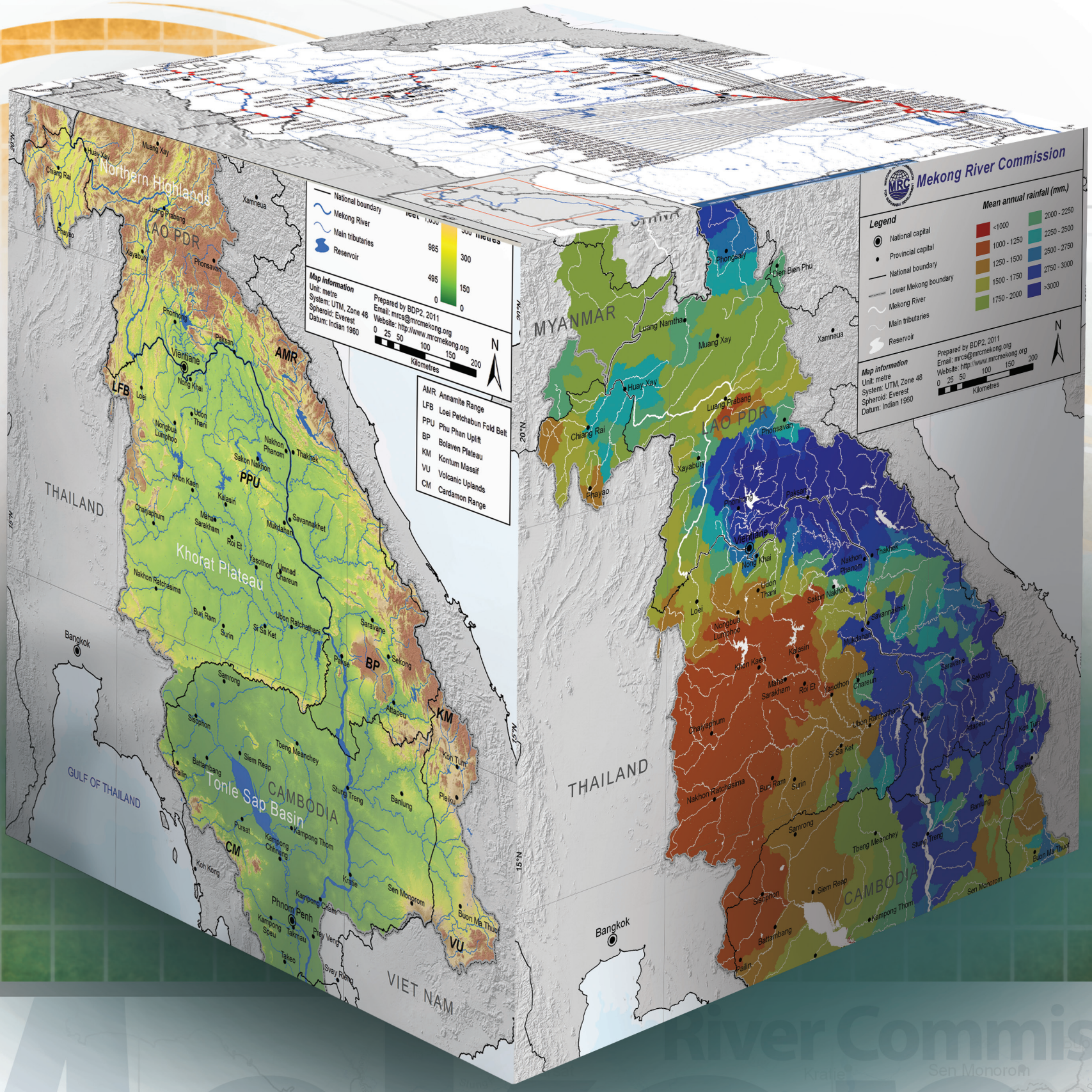
Basin Development Plan Programme

Planning Atlas of the Lower Mekong River Basin



Cambodia • Lao PDR • Thailand • Viet Nam

For sustainable development

2011

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The planning atlas is based on data and information assembled for the formulation and assessment of basin-wide development scenarios during 2008-2010 by MRC's Basin Development Plan Programme in cooperation with a wide range of national and regional stakeholders. The data and information in the atlas are those of the authors and do not imply endorsement by the MRC.

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Mekong River Commission
For sustainable development

Preface

The Mekong River Basin

The Mekong is one of the world's great rivers. Like other great rivers, it rises in high mountains, traverses a floodplain and enters the sea via a wide delta, each landform with its own opportunities and challenges. The Upper Mekong (named the Lancang in China) rises in the Himalayas at an elevation of about 5,000m and is the world's 12th longest river, flowing for almost 4,350 km into the East Sea (more commonly known as the South China Sea), via a large delta. It has the world's 8th largest flow, with a mean annual discharge of approximately 475 km^3, and its basin is the world's 21st largest by area, draining 795,000 km^2.

One of the important features of the Mekong is the very large difference in wet and dry season flow, caused by the Southwest Monsoon, which generates wet and dry seasons of more or less equal length. The seasonal cycle of changing water levels at Phnom Penh results in the large flow reversal of water into and out of the Great Lake via the Tonle Sap river.

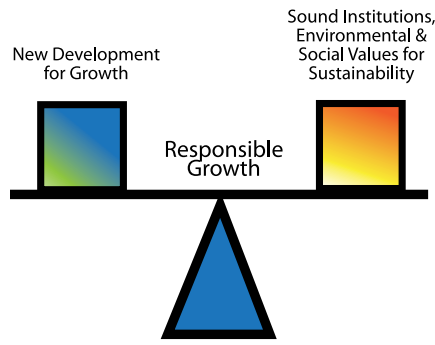
Agriculture is the dominant water-related sector in the Basin, intensively developed in Thailand and Viet Nam and less so in Cambodia and Lao PDR. Overall, the dry-season irrigated area of about 1.2 million hectares is less than 10% of the total agricultural area of 15 million hectares in the Lower Mekong Basin (LMB). The full hydropower potential of the LMB is estimated at over 30,000 MW, with 10% of this developed to date. Navigation is important but largely undeveloped as an integrated transport sector.

The Mekong contains the world's largest fresh water capture fishery of about 2.3 million tonnes per year. Aquaculture is increasing fast, particularly in the Viet Nam Delta, where it has risen from 200,000 to 2 million tonnes per year since 1990. River-related tourism is already important for national revenue and local income generation and has the potential to grow.

Until recently, human interventions have had little impact on the river's regime. As a consequence, the Mekong River remains one of the most bio-diverse rivers in the world, second only to the Amazon. The river's annual flood pulse continues to support a rich natural fishery and an extensive and unique wetland environment.

The total population of the LMB is about 60 million, with population growth of 1-2% in Thailand, Viet Nam and Cambodia, and 2-3% in Lao PDR. Although urbanization is occurring in all LMB countries, about 85% of the basin's population lives in rural areas.

Many in the Basin are subsistence farmers, who supplement what they grow with the fish they catch and the food and other materials they gather from forests and wetlands. This makes the rich ecology of the Basin extraordinarily important in terms of its contribution to livelihoods, particularly of the poor. Over 25% of the population of Cambodia and Lao PDR has an income below the poverty line, with much higher percentages in many rural areas. Food security and malnutrition pose great challenges. About half of all households have no safe water supply and half of all villages are inaccessible by all-weather roads. In much of the Mekong Basin, electricity consumption is less than 5% of that in the industrial world.



The great challenge for the future is to be able to respond to growing pressures arising from population growth, urbanization, industrialization, and the increasing and changing demands and sanitation, etc). Meeting this challenge requires careful management of the inevitable tradeoffs between river development and the environment, ensuring positive outcomes for poverty reduction and growth as well as for conservation and sustainability.

Historical background

The river and its tributaries have supported complex civilizations for millennia, with growing archaeological evidence of several thousand years of organized societies with rice culture. There is evidence that the Mekong has been at the centre of great movements of people across the sub-continent; it has long been both a source of production and prosperity, as well as one of destruction and collapse.

The iconic Khmer kingdom of Angkor, at its peak from the 9th to the 14th centuries, depended on monsoon flooding to fill complex hydraulic structures feeding its large urban complexes and agricultural systems.

However, until recent times the Mekong River remained largely undeveloped and its hydrology little understood. It was not until 1952 that the UN Economic Commission for Asia and the Far East (ECAFE – now ESCAP) presented a first report on flood control and water resources development in the Lower Mekong Basin. This was followed in 1956 by the US Bureau of Reclamation's "Reconnaissance Report – Lower Mekong Basin", which also emphasized the need for extensive data gathering and for studies on agriculture, fisheries, navigation and education.

Opening of Mekong Committee office in Bangkok by Dag Hammarskjold (left), Secretary-General of the United Nations, 1959

The following year, drawing on an ECAFE report on "Development of Water Resources in the Lower Mekong Basin", the four LMB governments issued a Joint Declaration that led, later in 1957, to establishment of the Mekong Committee under a "Statute of the Committee for Coordination of Investigations of the Lower Mekong Basin".

