River. Fry of the species have been reported in tributaries of the Mekong River in LMRB, indicating that it has possibly established there. The species feeds on detritus and phytoplankton and may compete with species of similar habit in the MRB.
10. Bighead carp (*Hypothalmichthys nobilis*)	Bighead carp were introduced from China into Thailand in 1932 and Vietnam in 1958 for aquaculture. This species does not breed naturally in ponds and continues to be artificially reproduced. However, fry of the species have been found in the Red River and Saigon River indicating that it has possibly established in those rivers as well. The species feeds primarily on phytoplankton.
11. Black sucker catfish (*Hypostomus plecostomus*)	Black sucker catfish were introduced throughout the MRB countries for the aquarium fish trade. They have been found in rice fields in northeast Thailand for at least ten years and in small urban water bodies. The natural environment where the species dwells ranges from rapids to floodplain pools. Therefore, it can be anticipated that it will spread throughout the MRB.
12. Rohu carp (*Labeo rohita*)	This is another species of the Indian major carp group that was introduced from India into Thailand in 1968, Lao PDR in 1977 and Vietnam in 1982-1984 for aquaculture. Nowadays, the species is widely used for aquaculture throughout the MRB countries. It is preferred more than the native species because it is easier to breed artificially and responds better to handling. Its fry are occasionally found in the mainstream of the Mekong River, indicating that the species is breeding naturally although some fry may be released from culture installations. The Rohu carp are generally periphyton and detritus feeders and lay semi-pelagic eggs.
13. Black carp (*Mylopharyngodon aureus*)	Black carp were introduced from China into Thailand for aquaculture as early as 1913. But since 1980, the species has not been aquacultured; the reason for the disappearance of the species is not known.
14. Green tilapia (*Oreochromis aureus*)	This species was introduced into Thailand in 1970 from Israel. Although the species has not been popular for aquaculture, it appears to have established itself in reservoirs in tributaries of the Mekong River in northern Thailand. These populations are still in existence and the spread of the species further downstream cannot be excluded. The species is a generalised feeder with a preference for detritus and decanted phytoplankton. It also eats small fish and fish larvae. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilisation.
15. Red throat tilapia (*O. mossambicus*)	This is one of the most widespread tilapia species used for aquaculture and stocking of reservoirs in the MRB. It was first introduced to Thailand in 1949 from Malaysia, and into Vietnam from Africa and the Philippines during the period of 1951-1955, into Lao PDR in 1955 from Thailand, and into Cambodia at an unknown date. The species may form established stocks in the MRB, particularly in saline environments, such as Lake Nont Bo in northeast Thailand, as well as throughout the Mekong Delta. Red throat tilapis is notorious for forming dense populations of stunted fish, particularly in brackish water areas and small canals and lakes, as has happened in the Mekong Delta. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilisation.

16. Nile tilapia (*O. niloticus*)	This introduced species is one of the most popular for aquaculture and for stocking dams and reservoirs throughout the tropical world, including the LMRB. It was introduced into Thailand from Japan in 1965, into Vietnam in 1973 and 1994 from Taiwan, the Philippines and Thailand, and into Lao PDR and Cambodia at an unknown date. The species is not known to have any detrimental environmental impact throughout its introduced range and has become one of the pan-tropical species. It is one of the few species that can readily digest blue green algae and as such is of value in the control of eutrophication. It also eats detritus and can feed on small fish and fish larvae. The species is a maternal mouth brooder that constructs nests in shallow water for breeding and fertilisation. The GIFT strain of *O. niloticus* is now reared in and distributed from the Government hatchery in Khon Kaen (Thailand), which is further developing the strain to meet local conditions. Several private hatcheries are licensed to produce this fish for sale to both pond and cage culture locations. The Khon Kaen hatchery maintains the Egyptian Manzalla strain of *O. niloticus*.
17. Red tilapia	Red tilapia is in fact the variant species formed from hybrids between *O.niloticus* and *O. mossambicus*. This variant hybrid is saline tolerant and is popular in Thailand and Lao PDR for aquaculture in ponds and cages.
18. Red cheek tilapia (*Oreochromis rendalli*)	Red cheek tilapia was introduced from Belgium into Thailand in 1955 for aquaculture. Established populations of this species exist in reservoirs around Sakhon Nakhon in northeast Thailand. It is a parental guarder that lays its eggs in a series of small pit-like nests.
19. Guppy (*Poecilia reticulate*)	This species has been introduced into Thailand as an ornamental fish for the aquarium trade as well as for mosquito control. It has established itself in the wild in small streams and ditches, rice fields and other shallow, still water habitats throughout the LMRB. The species is a live bearer and feeds mainly on surface material, including small insects.
20. Sailfin molly (*Poecilia velifera*)	The Sailfin molly was first introduced from Taiwan into Thailand for the aquarium fish trade around 1970. The species is also found in the Mekong Delta in Vietnam. It is a live bearer and is a microphagous omnivore.
21. Apple snails (*Pomacea canaliculatus, P. gagas*)	These species have been introduced from various sources into Thailand for aquaculture from 1988 onwards. Apple snails have now established in the wild and have shown a major impact on aquatic habitats, including rice fields because they have the habit of destroying the bases of growing aquatic plants, causing enormous economic losses for rice farmers and the degradation of natural wetland habitats by stripping vegetation. The snails have a very broad spectrum of feeding habits, using most aquatic plants including water hyacinths. In addition, the introduced snails compete with the endemic species of snails such as *Pila* spp., which are relatively benign in their effect, since they feed only on already moribund plants. Apple snails are tolerant of salinity and are thus able to penetrate coastal habitats. This is an example of the disastrous consequences that can follow an inappropriate introduction of an alien species.
22. Louisiana crayfish (*Procambarus charkii*)	It has been introduced into Thailand from an unknown source for aquaculture. The species has established itself in the wild where it is regarded as a nuisance.
23. Chinese soft-shell turtle (*Pelodiscus chinensis*)	Chinese soft-shell turtle was introduced into Thailand on several occasions since 1977. It is now regularly reproduced in captivity and has formed natural populations. These have impacted on native turtle species.
24. American painted turtle (*Pseudemys scriptac*)	This turtle species was introduced to Thailand in 1975 for the aquarium trade. It is now bred in captivity and has formed natural populations in Central Thailand. It is probably found in the Mekong River watersheds because there is a tendency on the part of owners to release them when they have grown beyond an acceptable size.
25. American bullfrog (*Rana catesbiana*)	The American bullfrog was introduced into Thailand for aquaculture in the 1980s. It has become established in the wild and its ecological impact is unknown. The species is apparently already found in the Vietnamese part of the MRB; probably having been released by farmers when it was apparent that the culture of this species was not profitable.
26. Japanese eel (*Anguilla japonicus*)	Although the species was introduced into Thailand in 1973 for the purpose of aquaculture, commercial aquaculture of this species was not popular. There is no indication that this species has established itself in the MRB.
27. Channel catfish (*Ictalurus punctatus*)	Channel catfish was first introduced from the United States into Thailand in 1989 for aquaculture. It was also introduced into central and northern Thailand where it was cultured experimentally. All fish escaped during the great flood of 1995 and were later found in the natural habitat. However, there are no further records of the impact of this introduction. This species is a generalised bottom feeder that can adopt predatory habits. It builds nests for its eggs, which are later guarded by the parents.
28. Rainbow trout (*Onchorhynchus mykiss*)	This species was introduced from Canada into Thailand in 1963 for the purpose of establishing a sport fishery in the mountainous areas in the north of the country. The introduction was unsuccessful and did not affect the Mekong River system. However, similar proposals surface from time to time in the interests of tourism and some eggs have been introduced into Northern Thailand for experimental culture. It is doubtful that this species would establish in the lower reaches of the river but may do so in the high mountainous tributaries of the UMRB in Yunnan province, China.

The Global International Waters Assessment

This report presents the results of the Global International Waters Assessment (GIWA) of the transboundary waters of the Mekong River region. This and the subsequent chapter offer a background that describes the impetus behind the establishment of GIWA, its objectives and how the GIWA was implemented.

The need for a global international waters assessment

Globally, people are becoming increasingly aware of the degradation of the world's water bodies. Disasters from floods and droughts, frequently reported in the media, are considered to be linked with ongoing global climate change (IPCC 2001), accidents involving large ships pollute public beaches and threaten marine life and almost every commercial fish stock is exploited beyond sustainable limits - it is estimated that the global stocks of large predatory fish have declined to less that 10% of pre-industrial fishing levels (Myers & Worm 2003). Further, more than 1 billion people worldwide lack access to safe drinking water and 2 billion people lack proper sanitation which causes approximately 4 billion cases of diarrhoea each year and results in the death of 2.2 million people, mostly children younger than five (WHO-UNICEF 2002). Moreover, freshwater and marine habitats are destroyed by infrastructure developments, dams, roads, ports and human settlements (Brinson & Malvárez 2002, Kennish 2002). As a consequence, there is growing public concern regarding the declining quality and quantity of the world's aquatic resources because of human activities, which has resulted in mounting pressure on governments and decision makers to institute new and innovative policies to manage those resources in a sustainable way ensuring their availability for future generations.