The Mekong Committee remained the central institution for LMB cooperation for the next 37 years. The Committee was supported by the United Nations and other countries throughout this period. The Committee, which changed its name in 1965 to the "Committee for Coordination of Comprehensive Development of the LMB", oversaw implementation of extensive studies and preparation of a number of plans for the lower basin. By 1975 the Committee were able to sign a "Declaration of Principles" with robust rules, particularly on mainstream development.

Internal conflict within Cambodia in 1976 led the country's disengagement from the MC for 14 years, during which time the other three countries established an Interim Mekong Committee as a holding measure. Peace came at last to the Mekong Basin in 1989, providing the necessary stability and opportunity for real and effective cooperation between Cambodia, Lao PDR, Thailand and Viet Nam. Following the Paris peace agreement of 1991, negotiations between the four countries began in 1994 for a new agreement that would take the Mekong Committee out of the UN system and create a separate inter-governmental organization under international treaty law.

The Mekong River Commission

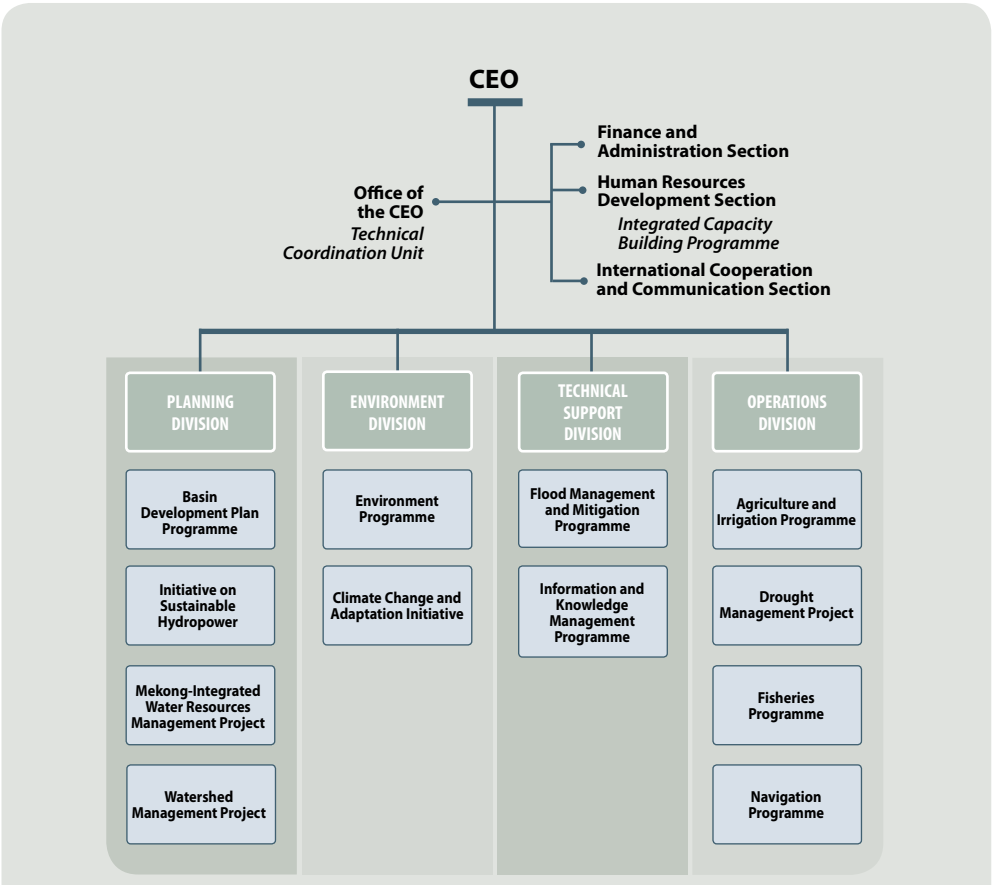
The Mekong River Commission (MRC) was established in 1995 by the governments of Cambodia, Lao PDR, Thailand and Viet Nam with the purpose of promoting cooperation in the management and development of the water and related resources of the Mekong River Basin to achieve the full potential of sustainable benefits to all basin countries. PR China and Myanmar, who share the basin as well, are dialogue partners of MRC and are increasingly engaged in discussions about the future management of the basin.

The MRC is presided over by a Council made up of ministerial level representation from each country. The Council is supported by a Joint Committee that meets normally four times a year to oversee and direct the activities of the MRC. National Mekong Committees coordinate national inputs to the MRC.

The Mekong River Commission Secretariat (MRCS), which has offices in Vientiane and Phnom Penh, provides technical support to the Joint Committee. The MRCS is presently organised into four divisions within which the twelve current main MRC Programmes are grouped.

MRC activities are governed by the rules set out in the 1995 Mekong Agreement. In a number of important cases, these rules are supplemented by Procedures and Guidelines agreed by the MRC Council. The Agreement provides a clear framework for the MRC to work within (see box).

MRCS operational structure, 2011



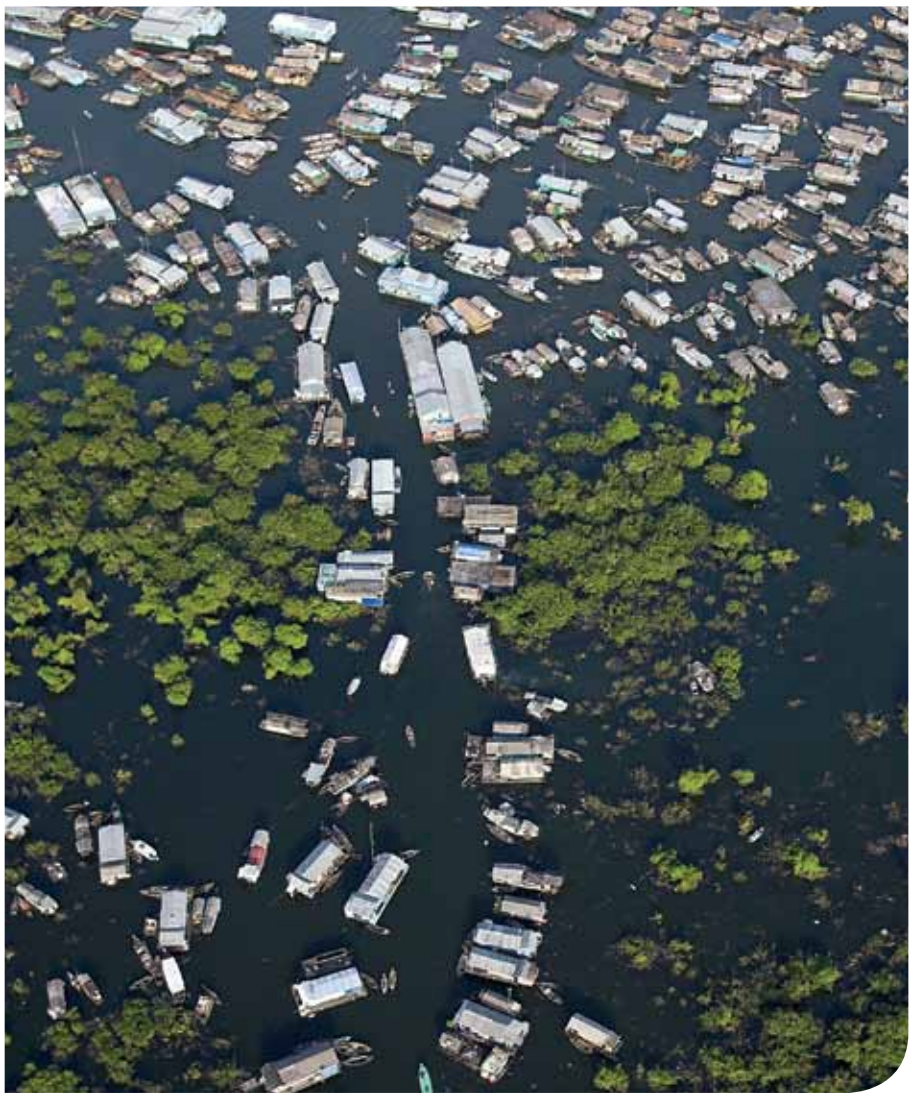
Overview of the 1995 Agreement on the Cooperation for the Sustainable Development of the Mekong River basin

- **Policy:** The Agreement sets high-level goals that are to be achieved through implementation of the Agreement, viz.: social and economic development, environmental protection and inter-dependent sub-regional growth and cooperation.

- **Key instruments:** The Agreement provides for a set of rules of procedure (Art.5) by which to utilize the Mekong's waters in a reasonable and equitable manner in each country, the basis for determining an acceptable set of flow conditions in the shared mainstream (Art.6), a rolling planning process (Art.2 et al) to determine a programme of joint actions by which to fulfil the goals of the Agreement and associated investment opportunities (Art.24B), and a set of rules for monitoring water utilization (Art.26).

- **Principles:** The Agreement provides guidance on how the MRC will act in implementing the Agreement, allowing that many developments are subject to notification only, whilst others require active consultation and/or prior agreement, providing always that these activities do not cause harm to others (Art.7 et al).

- **Areas of Cooperation:** The Agreement defines also the areas of cooperation covered by the Agreement in Article 1, being (but not limited to) irrigation, hydropower, navigation, flood control, fisheries, timber floating, recreation and tourism.



Basin planning

The 1995 Agreement specifically defines the Basin Development Plan as the general planning tool and process that the Joint Committee would use as a blueprint to identify, categorize and prioritise the projects and programs to seek assistance for and to implement the plan at the basin level.

In January 2011, the MRC Council approved its first Basin Development Strategy. Founded on integrated water resources management (IWRM) principles, the Strategy (see box overleaf) sets out MRC's strategic priorities for basin development and management together with an agreed road map for their implementation during 2011-2015.

The road map commences with the preparation of a Basin Action Plan comprising four national indicative plans integrated with one regional action plan. The latter is to be delivered principally through the MRC Programmes. The Strategy will be updated every five years in line with the MRC's basin planning cycle.

The Basin Development Strategy was the outcome of lengthy technical discussions, widespread internal and external consultations and, finally, detailed negotiations between the four Member States. Underpinning and informing the technical discussions were the assessments of a range of alternative planning scenarios, based on individual short, medium and long term plans put forward by each country. These were assessed on a triple-bottom-line basis by the Basin Development Plan Programme team against a wide range of social, economic and environmental criteria, which had themselves been agreed in advance by each country.

IWRM-based Basin Development Strategy

The MRC Council of Ministers adopted the Basin Development Strategy in January 2011, following several intensive rounds of drafting, consultation and revision during 2010. In his preface to the document, the 2010-11 MRC Chairman (Dr. Pham Khoi Nguyen, Water Resources Minister of Viet Nam) summarised the achievement as follows:

"For the first time since the signing of the 1995 Mekong Agreement, the MRC Member Countries have developed shared understandings of the opportunities and risks of the national plans for water resources development in LMB and agreed on a number of Strategic Priorities to optimise the development opportunities and minimize uncertainty and risks associated with them. This provides incentives for the timely implementation of the agreed procedures under the 1995 Mekong Agreement."

The Strategy represents an important milestone in the history of Mekong cooperation. It represents a revised role and focus of the MRCS, moving it from an almost exclusive focus on acquisition of knowledge and on best practice in water management to include, once again, a sharp focus on water development to support economic growth and reduce poverty.

The IWRM-based Basin Development Strategy enables the four MRC Member States jointly to set out how they will share, utilize, manage and conserve the water and related resources of the Mekong to achieve the goals of the 1995 Mekong Agreement. It provides initial directions for sustainable basin development and management that are subject to review and updating by MRC every five years.

The Strategy provides an integrated basin perspective against which current and future national water resources development plans can be assessed to ensure an acceptable balance between economic, environmental and social outcomes in the LMB, and mutual benefits to the LMB countries, as required by the 1995 Mekong Agreement. It does this by:

- Defining the scope of opportunities for water resources development (hydropower, irrigation, water supply, flood management) and their associated risks and required actions to optimize the opportunities and minimize the risks;
- Defining other water-related opportunities (fisheries, navigation, environment and ecosystems, watershed management); and
- Providing a coordinated, participatory and transparent process that promotes sustainable development.

A total of 15 Strategic Priorities are set out in the IWRM-based Basin Development Strategy and within these 64 Strategic Actions have been identified, each of which are stipulated within the Strategy as necessary to address the Strategic Priorities. These include measures to strengthen cooperation with China, for which the Strategy provides a framework.

The Strategy also provides an agreed road map by which to address these strategic priorities and actions during 2011-2015, commencing with the preparation of a Basin Action Plan comprising four national indicative plans integrated with one regional action plan. The latter is to be delivered principally through the MRC Programmes whose work plans are to be progressively aligned with the IWRM-based Basin Development Strategy.

As the BDP Programme moves forward, its central role will be to ensure that the road map is being effectively implemented through the collective efforts of all concerned and that the MRC's strategic aims for developing and managing the basin are being realised.

Integrated Water Resources Management

IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximize economic and social welfare in a balanced way without compromising the sustainability of the ecosystems.

IWRM is not an end in itself but a means of achieving three key strategic objectives of efficiency (attempt to maximize the economic and social welfare derived not only from the water resources base but also from investments in water service provision); equity (in the allocation of scarce water resources and services across different economic and social groups) and sustainability (as the water resources base and associated ecosystems are finite).

Global Water Partnership, 2000

The Planning Atlas
This Planning Atlas is a product of MRC's Basin Development Plan Programme and is intended to illustrate the wide range of information that has been assembled to underpin the recent assessment of basin-wide development scenarios and also the formulation of the MRC's Basin Development Strategy.

Modern day planning of river basins generally follows the commonly acceptable principles of integrated water resources management (see box). These principles have been adopted by MRC to guide its activities in implementing the 1995 Mekong Agreement.

The Mekong River is vital to the interests of the MRC Member States and until recently has remained in a largely unchanged state from historical times. However, development pressures in all countries sharing the Basin are already affecting the river's regime and the livelihoods of those dependent upon the river's rich bio-diversity.

Planners have for many years recognised that there are tremendous opportunities to develop the water and water-related resource systems within the Basin for economic gain. In recent years, cautionary voices have grown that such developments have attendant risks in both social and environmental terms. The MRC's Basin Development Strategy seeks to address these concerns by strengthening the MRC's knowledge base and by seeking to guide development of the basin's full potential along a balanced and sustainable path.

The challenge ahead to achieve this balance is considerable. The MRC recognises that its goal will be more easily achieved if a common understanding amongst stakeholders is arrived at based on informed discussion of the issues affecting development choices.

This Planning Atlas should be seen as a contribution to building that common understanding. The Atlas summarises and explains the key baseline data that have supported the recent planning cycle within the themes of: boundaries; social attributes; physical landforms and transport infrastructure; water resources; environment; and water uses. A final section illustrates the key monitoring stations used for meteorological, hydrological and water quality data collection.

The reader is encouraged to explore these different themes in this Atlas and to consider how each has bearing on the choices that MRC has to make to fulfil its 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 and to achieve its stated vision for an economically prosperous, socially just and environmentally sound Mekong River Basin.

Further information
Further information on the Mekong River Commission and its activities can be found at http://www.mrcmekong.org/.

MRC collects and manages a range of data and information with its Member Countries and other regional stakeholders. The MRC Data and Information Services Portal is accessible at http://portal.mrcmekong.org/. The site provides a summary of MRC's services and enables direct access, including to real time information and downloadable data. Visitors to the site can browse the Data and Information Services, or search for data and technical reports that have been quality assured and registered in the MRC Master Catalogue.

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1.4 Catchments

Mekong overview

1.1 Mekong Overview

The Mekong is one of the world's largest rivers, ranking 12th in terms of length at 4880 km (Gupta and Liew 2007) and 8th in terms of mean annual discharge (flow) at the mouth, which is about 14,500 m^3/s (Meade 1996; MRC 2005). The Mekong has a catchment area of 795,000 km^2 within the six countries of China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam. The Mekong Basin has been commonly divided into upper and lower basins. The upper Mekong Basin is located in China where the Mekong is known as the Lancang Jiang. The upper Mekong Basin makes up 24% of the total Basin area and contributes 15-20% of the water that flows into the Mekong River (MRC 2005). The lower Mekong Basin (LMB) downstream of the Chinese border with Lao PDR includes the majority of the total land area of Lao PDR and Cambodia, the northern and northeast regions of Thailand and the Mekong Delta and Central Highland regions of Viet Nam.

The shape of the Mekong Basin, especially the elongated narrow upper part of the basin in China, is unlike that of other large river basins draining the interior of continents, such as the Mississippi, Congo or Amazon basins, which tend to have much wider upper basins and relatively simple dendritic drainage networks that resemble the branches of a tree (Clark et al. 2004). The unique shape of the Mekong Basin and the abrupt changes in the path of the Mekong River are evidence of a long and complex tectonic history. One of the most important tectonic events shaping the physiography of the Basin was the collision of the Indian Plate with the Asian subcontinent, which caused the uplift of the Himalayas and Tibetan Plateau in the Tertiary period (Brookfield 1998; Fielding 2000). The uplift of the Tibetan Plateau was also a key trigger of the formation of the south-west monsoon, which now dominates the climate of the region (Clift and Plumb 2008). The Mekong River begins on the Tibetan Plateau at more than 4,500 m above sea level along with its sister rivers, the Salween and Yangtze. The three rivers converge to a narrow zone not more than 100km wide as they fall off the Tibetan Plateau. In the so-called 'Three Rivers Area', the rivers have cut deep and narrow gorges. Unlike the lower Mekong Basin, the tributary river systems in the upper Mekong are small due to the narrow width of the upper basin.