Adequately managing the world's aquatic resources for the benefit of all is, for a variety of reasons, a very complex task. The liquid state of the most of the world's water means that, without the construction of reservoirs, dams and canals it is free to flow wherever the laws of nature dictate. Water is, therefore, a vector transporting not only a wide variety of valuable resources but also problems from one area to another. The effluents emanating from environmentally destructive activities in upstream drainage areas are propagated downstream and can affect other areas considerable distances away. In the case of transboundary river basins, such as the Nile, Amazon and Niger, the impacts are transported across national borders and can be observed in the numerous countries situated within their catchments. In the case of large oceanic currents, the impacts can even be propagated between continents (AMAP 1998). Therefore, the inextricable linkages within and between both freshwater and marine environments dictates that management of aquatic resources ought to be implemented through a drainage basin approach.

In addition, there is growing appreciation of the incongruence between the transboundary nature of many aquatic resources and the traditional introspective nationally focused approaches to managing those resources. Water, unlike laws and management plans, does not respect national borders and, as a consequence, if future management of water and aquatic resources is to be successful, then a shift in focus towards international cooperation and intergovernmental agreements is required (UN 1972). Furthermore, the complexity of managing the world's water resources is exacerbated by the dependence of a great variety of domestic and industrial activities on those resources. As a consequence, cross-sectoral multidisciplinary approaches that integrate environmental, socio-economic and development aspects into management must be adopted. Unfortunately however, the scientific information or capacity within each discipline is often not available or is inadequately translated for use by managers, decision makers and

policy developers. These inadequacies constitute a serious impediment to the implementation of urgently needed innovative policies.

Continual assessment of the prevailing and future threats to aquatic ecosystems and their implications for human populations is essential if governments and decision makers are going to be able to make strategic policy and management decisions that promote the sustainable use of those resources and respond to the growing concerns of the general public. Although many assessments of aquatic resources are being conducted by local, national, regional and international bodies, past assessments have often concentrated on specific themes, such as biodiversity or persistent toxic substances, or have focused only on marine or freshwaters. A globally coherent, drainage basin based assessment that embraces the inextricable links between transboundary freshwater and marine systems, and between environmental and societal issues, has never been conducted previously.

The Global Environment Facility (GEF)

The Global Environment Facility forges international co-operation and finances actions to address six critical threats to the global environment: biodiversity loss, climate change, degradation of international waters, ozone depletion, land degradation, and persistent organic pollutants (POPs).

The overall strategic thrust of GEF-funded international waters activities is to meet the incremental costs of: (a) assisting groups of countries to better understand the environmental concerns of their international waters and work collaboratively to address them; (b) building the capacity of existing institutions to utilise a more comprehensive approach for addressing transboundary water-related environmental concerns; and (c) implementing measures that address the priority transboundary environmental concerns. The goal is to assist countries to utilise the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalise sustainable development strategies for international waters.

United Nations Environment Programme (UNEP)

United Nations Environment Programme, established in 1972, is the voice for the environment within the United Nations system. The mission of UNEP is to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations.

UNEP work encompasses:

- Assessing global, regional and national environmental conditions and trends;
- Developing international and national environmental instruments;
- Strengthening institutions for the wise management of the environment;
- Facilitating the transfer of knowledge and technology for sustainable development;
- Encouraging new partnerships and mind-sets within civil society and the private sector.

University of Kalmar

University of Kalmar hosts the GIWA Co-ordination Office and provides scientific advice and administrative and technical assistance to GIWA. University of Kalmar is situated on the coast of the Baltic Sea. The city has a long tradition of higher education; teachers and marine officers have been educated in Kalmar since the middle of the 19th century. Today, natural science is a priority area which gives Kalmar a unique educational and research profile compared with other smaller universities in Sweden. Of particular relevance for GIWA is the established research in aquatic and environmental science. Issues linked to the concept of sustainable development are implemented by the research programme Natural Resources Management and Agenda 21 Research School.

Since its establishment GIWA has grown to become an integral part of University activities. The GIWA Co-ordination office and GIWA Core team are located at the Kalmarsund Laboratory, the university centre for water-related research. Senior scientists appointed by the University are actively involved in the GIWA peer-review and steering groups. As a result of the cooperation the University can offer courses and seminars related to GIWA objectives and international water issues.

International call for action

The need for a holistic assessment of transboundary waters in order to respond to growing public concerns and provide advice to governments and decision makers regarding the management of aquatic resources was recognised by several international bodies focusing on the global environment. In particular, the Global Environment Facility (GEF) observed that the International Waters (IW) component of the GEF suffered from the lack of a global assessment which made it difficult to prioritise international water projects, particularly considering the inadequate understanding of the nature and root causes of environmental problems. In 1996, at its fourth meeting in Nairobi, the GEF Scientific and Technical Advisory Panel (STAP), noted that: *"Lack of an International Waters Assessment comparable with that of the IPCC, the Global Biodiversity Assessment, and the Stratospheric Ozone Assessment, was a unique and serious impediment to the implementation of the International Waters Component of the GEF"*.

The urgent need for an assessment of the causes of environmental degradation was also highlighted at the UN Special Session on the Environment (UNGASS) in 1997, where commitments were made regarding the work of the UN Commission on Sustainable Development (UNCSD) on freshwater in 1998 and seas in 1999. Also in 1997, two international Declarations, the Potomac Declaration: Towards enhanced ocean security into the third millennium, and the Stockholm Statement on interaction of land activities, freshwater and enclosed seas, specifically emphasised the need for an investigation of the root causes of degradation of the transboundary aquatic environment and options for addressing them. These processes led to the development of the Global International Waters Assessment (GIWA) that would be implemented by the United Nations Environment Programme (UNEP) in conjunction with the University of Kalmar, Sweden, on behalf of the GEF. The GIWA was inaugurated in Kalmar in October 1999 by the Executive Director of UNEP, Dr. Klaus Töpfer, and the late Swedish Minister of the Environment, Kjell Larsson. On this occasion Dr. Töpfer stated: "*GIWA is the framework of UNEP´s global water assessment strategy and will enable us to record and report on critical water resources for the planet for consideration of sustainable development management practices as part of our responsibilities under Agenda 21 agreements of the Rio conference*".

The importance of the GIWA has been further underpinned by the UN Millennium Development Goals adopted by the UN General Assembly in 2000 and the Declaration from the World Summit on Sustainable

Development in 2002. The development goals aimed to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015 (United Nations Millennium Declaration 2000). The WSSD also calls for integrated management of land, water and living resources (WSSD 2002) and, by 2010, the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem should be implemented by all countries that are party to the declaration (FAO 2001).

The conceptual framework and objectives

Considering the general decline in the condition of the world's aquatic resources and the internationally recognised need for a globally coherent assessment of transboundary waters, the primary objectives of the GIWA are:

- To provide a prioritising mechanism that allows the GEF to focus their resources so that they are used in the most cost effective manner to achieve significant environmental benefits, at national, regional and global levels; and
- To highlight areas in which governments can develop and implement strategic policies to reduce environmental degradation and improve the management of aquatic resources.

In order to meet these objectives and address some of the current inadequacies in international aquatic resources management, the GIWA has incorporated four essential elements into its design:

- A broad transboundary approach that generates a truly regional perspective through the incorporation of expertise and existing information from all nations in the region and the assessment of all factors that influence the aquatic resources of the region;
- A drainage basin approach integrating freshwater and marine systems;
- A multidisciplinary approach integrating environmental and socio-economic information and expertise; and
- A coherent assessment that enables global comparison of the results.

The GIWA builds on previous assessments implemented within the GEF International Waters portfolio but has developed and adopted a broader definition of transboundary waters to include factors that influence the quality and quantity of global aquatic resources. For example, due to globalisation and international trade, the market for penaeid shrimps has widened and the prices soared. This, in turn, has encouraged entrepreneurs in South East Asia to expand aquaculture resulting in the large-scale deforestation of mangroves for ponds (Primavera 1997). Within the GIWA, these "non-hydrological" factors constitute as large a transboundary influence as more traditionally recognised problems, such as the construction of dams that regulate the flow of water into a neighbouring country, and are considered equally important. In addition, the GIWA recognises the importance of hydrological units that would not normally be considered transboundary but exert a significant influence on transboundary waters, such as the Yangtze River in China which discharges into the East China Sea (Daoji & Daler 2004) and the Volga River in Russia which is largely responsible for the condition of the Caspian Sea (Barannik et al. 2004). Furthermore, the GIWA is a truly regional assessment that has incorporated data from a wide range of sources and included expert knowledge and information from a wide range of sectors and from each country in the region. Therefore, the transboundary concept adopted by the GIWA extends to include impacts caused by globalisation, international trade, demographic changes and technological advances and recognises the need for international cooperation to address them.