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Administrative boundaries

GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Urban center	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IWMI	2003
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IWMI	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
District boundary	Forest Cover Monitoring Project (FCMP), MRCS	1998	BDP	April 2010

1.2 Administrative Boundaries

This map illustrates the administrative divisions of the lower Mekong countries: the Provinces of each country that fall within the lower Mekong Basin and the boundaries of districts located in each Province. The provincial capitals are marked along with other important cities and towns referred to in the map as 'urban centres' but which are not administrative centres. All 17 Provinces of the Lao PDR fall within the lower Mekong Basin while in Cambodia, all but one Province, Koh Kong located the southwest, are wholly or partly contained within the Basin boundaries. In the case of Thailand, 25 out of a total of 76 Provinces are located in the Basin: 22 of these are located in the northeast 'Isaan' region of the country and three in the north. In Viet Nam, 22 of the total 63 Provinces fall in the Basin. Thirteen of these 22 are clustered in the Mekong River delta. Another five are located in the headwaters of the Se San and Se Prok catchments (Map 1.4) near Viet Nam's western border with Cambodia and small portions of three other Provinces fall within the Basin along the its eastern boundary. The map and its descriptive table were generated from the four countries' national data from 2001.

Table 1 Names of Provinces of four countries located within the lower Mekong Basin and the number of districts in each.

CAMBODIA	No. of districts	LAO PDR	No. of districts	THAILAND	No. of districts	VIET NAM	No. of districts
Banteay Meanchey	9	Attapeu	5	Amnat Charoen	7	An Giang	11
Battambang	14	Bokeo	5	Burirum	23	Bac Lieu	7
Kampong Cham	16	Borikhamxay	6	Chaiyaphum	16	Ben Tre	8
Kampong Chhnang	8	Champasak	10	Chantaburi	2	Binh Phuoc	1
Kampong Speu	8	Huaphanh	3	Chiang Mai	4	Ca Mau	9
Kampong Thom	8	Khammuane	9	Chiang Rai	19	Can Tho	8
Kampot	6	Luangnamtha	5	Kalasin	18	Dak lak	13
Kandal	11	Luangprabang	11	Khon Kaen	25	Dak Nong	5
Koh Kong	2	Oudomxay	7	Loei	14	Dien Bien	1
Kratie	6	Phongsaly	7	Maha Sarakham	13	Dong Thap	11
Mondul Kiri	5	Saravane	8	Mukdahan	7	Gia Lai	8
Otdar Meanchey	5	Savannakhet	15	Nakhon Phanom	12	Hau Giang	7
Pailin	2	Sekong	4	Nakhon Ratchasima	32	Kien Giang	12
Phnom Penh	8	Vientiane	12	Nong Bua Lamphu	6	Kon Tum	7
Preah Sihanouk	1	Vientiane Capital	9	Nong Khai	17	Lam Dong	2
Preah Vihear	8	Xayaboury	10	Phayao	8	Long An	2
Prey Veng	11	Xiengkhuang	7	Phet Chabun	5	Quang Tri	3
Pursat	6			Roi Et	20	Soc Trang	9
Ratanak Kiri	9			Sa Keo	5	Thua Thien Hue	1
Siem Reap	12			Sakon Nakhon	18	Tien Giang	11
Stung Treng	5			Si Saket	22	Tra Vinh	8
Takeo	10			Surin	17	Vinh Long	7
Tonle Sap Lake	1			Ubon Ratchathani	25		
				Udon Thani	20		
				Yasothon	9		
Total: 23	171	17	133	25	364	22	151

Sub-areas


Mekong River Commission
Legend
National capital
Provincial capital
Sub-area boundary
National boundary
Mekong River
Main tributaries
Reservoir
Map information
Unit: metre
System: UTM, Zone 48
Spheroid: Everest
Datum: Indian 1960
Prepared by BDP2, 2011
Email: mrcs@mrcmekong.org
Website: http://www.mrcmekong.org
0 25 50 100 150 200
Kilometres
N
CHINA
MYANMAR
LAO PDR
THAILAND
CAMBODIA
VIET NAM
GULF OF TONKIN
GULF OF THAILAND
1L
2T
3L
3T
4L
5T
6L
6C
7L
7C
7V
8C
9C
10C
10V
Phongsaly
Dien Bien Phu
Luang Namtha
Muang Xay
Huay Xay
Xamneua
Chiang Rai
Luang Prabang
Phayao
Xayabury
Phonsavan
Phonhong
Paksan
Vientiane
Nong Khai
Loei
Udon Thani
Nakhon Phanom
Thakhek
Nongbua Lumphoo
Sakon Nakhon
Savannakhet
Khon Kaen
Kalasin
Mukdahan
Maha Sarakham
Roi Et
Chaiyaphum
Yasothon
Umnad Chareun
Saravane
Sekong
Ubon Ratchathani
Nakhon Ratchasima
Si Sa Ket
Buri Ram
Surin
Pakse
Attapeu
Koh Tum
Samrong
Pleiku
Bangkok
Tbeng Meanchey
Banlung
Sisophon
Stung Treng
Siem Reap
Battambang
Pailin
Kampong Thom
Sen Monorom
Buon Ma Thuot
Pursat
Kampong Chhnang
Kratie
Kampong Cham
Koh Kong
Phnom Penh
Prey Veng
Kampong Speu
Takmau
Takeo
Svay Rieng
Kampot
Krong Kaeb
Sihanoukville
Ho Chi Minh City
Dong Thap
An Giang
Tien Giang
Ha Tien
Vinh Long
Ben Tre
Kien Giang
Can Tho
Tra Vinh
Soc Trang
Bac Lieu
Ca Mau
100°E
105°E
20°N
15°N
10°N
210000
160000
110000
100000
600000
GIS DATA SET
ORIGINAL SOURCE
AGENCY
YEAR
LAST UPDATE
MRCS
YEAR
National capital | Forest Cover Monitoring Project (FCMP), MRCS | 2000 | BDP | Nov 2009
Provincial capital | Forest Cover Monitoring Project (FCMP), MRCS | 2000 | BDP | May 2010
Sub-area boundary | Created by MRCS | NONE | BDP | Nov 2009
National boundary | 1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey | Oct 2001 | IKMP | Nov 2004
River LMB | Watershed Classification Project (WSCP), MRCS | Nov 2001 | BDP | April 2009
River UMB | U.S. Geological Survey's (USGS) EROS Data Center | 2001 | IKMP | 2003
Reservoir | Watershed Classification Project (WSCP), MRCS | 2001 | BDP | 2008
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1.3 Sub-areas

Sub-areas represent the intersection of one or more river catchments with national boundaries. They are numbered sequentially from upstream to downstream, while the letter refers to the country within which the sub-area is located (Table 2).

The sub-areas were defined by the Basin Development Plan Programme of the Mekong River Commission in 2002 for the purpose of aiding basin development planning. Sub-area activities include inventories of the status and use of water related resources, the formulation of sub-area scenarios and development strategies, and the identification of projects. The activities are implemented in a bottom-up and participatory process, led by the National Mekong Committees. The results have been used to formulate strategic directions for IWRM in the Lower Mekong Basin and, more recently, the assessment of basin-wide development scenarios, and preparation of the IWRM-based Basin Development Strategy.

Currently, the sub-area reports are being updated, with a view to classifying river basins or sub-basins into: conservation sub-basins, with high ecological value to be protected; development sub-basins, where water resources can be developed with limited social and environmental impacts; and critical sub-basins with significant development-protection trade-offs. In a next planning stage, IWRM strategies will be prepared for selected sub-basins to guide the development and management of the land and water related resources.

Table 2 Sub-area descriptions and surface areas

Region and catchment groupings	Sub-area code	Area (km²)
A: Northern Highlands		
Northern Lao PDR	1L	80,544
Chiang Rai, northern Thailand	2T	17,321
B: Central Plateau & Highlands		
Nong Khai / Songkhram	3L (Lao PDR)	3,299
	3T (Thailand)	47,260
Central Lao PDR	4L	87,093
Mun / Chi River Basin	5T	119,163
C: Southeast Highlands		
Southern Lao PDR	6L (Lao PDR)	15,861
	6C (Cambodia)	3,210
Se San / Sre Pok / Se Kong river basins	7L (Lao PDR)	22,585
	7C (Cambodia)	26,377
	7V (Viet Nam)	29,385
D: Southern Region		
Kratie	8C	22,680
Tonle Sap basin	9C	86,045
Mekong delta	10C (Cambodia)	23,346
	10V (Viet Nam)	35,158

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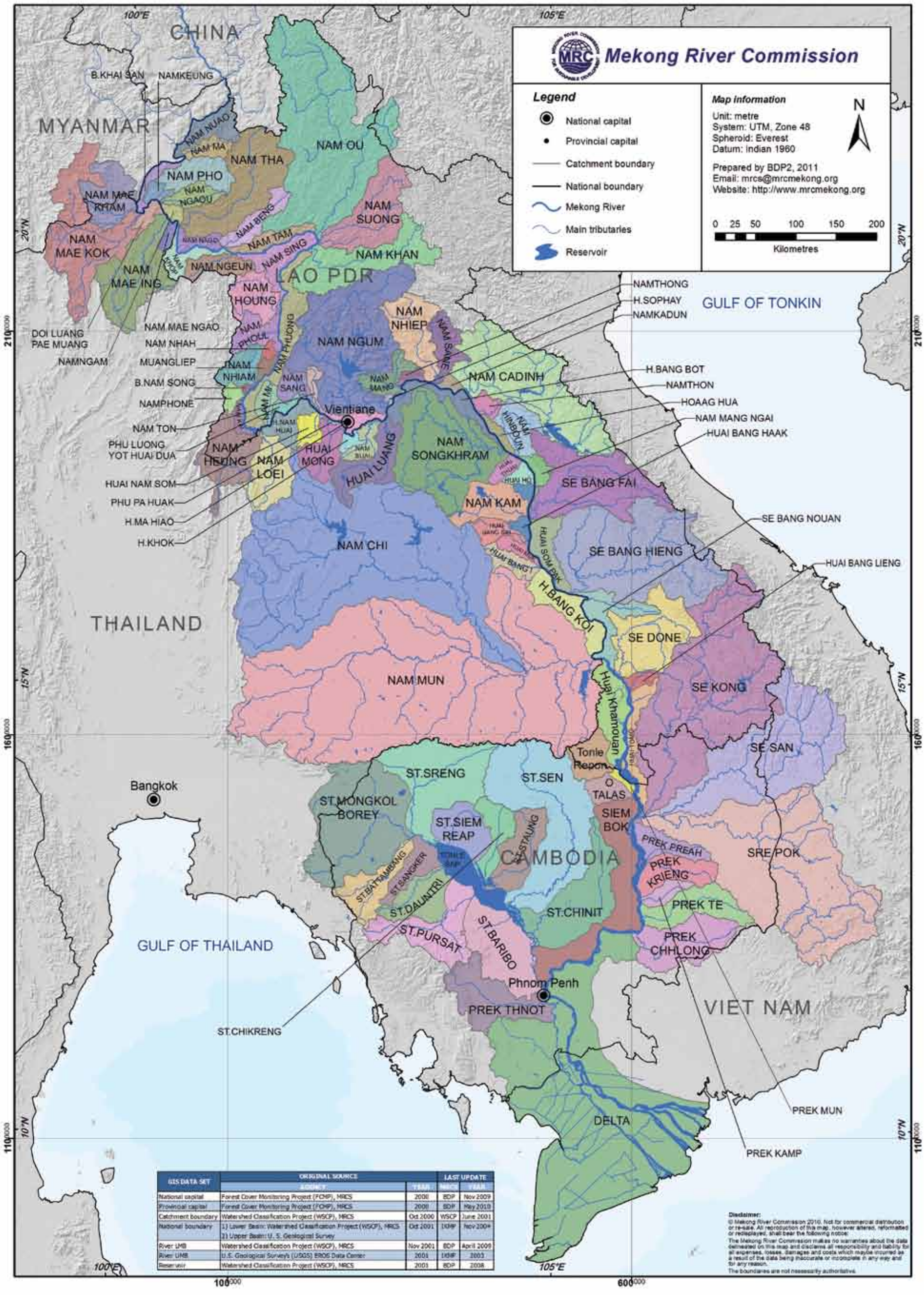
- MRC (2011) IWRM-based Basin Development Strategy for the Lower Mekong Basin, Mekong River Commission, Vientiane, Lao PDR.
- MRC-BDP (2005) The MRC Basin Development Plan: Sub-Area Report, BDP Library Volume 3-10C. Mekong River Commission, Basin Development Programme.
- MRC-BDP (2006) Basin Development Plan Completion Report for Phase 1: 2001-2006., Mekong River Commission, Basin Development Programme, Vientiane, Lao PDR.
- MRC-BDP (2006) Sub-area analysis and transboundary planning, BDP Library Volume 2. Mekong River Commission, Basin Development Programme, December 2004, revised January 2006.

Catchments



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Catchment boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	WSCP	June 2001
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

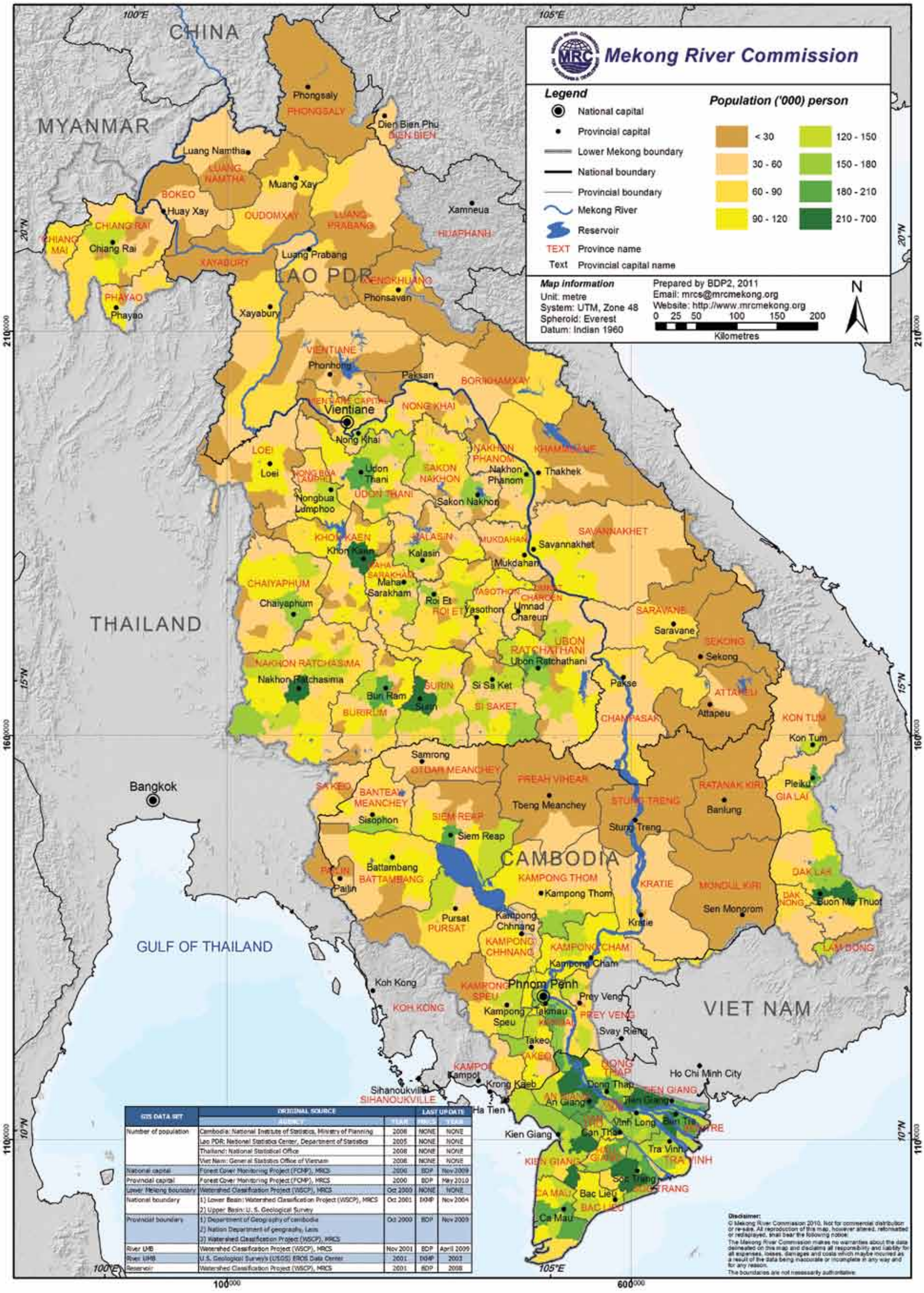
1.4 Catchments

This map illustrates the catchment areas of tributary rivers draining into the Mekong River. A total of 104 catchments have been delineated as part of the Watershed Classification Project which was completed by the Mekong River Commission in 2001. Certain larger catchments including those of the Tonle Sap, Mun and Se Kong Rivers have been split into two or more sub-catchments. This has been done because the catchments are drained by two or more major rivers of similar length and with similar catchment sizes. In the case of the Se Kong – Se San – Sre Pok (often referred to as the 3-S basin) and Chi-Mun catchments, the multiple major rivers join together close to the Mekong River. Some of the smaller catchments located along the Mekong River corridor contain a number of small (typically short) rivers that flow directly into the Mekong River. The name of these catchments usually reflects the name of the largest of these rivers.