International waters and transboundary issues

The term "international waters", as used for the purposes of the GEF Operational Strategy, includes the oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries, as well as rivers, lakes, groundwater systems, and wetlands with transboundary drainage basins or common borders. The water-related ecosystems associated with these waters are considered integral parts of the systems.

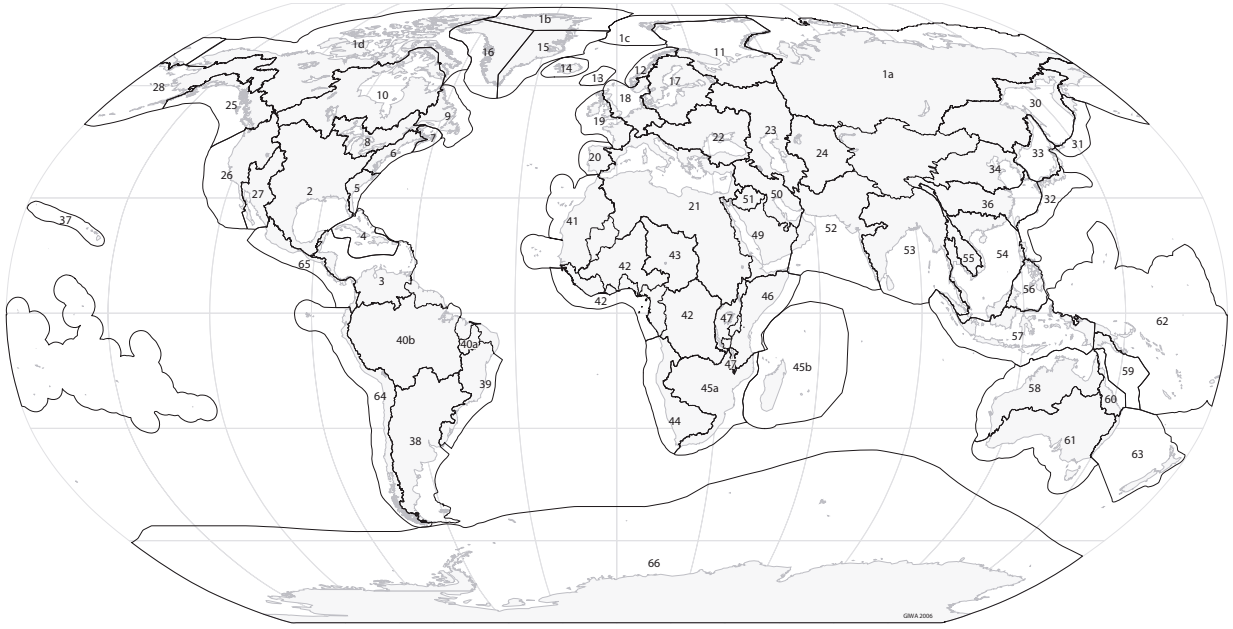
The term "transboundary issues" is used to describe the threats to the aquatic environment linked to globalisation, international trade, demographic changes and technological advancement, threats that are additional to those created through transboundary movement of water. Single country policies and actions are inadequate in order to cope with these challenges and this makes them transboundary in nature.

The international waters area includes numerous international conventions, treaties, and agreements. The architecture of marine agreements is especially complex, and a large number of bilateral and multilateral agreements exist for transboundary freshwater basins. Related conventions and agreements in other areas increase the complexity. These initiatives provide a new opportunity for cooperating nations to link many different programmes and instruments into regional comprehensive approaches to address international waters.

The organisational structure and implementation of the GIWA

The scale of the assessment

Initially, the scope of the GIWA was confined to transboundary waters in areas that included countries eligible to receive funds from the GEF. However, it was recognised that a truly global perspective would only be achieved if industrialised, GEF-ineligible regions of the world were also assessed. Financial resources to assess the GEF-eligible countries were obtained primarily from the GEF (68%), the Swedish International Development Cooperation Agency (Sida) (18%), and the Finnish Department for International Development Cooperation (FINNIDA)



1a Russian Arctic (4 LMEs)
1b Arctic Greenland (LME)
1c Arctic European/Atlantic
1d Arctic North American
2 Gulf of Mexico (LME)
3 Caribbean Sea (LME)
4 Caribbean Islands (LME)
5 Southeast Shelf (LME)
6 Northeast Shelf (LME)
7 Scotian Shelf (LME)
8 Gulf of St Lawrence
9 Newfoundland Shelf (LME)
10 Baffin Bay, Labrador Sea, Canadian Archipelago
11 Barents Sea (LME)
12 Norwegian Sea (LME)
13 Faroe plateau
14 Iceland Shelf (LME)
15 East Greenland Shelf (LME)
16 West Greenland Shelf (LME)
17 Baltic Sea (LME)
18 North Sea (LME)
19 Celtic-Biscay Shelf (LME)
20 Iberian Coastal Sea (LME)
21 North Africa and Nile River Basin (LME)
22 Black Sea (LME)
23 Caspian Sea
24 Aral Sea
25 Gulf of Alaska (LME)
26 California Current (LME)
27 Gulf of California (LME)
28 Bering Sea (LME)
30 Sea of Okhotsk (LME)
31 Oyashio Current (LME)
32 Kuroshio Current (LME)
33 Sea of Japan (LME)
34 Yellow Sea (LME)
36 East China Sea (LME)
37 Hawaiian Archipelago (LME)
38 Patagonian Shelf (LME)
39 Brazil Current (LME)
40a Northeast Brazil Shelf (2 LMEs)
40b Amazon
41 Canary Current (LME)
42 Guinea Current (LME)
43 Lake Chad
44 Benguela Current (LME)
45a Agulhas Current (LME)
45b Indian Ocean Islands
46 Somali Coastal Current (LME)
47 East African Rift Valley Lakes
49 Red Sea and Gulf of Aden (LME)
50 Euphrates and Tigris River Basin
51 Jordan
52 Arabian Sea (LME)
53 Bay of Bengal
54 South China Sea (2 LMEs)
55 Mekong River
56 Sulu-Celebes Sea (LME)
57 Indonesian Seas (LME)
58 North Australian Shelf (LME)
59 Coral Sea Basin
60 Great Barrier Reef (LME)
61 Great Australian Bight
62 Pacific Islands
63 Tasman Sea
64 Humboldt Current (LME)
65 Eastern Equatorial Pacific (LME)
66 Antarctic (LME)

Figure 1 The 66 transboundary regions assessed within the GIWA project.

(10%). Other contributions were made by Kalmar Municipality, the University of Kalmar and the Norwegian Government. The assessment of regions ineligible for GEF funds was conducted by various international and national organisations as in-kind contributions to the GIWA.

In order to be consistent with the transboundary nature of many of the world's aquatic resources and the focus of the GIWA, the geographical units being assessed have been designed according to the watersheds of discrete hydrographic systems rather than political borders (Figure 1). The geographic units of the assessment were determined during the preparatory phase of the project and resulted in the division of the world into 66 regions defined by the entire area of one or more catchments areas that drains into a single designated marine system. These marine systems often correspond to Large Marine Ecosystems (LMEs) (Sherman 1994, IOC 2002).

Considering the objectives of the GIWA and the elements incorporated into its design, a new methodology for the implementation of the assessment was developed during the initial phase of the project. The methodology focuses on five major environmental concerns which constitute the foundation of the GIWA assessment; Freshwater shortage, Pollution, Habitat and community modification, Overexploitation of fish and other living resources, and Global change. The GIWA methodology is outlined in the following chapter.

Large Marine Ecocsystems (LMEs)

Large Marine Ecosystems (LMEs) are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margin of the major current systems. They are relatively large regions on the order of 200 000 km^2 or greater, characterised by distinct: (1) bathymetry, (2) hydrography, (3) productivity, and (4) trophically dependent populations.

The Large Marine Ecosystems strategy is a global effort for the assessment and management of international coastal waters. It developed in direct response to a declaration at the 1992 Rio Summit. As part of the strategy, the World Conservation Union (IUCN) and National Oceanic and Atmospheric Administration (NOAA) have joined in an action program to assist developing countries in planning and implementing an ecosystem-based strategy that is focused on LMEs as the principal assessment and management units for coastal ocean resources. The LME concept is also adopted by GEF that recommends the use of LMEs and their contributing freshwater basins as the geographic area for integrating changes in sectoral economic activities.

The global network

In each of the 66 regions, the assessment is conducted by a team of local experts that is headed by a Focal Point (Figure 2). The Focal Point can be an individual, institution or organisation that has been selected on the basis of their scientific reputation and experience implementing international assessment projects. The Focal Point is responsible for assembling members of the team and ensuring that it has the necessary expertise and experience in a variety of environmental and socio-economic disciplines to successfully conduct the regional assessment. The selection of team members is one of the most critical elements for the success of GIWA and, in order to ensure that the most relevant information is incorporated into the assessment, team members were selected from a wide variety of institutions such as

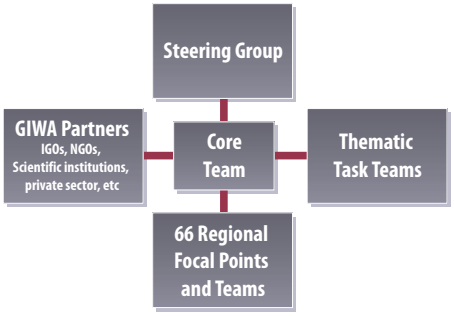


Figure 2 The organisation of the GIWA project.

universities, research institutes, government agencies, and the private sector. In addition, in order to ensure that the assessment produces a truly regional perspective, the teams should include representatives from each country that shares the region.

In total, more than 1 000 experts have contributed to the implementation of the GIWA illustrating that the GIWA is a participatory exercise that relies on regional expertise. This participatory approach is essential because it instils a sense of local ownership of the project, which ensures the credibility of the findings and moreover, it has created a global network of experts and institutions that can collaborate and exchange experiences and expertise to help mitigate the continued degradation of the world's aquatic resources.

GIWA Regional reports

The GIWA was established in response to growing concern among the general public regarding the quality of the world's aquatic resources and the recognition of governments and the international community concerning the absence of a globally coherent international waters assessment. However, because a holistic, region-by-region, assessment of the condition of the world's transboundary water resources had never been undertaken, a methodology guiding the implementation of such an assessment did not exist. Therefore, in order to implement the GIWA, a new methodology that adopted a multidisciplinary, multi-sectoral, multi-national approach was developed and is now available for the implementation of future international assessments of aquatic resources.

The GIWA is comprised of a logical sequence of four integrated components. The first stage of the GIWA is called Scaling and is a process by which the geographic area examined in the assessment is defined and all the transboundary waters within that area are identified. Once the geographic scale of the assessment has been defined, the assessment teams conduct a process known as Scoping in which the magnitude of environmental and associated socio-economic impacts of Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources, and Global change is assessed in order to identify and prioritise the concerns that require the most urgent intervention. The assessment of these predefined concerns incorporates the best available information and the knowledge and experience of the multidisciplinary, multi-national assessment teams formed in each region. Once the priority concerns have been identified, the root causes of these concerns are identified during the third component of the GIWA, Causal chain analysis. The root causes are determined through a sequential process that identifies, in turn, the most significant immediate causes followed by the economic sectors that are primarily responsible for the immediate causes and finally, the societal root causes. At each stage in the Causal chain analysis, the most significant contributors are identified through an analysis of the best available information which is augmented by the expertise of the assessment team. The final component of the GIWA is the development of Policy options that focus on mitigating the impacts of the root causes identified by the Causal chain analysis.

The results of the GIWA assessment in each region are reported in regional reports that are published by UNEP. These reports are designed to provide a brief physical and socio-economic description of the most important features of the region against which the results of the assessment can be cast. The remaining sections of the report present the results of each stage of the assessment in an easily digestible form. Each regional report is reviewed by at least two independent external reviewers in order to ensure the scientific validity and applicability of each report. The 66 regional assessments of the GIWA will serve UNEP as an essential complement to the UNEP Water Policy and Strategy and UNEP's activities in the hydrosphere.

UNEP Water Policy and Strategy

The primary goals of the UNEP water policy and strategy are:

(a) Achieving greater global understanding of freshwater, coastal and marine environments by conducting environmental assessments in priority areas;

(b) Raising awareness of the importance and consequences of unsustainable water use;

(c) Supporting the efforts of Governments in the preparation and implementation of integrated management of freshwater systems and their related coastal and marine environments;

(d) Providing support for the preparation of integrated management plans and programmes for aquatic environmental hot spots, based on the assessment results;

(e) Promoting the application by stakeholders of precautionary, preventive and anticipatory approaches.

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The GIWA methodology

The specific objectives of the GIWA were to conduct a holistic and globally comparable assessment of the world's transboundary aquatic resources that incorporated both environmental and socio-economic factors and recognised the inextricable links between freshwater and marine environments, in order to enable the GEF to focus their resources and to provide guidance and advice to governments and decision makers. The coalition of all these elements into a single coherent methodology that produces an assessment that achieves each of these objectives had not previously been done and posed a significant challenge.

The integration of each of these elements into the GIWA methodology was achieved through an iterative process guided by a specially convened Methods task team that was comprised of a number of international assessment and water experts. Before the final version of the methodology was adopted, preliminary versions underwent an extensive external peer review and were subjected to preliminary testing in selected regions. Advice obtained from the Methods task team and other international experts and the lessons learnt from preliminary testing were incorporated into the final version that was used to conduct each of the GIWA regional assessments.

Considering the enormous differences between regions in terms of the quality, quantity and availability of data, socio-economic setting and environmental conditions, the achievement of global comparability required an innovative approach. This was facilitated by focusing the assessment on the impacts of five pre-defined concerns namely; Freshwater shortage, Pollution, Habitat and community modification, Unsustainable exploitation of fish and other living resources and Global change, in transboundary waters. Considering the diverse range of elements encompassed by each concern, assessing the magnitude of the impacts caused by these concerns was facilitated by evaluating the impacts of 22 specific issues that were grouped within these concerns (see Table 1).

The assessment integrates environmental and socio-economic data from each country in the region to determine the severity of the impacts of each of the five concerns and their constituent issues on the entire region. The integration of this information was facilitated by implementing the assessment during two participatory workshops that typically involved 10 to 15 environmental and socio-economic experts from each country in the region. During these workshops, the regional teams performed preliminary analyses based on the collective knowledge and experience of these local experts. The results of these analyses were substantiated with the best available information to be presented in a regional report.

Table 1 Pre-defined GIWA concerns and their constituent issues addressed within the assessment.

Environmental issues	Major concerns
1. Modification of stream flow 2. Pollution of existing supplies 3. Changes in the water table	**I Freshwater shortage**
4. Microbiological 5. Eutrophication 6. Chemical 7. Suspended solids 8. Solid wastes 9. Thermal 10. Radionuclide 11. Spills	**II Pollution**
12. Loss of ecosystems 13. Modification of ecosystems or ecotones, including community structure and/or species composition	**III Habitat and community modification**
14. Overexploitation 15. Excessive by-catch and discards 16. Destructive fishing practices 17. Decreased viability of stock through pollution and disease 18. Impact on biological and genetic diversity	**IV Unsustainable exploitation of fish and other living resources**
19. Changes in hydrological cycle 20. Sea level change 21. Increased uv-b radiation as a result of ozone depletion 22. Changes in ocean CO2 source/sink function	**V Global change**

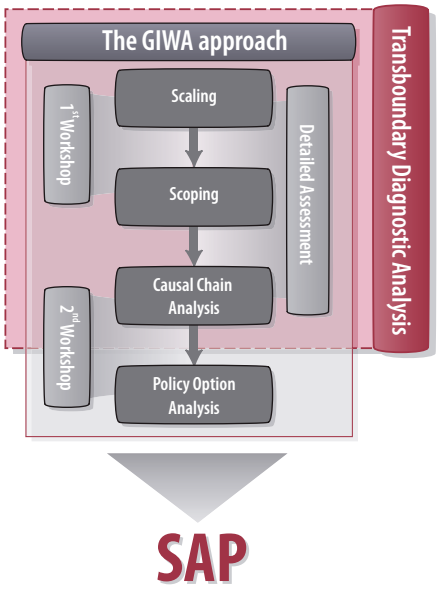


Figure 1 Illustration of the relationship between the GIWA approach and other projects implemented within the GEF International Waters (IW) portfolio.

The GIWA is a logical contiguous process that defines the geographic region to be assessed, identifies and prioritises particularly problems based on the magnitude of their impacts on the environment and human societies in the region, determines the root causes of those problems and, finally, assesses various policy options that addresses those root causes in order to reverse negative trends in the condition of the aquatic environment. These four steps, referred to as Scaling, Scoping, Causal chain analysis and Policy options analysis, are summarised below and are described in their entirety in two volumes: *GIWA Methodology Stage 1: Scaling and Scoping*; and *GIWA Methodology: Detailed Assessment, Causal Chain Analysis and Policy Options Analysis*. Generally, the components of the GIWA methodology are aligned with the framework adopted by the GEF for Transboundary Diagnostic Analyses (TDAs) and Strategic Action Programmes (SAPs) (Figure 1) and assume a broad spectrum of transboundary influences in addition to those associated with the physical movement of water across national borders.