Name	Area (km²)	Name	Area (km²)	Name	Area (km²)
Ban Khai San	778	Nam Khan	7,490	Nam Thong	455
Ban Nam Song	138	Nam Khop	1,521	Nam Ton	587
Delta	48,235	Nam Loei	4,012	O Talas	1,448
Doi Luang Pae Muang	688	Nam Ma	1,141	Phu Luong Yot Huai Dua	491
Huai Khok	538	Nam Mae Ing	7,267	Phu Pa Huak	132
Huai Bang Bot	2,402	Nam Mae Kham	4,079	Prek Chhlong	5,957
Huai Bang Koi	3,313	Nam Mae Kok	10,701	Prek Kamp	1,142
Huai Ma Hiao	990	Nam Mae Ngao	485	Prek Krieng	3,332
Huai Nam Huai	1,755	Nam Mang	1,836	Prek Mun	476
Huai Sophay	186	Nam Mang Ngai	944	Prek Preah	2,400
Hoaag Hua	626	Nam Mi	1,032	Prek Te	4,364
Huai Bang Haak	938	Nam Mun	70,574	Prek Thnot	6,124
Huai Bang I	1,496	Nam Nago	1,008	Se Bang Fai	10,407
Huai Bang Lieng	695	Nam Ngam	489	Se Bang Hieng	19,958
Huai Bang Sai	1,367	Nam Ngaou	1,495	Se Bang Nouan	3,048
Huai Ho	691	Nam Ngeun	1,819	Se Done	7,229
Huai Khamouan	3,762	Nam Ngum	16,906	Se Kong	28,815
Huai Luang	4,090	Nam Nhah	316	Se San	18,888
Huai Mong	2,700	Nam Nhiam	1,990	Siem Bok	8,851
Huai Muk	792	Nam Nhiep	4,577	Sre Pok	30,942
Huai Nam Som	1,072	Nam Nuao	2,287	St. Baribo	7,154
Huai Som Pak	2,516	Nam Ou	26,033	St. Battambang	3,708
Huai Thuai	739	Nam Pho	2,855	St. Chikreng	2,714
Huai Tomo	2,611	Nam Phone	664	St. Chinit	8,237
Muang Liep	488	Nam Phoul	2,095	St. Dauntri	3,696
Nam Beng	2,131	Nam Phuong	4,139	St. Mongkol Borey	14,966
Nam Cadinh	14,822	Nam Sane	2,226	St. Pursat	5,965
Nam Chi	49,133	Nam Sang	1,290	St. Sangker	2,344
Nam Heung	4,901	Nam Sing	2,681	St. Sen	16,360
Nam Hinboun	2,529	Nam Songkhram	13,123	St. Siem Reap	3,619
Nam Houng	2,872	Nam Suai	1,247	St. Sreng	9,986
Nam Kadun	456	Nam Suong	6,578	St. Staung	4,357
Nam Kai	602	Nam Tam	1,548	Tonle Repon	2,379
Nam Kam	3,495	Nam Tha	8,918	Tonle Sap Lake	2,744
Nam Keung	633	Nam Thon	838		

Social Attributes

Population



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Number of population	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: National Statistical Office	2008	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2008	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IWMI	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River UMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River LMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IWMI	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.1 Population

This map shows the distribution of people across the Lower Mekong Basin (LMB), with population reported by district. Approximately 60.6 million people live in the LMB areas of the four riparian countries as recorded in the most recent national censuses or census updates conducted in 2005 in Lao PDR and 2008 in the other three countries. The population has increased by 14 % since the previous censuses conducted in 1995-2000, when the population of the LMB was approximately 53 million (Hook et al. 2003).

The population of Cambodia makes up 19% of the total population of the LMB, and 81% of its national population lives in the basin. Most of the country's people live in the rich rice-growing areas along the Mekong, surrounding Tonle Sap Lake and in and around Phnom Penh city. The north and eastern parts of the country are less populated.

Almost all (89%) of the people of Lao PDR live within the Mekong Basin. However, the country is sparsely populated and contributes only 9% to the total LMB population. The Central region, including the capital Vientiane, is the most populous.

Northeast Thailand is the most populous region of Thailand: together with the parts of northern Thailand that fall within the LMB, it is home to 36% of the Thai population. In total, Thailand represents 38% of the LMB population.

The Mekong Delta region in Viet Nam is one of the two main population centres in the country. The other is the Red River Delta near Hanoi in the north. The Central Highlands is also becoming an increasingly important centre because of government-sponsored migration policies. Around 24% of Viet Nam's population lives in the Mekong Delta and the Central Highlands, making up 34% of the LMB population.

Table 3 Population of the Lower Mekong Basin by country and proportion of total country populations living within the LMB

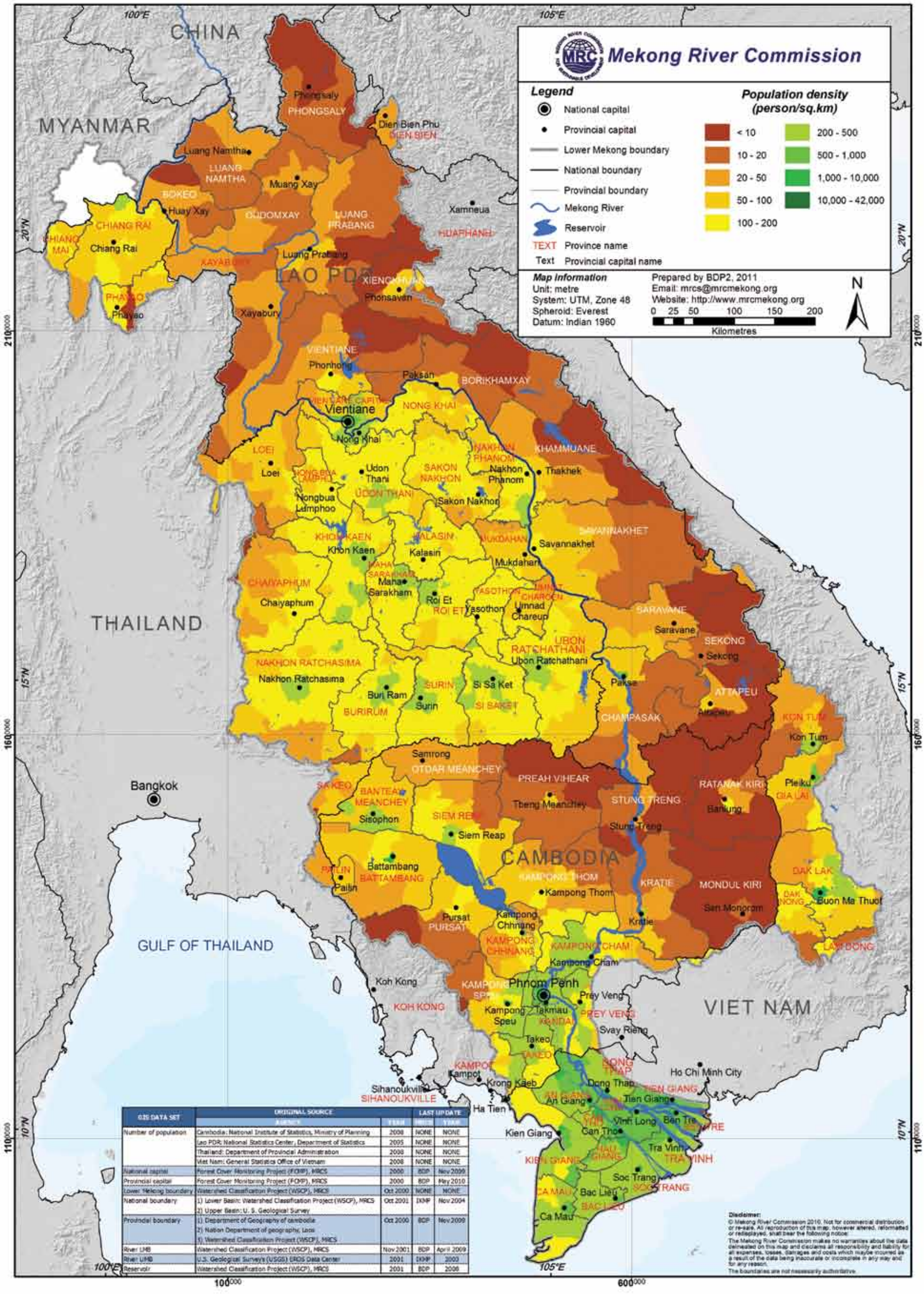
Country	Population in LMB	Proportion of total LMB population	Total country population	Proportion of country population residing in LMB
Cambodia	11.6	19%	14.4	81%
Lao PDR	5.3	9%	5.9	89%
Thailand	23.0	38%	63.9	36%
Viet Nam	20.7	34%	87.4	24%
Total	60.6	-	171.6	35%