Scaling – Defining the geographic extent of the region

Scaling is the first stage of the assessment and is the process by which the geographic scale of the assessment is defined. In order to facilitate the implementation of the GIWA, the globe was divided during the design phase of the project into 66 contiguous regions. Considering the transboundary nature of many aquatic resources and the transboundary focus of the GIWA, the boundaries of the regions did not comply with political boundaries but were instead, generally defined by a large but discrete drainage basin that also included the coastal marine waters into which the basin discharges. In many cases, the marine areas examined during the assessment coincided with the Large Marine Ecosystems (LMEs) defined by the US National Atmospheric and Oceanographic Administration (NOAA). As a consequence, scaling should be a relatively straight-forward task that involves the inspection of the boundaries that were proposed for the region during the preparatory phase of GIWA to ensure that they are appropriate and that there are no important overlaps or gaps with neighbouring regions. When the proposed boundaries were found to be inadequate, the boundaries of the region were revised according to the recommendations of experts from both within the region and from adjacent regions so as to ensure that any changes did not result in the exclusion of areas from the GIWA. Once the regional boundary was defined, regional teams identified all the transboundary elements of the aquatic environment within the region and determined if these elements could be assessed as a single coherent aquatic system or if there were two or more independent systems that should be assessed separately.

Scoping – Assessing the GIWA concerns

Scoping is an assessment of the severity of environmental and socio-economic impacts caused by each of the five pre-defined GIWA concerns and their constituent issues (Table 1). It is not designed to provide an exhaustive review of water-related problems that exist within each region, but rather it is a mechanism to identify the most urgent problems in the region and prioritise those for remedial actions. The priorities determined by Scoping are therefore one of the main outputs of the GIWA project.

Focusing the assessment on pre-defined concerns and issues ensured the comparability of the results between different regions. In addition, to ensure the long-term applicability of the options that are developed to mitigate these problems, Scoping not only assesses the current impacts of these concerns and issues but also the probable future impacts according to the "most likely scenario" which considered demographic, economic, technological and other relevant changes that will potentially influence the aquatic environment within the region by 2020.

The magnitude of the impacts caused by each issue on the environment and socio-economic indicators was assessed over the entire region using the best available information from a wide range of sources and the knowledge and experience of the each of the experts comprising the regional team. In order to enhance the comparability of the assessment between different regions and remove biases in the assessment caused by different perceptions of and ways to communicate the severity of impacts caused by particular issues, the

results were distilled and reported as standardised scores according to the following four point scale:

- 0 = no known impact
- 1 = slight impact
- 2 = moderate impact
- 3 = severe impact

The attributes of each score for each issue were described by a detailed set of pre-defined criteria that were used to guide experts in reporting the results of the assessment. For example, the criterion for assigning a score of 3 to the issue Loss of ecosystems or ecotones is: "*Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.*" The full list of criteria is presented at the end of the chapter, Table 5a-e. Although the scoring inevitably includes an arbitrary component, the use of predefined criteria facilitates comparison of impacts on a global scale and also encouraged consensus of opinion among experts.

The trade-off associated with assessing the impacts of each concern and their constituent issues at the scale of the entire region is that spatial resolution was sometimes low. Although the assessment provides a score indicating the severity of impacts of a particular issue or concern on the entire region, it does not mean that the entire region suffers the impacts of that problem. For example, eutrophication could be identified as a severe problem in a region, but this does not imply that all waters in the region suffer from severe eutrophication. It simply means that when the degree of eutrophication, the size of the area affected, the socio-economic impacts and the number of people affected is considered, the magnitude of the overall impacts meets the criteria defining a severe problem and that a regional action should be initiated in order to mitigate the impacts of the problem.

When each issue has been scored, it was weighted according to the relative contribution it made to the overall environmental impacts of the concern and a weighted average score for each of the five concerns was calculated (Table 2). Of course, if each issue was deemed to make equal contributions, then the score describing the overall impacts of the concern was simply the arithmetic mean of the scores allocated to each issue within the concern.
In addition, the socio-economic impacts of each of the five major concerns were assessed for the entire region. The socio-economic impacts were grouped into three categories; Economic impacts, Health impacts and Other social and community impacts (Table 3). For each category, an evaluation of the size, degree and frequency of the impact was performed and, once completed, a weighted average score describing the overall socio-economic impacts of each concern was calculated in the same manner as the overall environmental score.

Table 2 Example of environmental impact assessment of Freshwater shortage.

Environmental issues	Score	Weight %	Environmental concerns	Weight averaged score
1. Modification of stream flow	1	20	Freshwater shortage	1.50
2. Pollution of existing supplies	2	50		
3. Changes in the water table	1	30		

Table 3 Example of Health impacts assessment linked to one of the GIWA concerns.

Criteria for Health impacts	Raw score	Score	Weight %
Number of people affected	Very small ... Very large 0 1 2 3	2	50
Degree of severity	Minimum ... Severe 0 1 2 3	2	30
Frequency/Duration	Occasion/Short ... Continuous 0 1 2 3	2	20
Weight average score for Health impacts		**2**	

After all 22 issues and associated socio-economic impacts have been scored, weighted and averaged, the magnitude of likely future changes in the environmental and socio-economic impacts of each of the five concerns on the entire region is assessed according to the most likely scenario which describes the demographic, economic, technological and other relevant changes that might influence the aquatic environment within the region by 2020.

In order to prioritise among GIWA concerns within the region and identify those that will be subjected to causal chain and policy options analysis in the subsequent stages of the GIWA, the present and future scores of the environmental and socio-economic impacts of each concern are tabulated and an overall score calculated. In the example presented in Table 4, the scoping assessment indicated that concern III, Habitat and community modification, was the priority concern in this region. The outcome of this mathematic process was reconciled against the knowledge of experts and the best available information in order to ensure the validity of the conclusion.

In some cases however, this process and the subsequent participatory discussion did not yield consensus among the regional experts regarding the ranking of priorities. As a consequence, further analysis was required. In such cases, expert teams continued by assessing the relative importance of present and potential future impacts and assign weights to each. Afterwards, the teams assign weights indicating the relative contribution made by environmental and socio-economic factors to the overall impacts of the concern. The weighted average score for each concern is then recalculated taking into account

Table 4 Example of comparative environmental and socio-economic impacts of each major concern, presently and likely in year 2020.

Concern	Types of impacts								Overall score
	Environmental score		Economic score		Human health score		Social and community score		
	Present (a)	Future (b)	Present (c)	Future (d)	Present (e)	Future (f)	Present (g)	Future (h)	
Freshwater shortage	1.3	2.3	2.7	2.8	2.6	3.0	1.8	2.2	**2.3**
Pollution	1.5	2.0	2.0	2.3	1.8	2.3	2.0	2.3	**2.0**
Habitat and community modification	2.0	3.0	2.4	3.0	2.4	2.8	2.3	2.7	**2.6**
Unsustainable exploitation of fish and other living resources	1.8	2.2	2.0	2.1	2.0	2.1	2.4	2.5	**2.1**
Global change	0.8	1.0	1.5	1.7	1.5	1.5	1.0	1.0	**1.2**

the relative contributions of both present and future impacts and environmental and socio-economic factors. The outcome of these additional analyses was subjected to further discussion to identify overall priorities for the region.

Finally, the assessment recognises that each of the five GIWA concerns are not discrete but often interact. For example, pollution can destroy aquatic habitats that are essential for fish reproduction which, in turn, can cause declines in fish stocks and subsequent overexploitation. Once teams have ranked each of the concerns and determined the priorities for the region, the links between the concerns are highlighted in order to identify places where strategic interventions could be applied to yield the greatest benefits for the environment and human societies in the region.

Causal chain analysis

Causal Chain Analysis (CCA) traces the cause-effect pathways from the socio-economic and environmental impacts back to their root causes. The GIWA CCA aims to identify the most important causes of each concern prioritised during the scoping assessment in order to direct policy measures at the most appropriate target in order to prevent further degradation of the regional aquatic environment.

Root causes are not always easy to identify because they are often spatially or temporally separated from the actual problems they cause. The GIWA CCA was developed to help identify and understand the root causes of environmental and socio-economic problems in international waters and is conducted by identifying the human activities that cause the problem and then the factors that determine the ways in which these activities are undertaken. However, because there is no universal theory describing how root causes interact to create natural resource management problems and due to the great variation of local circumstances under which the methodology will be applied, the GIWA CCA is not a rigidly structured assessment but should be regarded as a framework to guide the analysis, rather than as a set of detailed instructions. Secondly, in an ideal setting, a causal chain would be produced by a multidisciplinary group of specialists that would statistically examine each successive cause and study its links to the problem and to other causes. However, this approach (even if feasible) would use far more resources and time than those available to GIWA[1]. For this reason, it has been necessary to develop a relatively simple and practical analytical model for gathering information to assemble meaningful causal chains.

Conceptual model

A causal chain is a series of statements that link the causes of a problem with its effects. Recognising the great diversity of local settings and the resulting difficulty in developing broadly applicable policy strategies, the GIWA CCA focuses on a particular system and then only on those issues that were prioritised during the scoping assessment. The starting point of a particular causal chain is one of the issues selected during the Scaling and Scoping stages and its related environmental and socio-economic impacts. The next element in the GIWA chain is the immediate cause; defined as the physical, biological or chemical variable that produces the GIWA issue. For example, for the issue of eutrophication the immediate causes may be, inter alia:

- Enhanced nutrient inputs;
- Increased recycling/mobilisation;
- Trapping of nutrients (e.g. in river impoundments);
- Run-off and stormwaters

Once the relevant immediate cause(s) for the particular system has (have) been identified, the sectors of human activity that contribute most significantly to the immediate cause have to be determined. Assuming that the most important immediate cause in our example had been increased nutrient concentrations, then it is logical that the most likely sources of those nutrients would be the agricultural, urban or industrial sectors. After identifying the sectors that are primarily

[1] This does not mean that the methodology ignores statistical or quantitative studies; as has already been pointed out, the available evidence that justifies the assumption of causal links should be provided in the assessment.

responsible for the immediate causes, the root causes acting on those sectors must be determined. For example, if agriculture was found to be primarily responsible for the increased nutrient concentrations, the root causes could potentially be:

- Economic (e.g. subsidies to fertilisers and agricultural products);
- Legal (e.g. inadequate regulation);
- Failures in governance (e.g. poor enforcement); or
- Technology or knowledge related (e.g. lack of affordable substitutes for fertilisers or lack of knowledge as to their application).

Once the most relevant root causes have been identified, an explanation, which includes available data and information, of how they are responsible for the primary environmental and socio-economic problems in the region should be provided.

Policy option analysis

Despite considerable effort of many Governments and other organisations to address transboundary water problems, the evidence indicates that there is still much to be done in this endeavour. An important characteristic of GIWA's Policy Option Analysis (POA) is that its recommendations are firmly based on a better understanding of the root causes of the problems. Freshwater scarcity, water pollution, overexploitation of living resources and habitat destruction are very complex phenomena. Policy options that are grounded on a better understanding of these phenomena will contribute to create more effective societal responses to the extremely complex water related transboundary problems. The core of POA in the assessment consists of two tasks:

Construct policy options

Policy options are simply different courses of action, which are not always mutually exclusive, to solve or mitigate environmental and socio-economic problems in the region. Although a multitude of different policy options could be constructed to address each root cause identified in the CCA, only those few policy options that have the greatest likelihood of success were analysed in the GIWA.

Select and apply the criteria on which the policy options will be evaluated

Although there are many criteria that could be used to evaluate any policy option, GIWA focuses on:

- Effectiveness (certainty of result)
- Efficiency (maximisation of net benefits)
- Equity (fairness of distributional impacts)
- Practical criteria (political acceptability, implementation feasibility).

The policy options recommended by the GIWA are only contributions to the larger policy process and, as such, the GIWA methodology developed to test the performance of various options under the different circumstances has been kept simple and broadly applicable.

Global International Waters Assessment

Table 5a: Scoring criteria for environmental impacts of Freshwater shortage

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 1: Modification of stream flow "An increase or decrease in the discharge of streams and rivers as a result of human interventions on a local/ regional scale (see Issue 19 for flow alterations resulting from global change) over the last 3-4 decades."	■ No evidence of modification of stream flow.	■ There is a measurably changing trend in annual river discharge at gauging stations in a major river or tributary (basin > 40 000 km^2); or ■ There is a measurable decrease in the area of wetlands (other than as a consequence of conversion or embankment construction); or ■ There is a measurable change in the interannual mean salinity of estuaries or coastal lagoons and/or change in the mean position of estuarine salt wedge or mixing zone; or ■ Change in the occurrence of exceptional discharges (e.g. due to upstream damming.	■ Significant downward or upward trend (more than 20% of the long term mean) in annual discharges in a major river or tributary draining a basin of >250 000 km^2; or ■ Loss of >20% of flood plain or deltaic wetlands through causes other than conversion or artificial embankments; or ■ Significant loss of riparian vegetation (e.g. trees, flood plain vegetation); or ■ Significant saline intrusion into previously freshwater rivers or lagoons.	■ Annual discharge of a river altered by more than 50% of long term mean; or ■ Loss of >50% of riparian or deltaic wetlands over a period of not less than 40 years (through causes other than conversion or artificial embankment); or ■ Significant increased siltation or erosion due to changing in flow regime (other than normal fluctuations in flood plain rivers); or ■ Loss of one or more anadromous or catadromous fish species for reasons other than physical barriers to migration, pollution or overfishing.
Issue 2: Pollution of existing supplies "Pollution of surface and ground fresh waters supplies as a result of point or diffuse sources"	■ No evidence of pollution of surface and ground waters.	■ Any monitored water in the region does not meet WHO or national drinking water criteria, other than for natural reasons; or ■ There have been reports of one or more fish kills in the system due to pollution within the past five years.	■ Water supplies does not meet WHO or national drinking water standards in more than 30% of the region; or ■ There are one or more reports of fish kills due to pollution in any river draining a basin of >250 000 km^2 .	■ River draining more than 10% of the basin have suffered polysaprobic conditions, no longer support fish, or have suffered severe oxygen depletion ■ Severe pollution of other sources of freshwater (e.g. groundwater)
Issue 3: Changes in the water table "Changes in aquifers as a direct or indirect consequence of human activity"	■ No evidence that abstraction of water from aquifers exceeds natural replenishment.	■ Several wells have been deepened because of excessive aquifer draw-down; or ■ Several springs have dried up; or ■ Several wells show some salinisation.	■ Clear evidence of declining base flow in rivers in semi-arid areas; or ■ Loss of plant species in the past decade, that depend on the presence of ground water; or ■ Wells have been deepened over areas of hundreds of km^2;or ■ Salinisation over significant areas of the region.	■ Aquifers are suffering salinisation over regional scale; or ■ Perennial springs have dried up over regionally significant areas; or ■ Some aquifers have become exhausted

Table 5b: Scoring criteria for environmental impacts of Pollution

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 4: Microbiological pollution "The adverse effects of microbial constituents of human sewage released to water bodies."	■ Normal incidence of bacterial related gastroenteric disorders in fisheries product consumers and no fisheries closures or advisories.	■ There is minor increase in incidence of bacterial related gastroenteric disorders in fisheries product consumers but no fisheries closures or advisories.	■ Public health authorities aware of marked increase in the incidence of bacterial related gastroenteric disorders in fisheries product consumers; or ■ There are limited area closures or advisories reducing the exploitation or marketability of fisheries products.	■ There are large closure areas or very restrictive advisories affecting the marketability of fisheries products; or ■ There exists widespread public or tourist awareness of hazards resulting in major reductions in the exploitation or marketability of fisheries products.
Issue 5: Eutrophication "Artificially enhanced primary productivity in receiving water basins related to the increased availability or supply of nutrients, including cultural eutrophication in lakes."	■ No visible effects on the abundance and distributions of natural living resource distributions in the area; and ■ No increased frequency of hypoxia[1] or fish mortality events or harmful algal blooms associated with enhanced primary production; and ■ No evidence of periodically reduced dissolved oxygen or fish and zoobenthos mortality; and ■ No evident abnormality in the frequency of algal blooms.	■ Increased abundance of epiphytic algae; or ■ A statistically significant trend in decreased water transparency associated with algal production as compared with long-term (>20 year) data sets; or ■ Measurable shallowing of the depth range of macrophytes.	■ Increased filamentous algal production resulting in algal mats; or ■ Medium frequency (up to once per year) of large-scale hypoxia and/or fish and zoobenthos mortality events and/or harmful algal blooms.	■ High frequency (>1 event per year), or intensity, or large areas of periodic hypoxic conditions, or high frequencies of fish and zoobenthos mortality events or harmful algal blooms; or ■ Significant changes in the littoral community; or ■ Presence of hydrogen sulphide in historically well oxygenated areas.