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	District	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	District	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2008	District	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	District	General Statistics Office of Viet Nam

- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin,* Mekong River Commission, Phnom Penh. p 154 pp.
- Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Population density



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	AGENCY	YEAR
Number of population	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: Department of Provincial Administration	2008	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2008	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2006

2.2 Population Density

Population density varies widely across the Lower Mekong Basin (LMB), as illustrated by the large colour contrasts in the adjacent map. The Mekong Delta in Viet Nam and the area around Phnom Penh city in Cambodia have the largest population densities, with most districts having at least 200 persons per km^2 and as high as 41,200 persons per km^2 in Phnom Penh city. The average population density in the Mekong Delta is 443 persons per km^2, while 17 districts have population densities greater than 1000 persons per km^2 and two districts in Can Tho Province have densities of 7,000-10,000. The very high population density of the Delta is due to a combination of factors including: good accessibility by road and inland waterways; proximity to Ho Chi Minh City; the fertile soils and access to irrigation infrastructure providing favourable conditions for agriculture and, more recently, aquaculture. Vientiane Capital Province, which includes nine districts in and around Vientiane city, also has a high population density of 739 persons per km^2.

In contrast, the upland regions of Lao PDR along the country's eastern border with Viet Nam have significantly lower population densities of less than 20 persons per km^2. There is a close relationship between population density and topography in Lao PDR with density decreasing with increasing elevation away from the Mekong River (see elevation map: Map 3.1). This aligns with Lao PDR's poverty alleviation strategy, which seeks to move people closer to urban centres where public services and employment opportunities are more easily provided. Districts located along the Mekong River corridor between Vientiane and Pakse, where urban centres are frequent and the lower topography allows rice cultivation, typically have higher densities in the order of 20 – 200 persons per km^2.

On the Khorat Plateau in northeast Thailand, population densities are moderate and exhibit a patchwork pattern ranging from approximately 40 to 400 persons per km^2. Higher densities occur around the numerous large towns and cities, which are distributed throughout the region, and lower densities in predominantly rural districts. Densities are lower in the west of the region at the edge of the Khorat Plateau where land elevation is higher.

Cambodia has widely variable population densities, with large contrasts between the densely populated low lying floodplains of the Mekong River around Phnom Penh, moderate densities on the fertile floodplains surrounding Tonle Sap Lake, and very low densities (<10 persons per km^2) in large parts of the country including upland areas (southwest and northern regions) and those areas that are not necessarily high in elevation but far from the administrative capital (the whole area east of the Mekong).

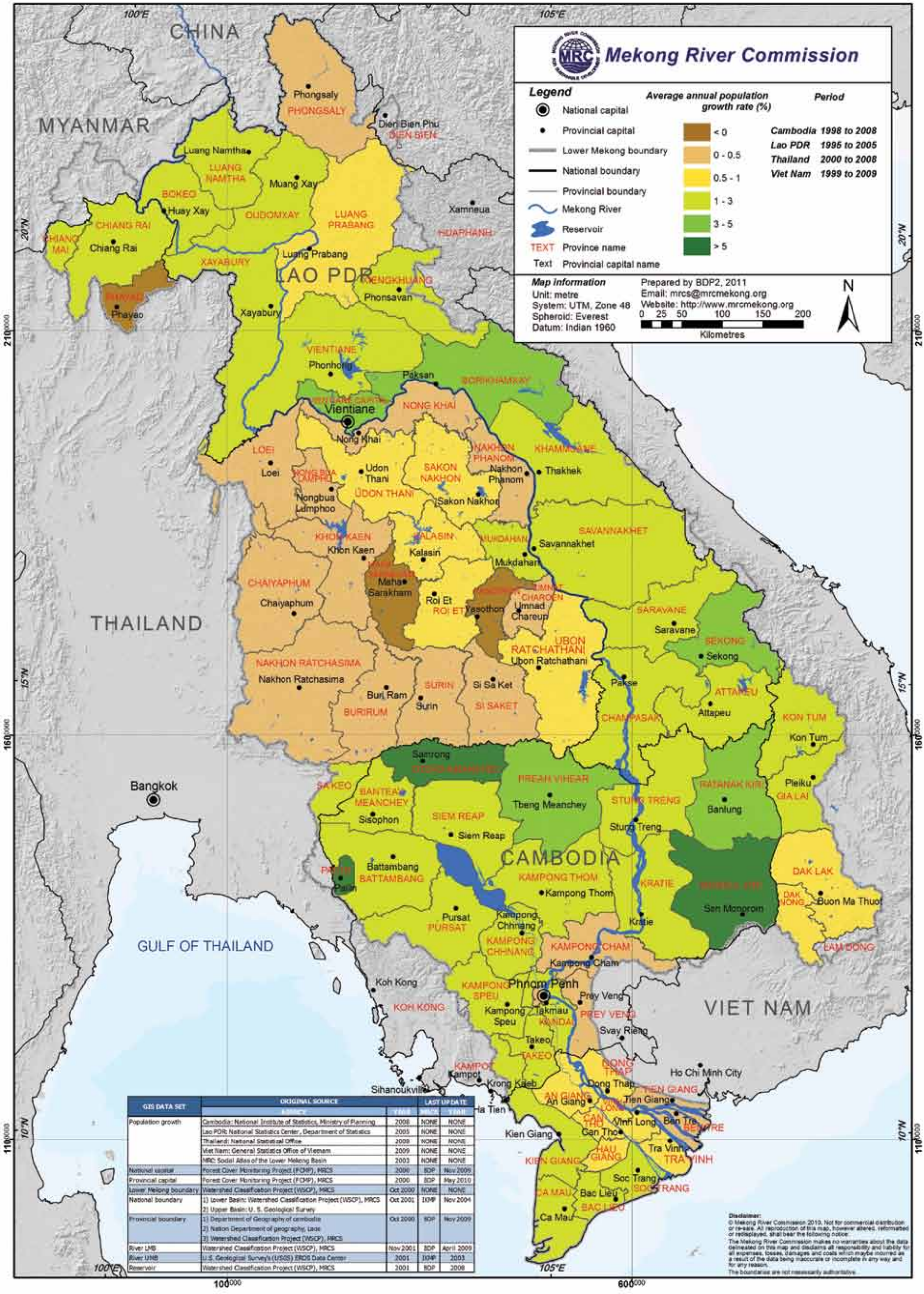
REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	District	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	District	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2008	District	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	District	General Statistics Office of Viet Nam

Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.

Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Population growth



2.3 Population Growth

This map illustrates the average annual rate of population growth in the Lower Mekong Basin by Province. The growth rates were calculated over a period of 10 years for Cambodia, Lao PDR and Viet Nam from national population census conducted in 1995-1999 and 2005-2009. In the case of Thailand, the growth rate was determined over a period of 8 years between the population census of 2000 and updated population estimates from the 2008 Statistical Yearbook.

Lao PDR has the lowest population but fastest average population growth rate in the LMB of 2.3% per year (Figure 1). The fastest growing Provinces are Borikhamxay, Sekong and Vientiane Capital with annual growth rates of over 3%. Phongsaly and Luang Prabang have the slowest growth rates of 0.4 and 1.0% respectively. The Cambodian population is growing at 1.6% per year. The fastest growth has occurred in Pailin (15.8%), Otdar Meanchey (14.5%) and Mondol Kiri (5.6%) Provinces, all located in relatively remote areas. Note that the gender ratio (Map 2.5) is also high in these areas with more males than females, suggesting a possible in-migration of male labourers into these areas. Pailin Province is a centre of logging and mining industries.

Thailand (northeast and northern regions) has the lowest annual population growth rate of the four countries at 0.4%. The population of three Provinces in these regions actually declined between 2000 and 2008, reflecting a trend towards increased urbanisation. These include Maha Sarakham and Yasothon Provinces in the northeast and Phayao Province in the north. The fastest growing Provinces are Sa Keo in the east (1.4%), Chiang Mai (1.4%) and Chiang Rai (1.1%) in the northeast. The Mekong Delta and Central Highlands of Viet Nam have an overall average population growth rate of 0.9% per year. Provincial rates of population growth range from about 0.4 % in Tien Giang and Ben Tre Provinces in the eastern part of the Delta to 2.3% in Gai Lai Province in the Cental Highlands. In the Delta, population has grown faster in the western part of the delta compared with the eastern areas.