Issue 6: Chemical pollution "The adverse effects of chemical contaminants released to standing or marine water bodies as a result of human activities. Chemical contaminants are here defined as compounds that are toxic or persistent or bioaccumulating."	■ No known or historical levels of chemical contaminants except background levels of naturally occurring substances; and ■ No fisheries closures or advisories due to chemical pollution; and ■ No incidence of fisheries product tainting; and ■ No unusual fish mortality events. If there is no available data use the following criteria: ■ No use of pesticides; and ■ No sources of dioxins and furans; and ■ No regional use of PCBs; and ■ No bleached kraft pulp mills using chlorine bleaching; and ■ No use or sources of other contaminants.	■ Some chemical contaminants are detectable but below threshold limits defined for the country or region; or ■ Restricted area advisories regarding chemical contamination of fisheries products. If there is no available data use the following criteria: ■ Some use of pesticides in small areas; or ■ Presence of small sources of dioxins or furans (e.g., small incineration plants or bleached kraft/pulp mills using chlorine); or ■ Some previous and existing use of PCBs and limited amounts of PCB-containing wastes but not in amounts invoking local concerns; or ■ Presence of other contaminants.	■ Some chemical contaminants are above threshold limits defined for the country or region; or ■ Large area advisories by public health authorities concerning fisheries product contamination but without associated catch restrictions or closures; or ■ High mortalities of aquatic species near outfalls. If there is no available data use the following criteria: ■ Large-scale use of pesticides in agriculture and forestry; or ■ Presence of major sources of dioxins or furans such as large municipal or industrial incinerators or large bleached kraft pulp mills; or ■ Considerable quantities of waste PCBs in the area with inadequate regulation or has invoked some public concerns; or ■ Presence of considerable quantities of other contaminants.	■ Chemical contaminants are above threshold limits defined for the country or region; and ■ Public health and public awareness of fisheries contamination problems with associated reductions in the marketability of such products either through the imposition of limited advisories or by area closures of fisheries; or ■ Large-scale mortalities of aquatic species. If there is no available data use the following criteria: ■ Indications of health effects resulting from use of pesticides; or ■ Known emissions of dioxins or furans from incinerators or chlorine bleaching of pulp; or ■ Known contamination of the environment or foodstuffs by PCBs; or ■ Known contamination of the environment or foodstuffs by other contaminants.
Issue 7: Suspended solids "The adverse effects of modified rates of release of suspended particulate matter to water bodies resulting from human activities"	■ No visible reduction in water transparency; and ■ No evidence of turbidity plumes or increased siltation; and ■ No evidence of progressive riverbank, beach, other coastal or deltaic erosion.	■ Evidently increased or reduced turbidity in streams and/or receiving riverine and marine environments but without major changes in associated sedimentation or erosion rates, mortality or diversity of flora and fauna; or ■ Some evidence of changes in benthic or pelagic biodiversity in some areas due to sediment blanketing or increased turbidity.	■ Markedly increased or reduced turbidity in small areas of streams and/or receiving riverine and marine environments; or ■ Extensive evidence of changes in sedimentation or erosion rates; or ■ Changes in benthic or pelagic biodiversity in areas due to sediment blanketing or increased turbidity.	■ Major changes in turbidity over wide or ecologically significant areas resulting in markedly changed biodiversity or mortality in benthic species due to excessive sedimentation with or without concomitant changes in the nature of deposited sediments (i.e., grain-size composition/redox); or ■ Major change in pelagic biodiversity or mortality due to excessive turbidity.
Issue 8: Solid wastes "Adverse effects associated with the introduction of solid waste materials into water bodies or their environs."	■ No noticeable interference with trawling activities; and ■ No noticeable interference with the recreational use of beaches due to litter; and ■ No reported entanglement of aquatic organisms with debris.	■ Some evidence of marine-derived litter on beaches; or ■ Occasional recovery of solid wastes through trawling activities; but ■ Without noticeable interference with trawling and recreational activities in coastal areas.	■ Widespread litter on beaches giving rise to public concerns regarding the recreational use of beaches; or ■ High frequencies of benthic litter recovery and interference with trawling activities; or ■ Frequent reports of entanglement/ suffocation of species by litter.	■ Incidence of litter on beaches sufficient to deter the public from recreational activities; or ■ Trawling activities untenable because of benthic litter and gear entanglement; or ■ Widespread entanglement and/or suffocation of aquatic species by litter.
Issue 9: Thermal "The adverse effects of the release of aqueous effluents at temperatures exceeding ambient temperature in the receiving water body."	■ No thermal discharges or evidence of thermal effluent effects.	■ Presence of thermal discharges but without noticeable effects beyond the mixing zone and no significant interference with migration of species.	■ Presence of thermal discharges with large mixing zones having reduced productivity or altered biodiversity; or ■ Evidence of reduced migration of species due to thermal plume.	■ Presence of thermal discharges with large mixing zones with associated mortalities, substantially reduced productivity or noticeable changes in biodiversity; or ■ Marked reduction in the migration of species due to thermal plumes.
Issue 10: Radionuclide "The adverse effects of the release of radioactive contaminants and wastes into the aquatic environment from human activities."	■ No radionuclide discharges or nuclear activities in the region.	■ Minor releases or fallout of radionuclides but with well regulated or well-managed conditions complying with the Basic Safety Standards.	■ Minor releases or fallout of radionuclides under poorly regulated conditions that do not provide an adequate basis for public health assurance or the protection of aquatic organisms but without situations or levels likely to warrant large scale intervention by a national or international authority.	■ Substantial releases or fallout of radionuclides resulting in excessive exposures to humans or animals in relation to those recommended under the Basic Safety Standards; or ■ Some indication of situations or exposures warranting intervention by a national or international authority.
Issue 11: Spills "The adverse effects of accidental episodic releases of contaminants and materials to the aquatic environment as a result of human activities."	■ No evidence of present or previous spills of hazardous material; or ■ No evidence of increased aquatic or avian species mortality due to spills.	■ Some evidence of minor spills of hazardous materials in small areas with insignificant small-scale adverse effects one aquatic or avian species.	■ Evidence of widespread contamination by hazardous or aesthetically displeasing materials assumed to be from spillage (e.g. oil slicks) but with limited evidence of widespread adverse effects on resources or amenities; or ■ Some evidence of aquatic or avian species mortality through increased presence of contaminated or poisoned carcasses on beaches.	■ Widespread contamination by hazardous or aesthetically displeasing materials from frequent spills resulting in major interference with aquatic resource exploitation or coastal recreational amenities; or ■ Significant mortality of aquatic or avian species as evidenced by large numbers of contaminated carcasses on beaches.

Table 5c: Scoring criteria for environmental impacts of Habitat and community modification

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 12: Loss of ecosystems or ecotones "The complete destruction of aquatic habitats. For the purpose of GIWA methodology, recent loss will be measured as a loss of pre-defined habitats over the last 2-3 decades."	■ There is no evidence of loss of ecosystems or habitats.	■ There are indications of fragmentation of at least one of the habitats.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by up to 30 % during the last 2-3 decades.	■ Permanent destruction of at least one habitat is occurring such as to have reduced their surface area by >30% during the last 2-3 decades.
Issue 13: Modification of ecosystems or ecotones, including community structure and/or species composition "Modification of pre-defined habitats in terms of extinction of native species, occurrence of introduced species and changing in ecosystem function and services over the last 2-3 decades."	■ No evidence of change in species complement due to species extinction or introduction; and ■ No changing in ecosystem function and services.	■ Evidence of change in species complement due to species extinction or introduction	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure	■ Evidence of change in species complement due to species extinction or introduction; and ■ Evidence of change in population structure or change in functional group composition or structure; and ■ Evidence of change in ecosystem services[2].

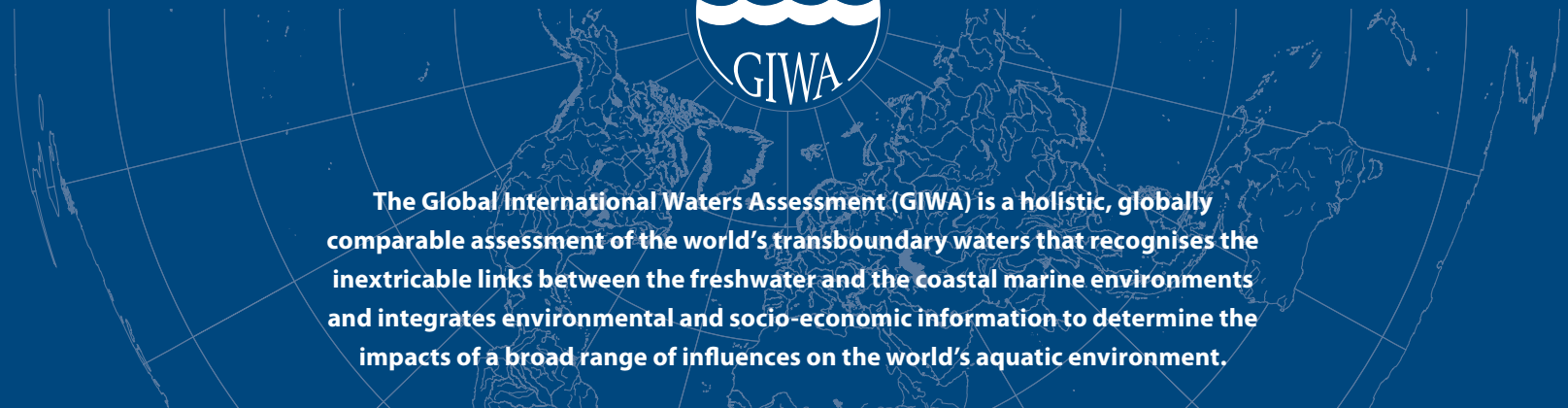
[2] Constanza, R. et al. (1997). The value of the world ecosystem services and natural capital, Nature 387:253-260.

Table 5d: Scoring criteria for environmental impacts of Unsustainable exploitation of fish and other living resources

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 14: Overexploitation "The capture of fish, shellfish or marine invertebrates at a level that exceeds the maximum sustainable yield of the stock."	■ No harvesting exists catching fish (with commercial gear for sale or subsistence).	■ Commercial harvesting exists but there is no evidence of over-exploitation.	■ One stock is exploited beyond MSY (maximum sustainable yield) or is outside safe biological limits.	■ More than one stock is exploited beyond MSY or is outside safe biological limits.
Issue 15: Excessive by-catch and discards "By-catch refers to the incidental capture of fish or other animals that are not the target of the fisheries. Discards refers to dead fish or other animals that are returned to the sea."	■ Current harvesting practices show no evidence of excessive by-catch and/or discards.	■ Up to 30% of the fisheries yield (by weight) consists of by-catch and/or discards.	■ 30-60% of the fisheries yield consists of by-catch and/or discards.	■ Over 60% of the fisheries yield is by-catch and/or discards; or ■ Noticeable incidence of capture of endangered species.
Issue 16: Destructive fishing practices "Fishing practices that are deemed to produce significant harm to marine, lacustrine or coastal habitats and communities."	■ No evidence of habitat destruction due to fisheries practices.	■ Habitat destruction resulting in changes in distribution of fish or shellfish stocks; or ■ Trawling of any one area of the seabed is occurring less than once per year.	■ Habitat destruction resulting in moderate reduction of stocks or moderate changes of the environment; or ■ Trawling of any one area of the seabed is occurring 1-10 times per year; or ■ Incidental use of explosives or poisons for fishing.	■ Habitat destruction resulting in complete collapse of a stock or far reaching changes in the environment; or ■ Trawling of any one area of the seabed is occurring more than 10 times per year; or ■ Widespread use of explosives or poisons for fishing.
Issue 17: Decreased viability of stocks through contamination and disease "Contamination or diseases of feral (wild) stocks of fish or invertebrates that are a direct or indirect consequence of human action."	■ No evidence of increased incidence of fish or shellfish diseases.	■ Increased reports of diseases without major impacts on the stock.	■ Declining populations of one or more species as a result of diseases or contamination.	■ Collapse of stocks as a result of diseases or contamination.
Issue 18: Impact on biological and genetic diversity "Changes in genetic and species diversity of aquatic environments resulting from the introduction of alien or genetically modified species as an intentional or unintentional result of human activities including aquaculture and restocking."	■ No evidence of deliberate or accidental introductions of alien species; and ■ No evidence of deliberate or accidental introductions of alien stocks; and ■ No evidence of deliberate or accidental introductions of genetically modified species.	■ Alien species introduced intentionally or accidentally without major changes in the community structure; or ■ Alien stocks introduced intentionally or accidentally without major changes in the community structure; or ■ Genetically modified species introduced intentionally or accidentally without major changes in the community structure.	■ Measurable decline in the population of native species or local stocks as a result of introductions (intentional or accidental); or ■ Some changes in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).	■ Extinction of native species or local stocks as a result of introductions (intentional or accidental); or ■ Major changes (>20%) in the genetic composition of stocks (e.g. as a result of escapes from aquaculture replacing the wild stock).

Table 5e: Scoring criteria for environmental impacts of Global change

Issue	Score 0 = no known impact	Score 1 = slight impact	Score 2 = moderate impact	Score 3 = severe impact
Issue 19: Changes in hydrological cycle and ocean circulation "Changes in the local/regional water balance and changes in ocean and coastal circulation or current regime over the last 2-3 decades arising from the wider problem of global change including ENSO."	■ No evidence of changes in hydrological cycle and ocean/coastal current due to global change.	■ Change in hydrological cycles due to global change causing changes in the distribution and density of riparian terrestrial or aquatic plants without influencing overall levels of productivity; or ■ Some evidence of changes in ocean or coastal currents due to global change but without a strong effect on ecosystem diversity or productivity.	■ Significant trend in changing terrestrial or sea ice cover (by comparison with a long-term time series) without major downstream effects on river/ocean circulation or biological diversity; or ■ Extreme events such as flood and drought are increasing; or ■ Aquatic productivity has been altered as a result of global phenomena such as ENSO events.	■ Loss of an entire habitat through desiccation or submergence as a result of global change; or ■ Change in the tree or lichen lines; or ■ Major impacts on habitats or biodiversity as the result of increasing frequency of extreme events; or ■ Changing in ocean or coastal currents or upwelling regimes such that plant or animal populations are unable to recover to their historical or stable levels; or ■ Significant changes in thermohaline circulation.
Issue 20: Sea level change "Changes in the last 2-3 decades in the annual/seasonal mean sea level as a result of global change."	■ No evidence of sea level change.	■ Some evidences of sea level change without major loss of populations of organisms.	■ Changed pattern of coastal erosion due to sea level rise has became evident; or ■ Increase in coastal flooding events partly attributed to sea-level rise or changing prevailing atmospheric forcing such as atmospheric pressure or wind field (other than storm surges).	■ Major loss of coastal land areas due to sea-level change or sea-level induced erosion; or ■ Major loss of coastal or intertidal populations due to sea-level change or sea level induced erosion.
Issue 21: Increased UV-B radiation as a result of ozone depletion "Increased UV-B flux as a result polar ozone depletion over the last 2-3 decades."	■ No evidence of increasing effects of UV/B radiation on marine or freshwater organisms.	■ Some measurable effects of UV/B radiation on behavior or appearance of some aquatic species without affecting the viability of the population.	■ Aquatic community structure is measurably altered as a consequence of UV/B radiation; or ■ One or more aquatic populations are declining.	■ Measured/assessed effects of UV/B irradiation are leading to massive loss of aquatic communities or a significant change in biological diversity.
Issue 22: Changes in ocean CO_2 source/sink function "Changes in the capacity of aquatic systems, ocean as well as freshwater, to generate or absorb atmospheric CO_2 as a direct or indirect consequence of global change over the last 2-3 decades."	■ No measurable or assessed changes in CO_2 source/sink function of aquatic system.	■ Some reasonable suspicions that current global change is impacting the aquatic system sufficiently to alter its source/sink function for CO_2.	■ Some evidences that the impacts of global change have altered the source/sink function for CO_2 of aquatic systems in the region by at least 10%.	■ Evidences that the changes in source/sink function of the aquatic systems in the region are sufficient to cause measurable change in global CO_2 balance.



The Global International Waters Assessment (GIWA) is a holistic, globally comparable assessment of the world's transboundary waters that recognises the inextricable links between the freshwater and the coastal marine environments and integrates environmental and socio-economic information to determine the impacts of a broad range of influences on the world's aquatic environment.

Broad Transboundary Approach

GIWA recognises that many water bodies and resources, and the human impacts on them, are not confined to a single country.

Regional Assessment – Global Perspective

GIWA provides a global perspective of the world's transboundary waters by assessing regions that encompass major drainage basins and adjacent Large Marine Ecosystems. The GIWA Assessment incorporates information and multidisciplinary expertise from all countries sharing the transboundary water resources of each region.

Global Comparability

In each region, the assessment focuses on five major concerns comprising 22 specific water-related issues.

Integration of Information and Ecosystems

GIWA recognises the inextricable links between the freshwater and the coastal marine environments and assesses them together as an integrated unit. GIWA recognises that the integration of socio-economic and environmental information and expertise is essential in order to obtain an holistic understanding of the interactions between the environmental and societal aspects of transboundary waters.

Priorities, Root Causes and Options for the Future

GIWA identifies the priority concerns of each region, determines their societal root causes and discusses options to mitigate the future impact of those concerns.

This Report

This report presents the GIWA assessment of the Mekong River region which comprises parts of Cambodia, China, Lao PDR, Myanmar, Thailand and Vietnam. Rapid economic development and population growth are increasing the demand for water, energy and food, necessitating more hydro-dams, the intensification of agricultural and fisheries production, and higher rates of deforestation. The resultant transboundary environmental changes, particularly to the fluxes of water and sediments, are leading to severe habitat and community modification. The past and present status and future prospects of water-related problems in the Mekong River Basin are discussed and traced back to their root causes. Policy relevant conclusions are provided so that appropriate solutions can be developed to address the emerging challenges to the management of the region's aquatic environment.

UNEP

GEF

HÖGSKOLAN KALMAR UNIVERSITY