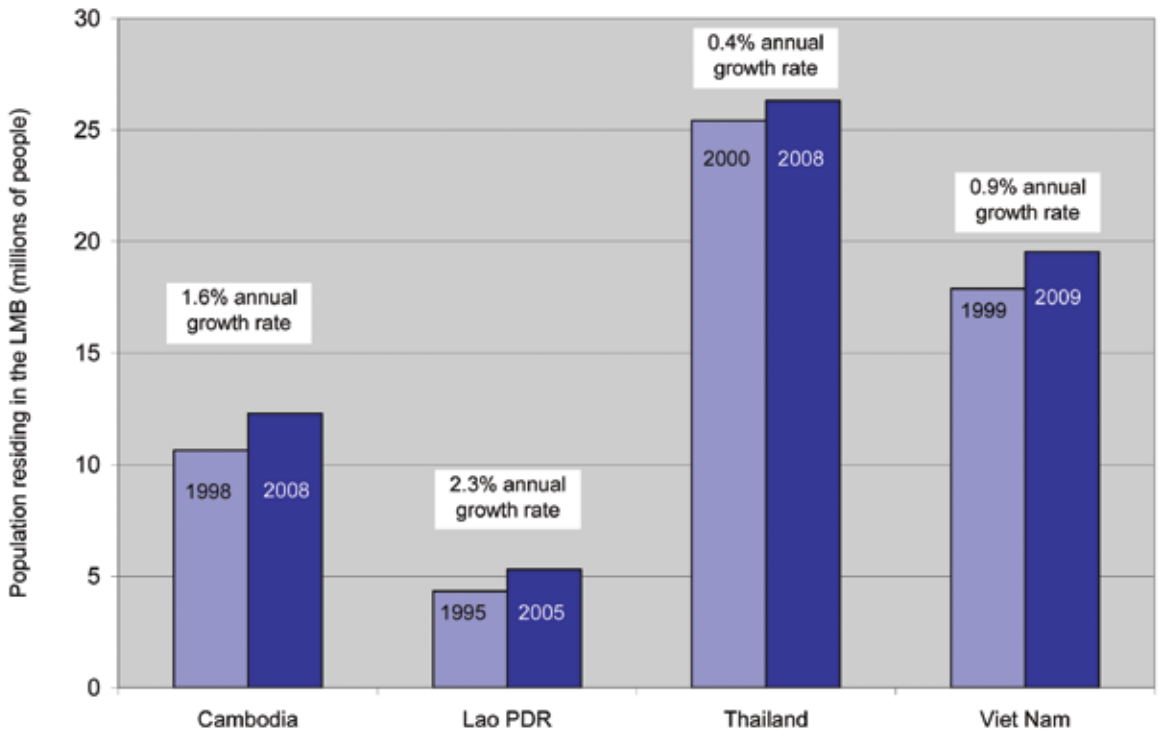


Figure 1 Population change during 8-10 years Cambodia, Lao PDR, Thailand and Cambodia (only Provinces located in the LMB are included). The average annual population growth rate ranges from 0.4% in Thailand and 2.3% in Lao PDR.

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
	Population census 1998	1998	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
	Lao Population Census 1995	1995	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2008	Province	National Statistical Office, Ministry of Information and Communication Technology
	Population Census 2000	2000	Province	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	Province	General Statistics Office of Viet Nam
	1999 Population and Housing Census	1999	Province	General Statistics Office of Viet Nam

Dependency ratio

GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Dependency ratio	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: National Statistical Office	2009	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2009	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
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River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.4 Dependency Ratio

The dependency ratio measures the number of dependants who must be supported by working-age adults. Dependants include children under the age of 15 and the elderly (65 years and older). A dependency ratio of 100%, for example, means that each working adult must, on average, provide for one other dependant household member. A lower ratio of 50% means that there is on average one dependant per two working-age adults. Dependency ratio data are available for Cambodia, Lao PDR and Viet Nam at the provincial level from population censuses conducted in 2005-2009 in each country and for Thailand at the regional level in 2009.

The lowest dependency ratios of less than 40 dependants per 100 working-age adults occur in the northeast and northern regions of Thailand and the two national capital cities in the LMB: Vientiane in Lao PDR and Phnom Penh in Cambodia. These low ratios reflect the larger number of working adults, as well as a smaller number of children. Ratios are also low (40-50%) throughout the Mekong Delta and districts along the Mekong River near Phnom Penh city. Urban centres attract large numbers of young migrants from the Provinces in search of employment and education. The low dependency ratio in the Delta in Viet Nam is due to the combination of two main factors: a post-war baby boom in Viet Nam that started in the mid 1970's, which has resulted in the large population of working-age adults in the country in the present day, and secondly a more recent trend for declining birth-rates (Hook et al. 2003).

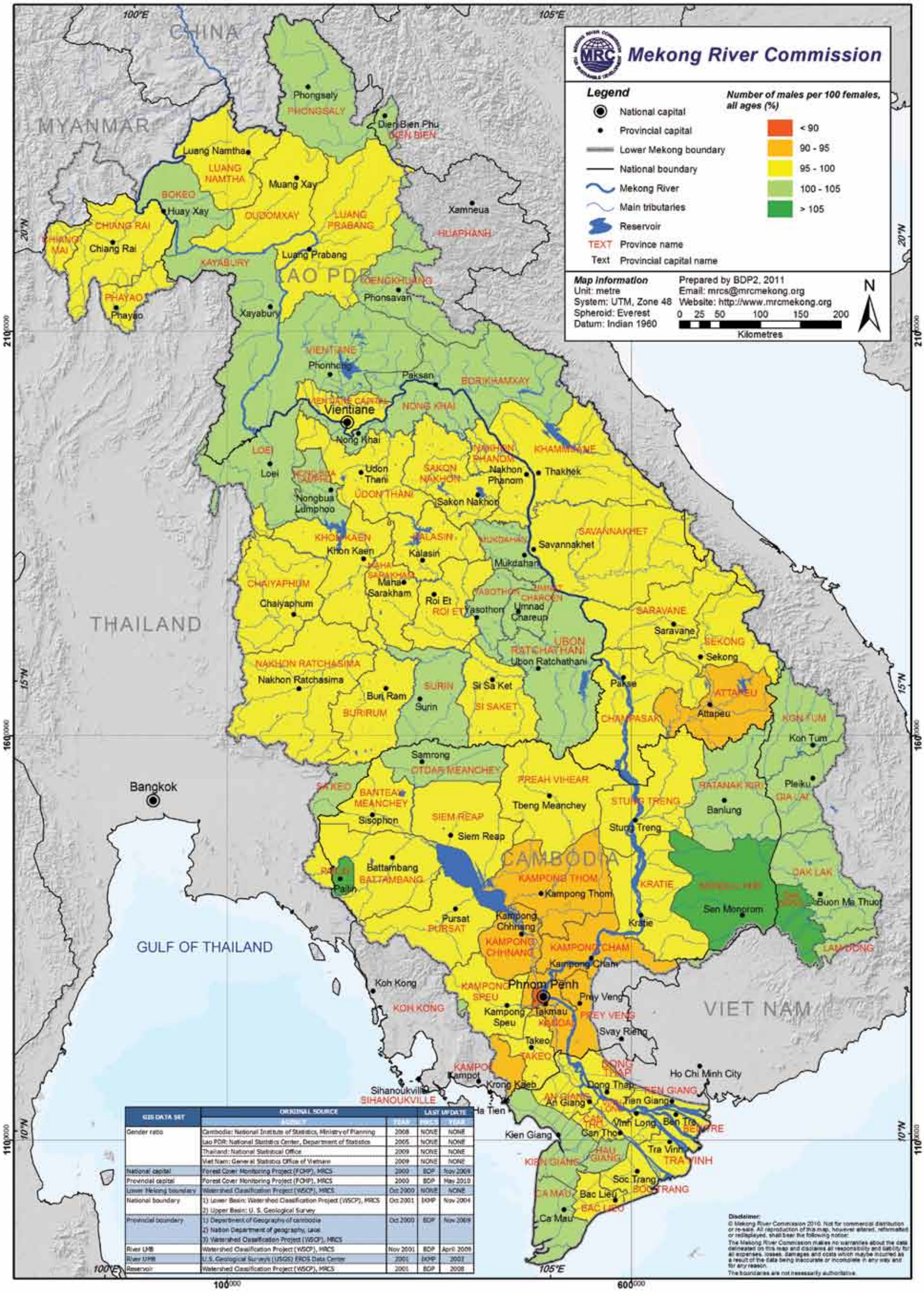
Other areas of Lao PDR and Cambodia have higher dependency ratios in the order of 60-100 dependents per 100 working-age adults. These higher ratios can be attributed to the loss of many adults in wars in the 1970s and 1980s, and the post-war baby booms in the two countries that started 5-10 years later than in Viet Nam and continued through the 1990s, resulting in a large number of children aged under 15 (Hook et al. 2003).

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2008	Region	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	Province	General Statistics Office of Viet Nam

- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.
- Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Gender ratio



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Gender ratio	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: National Statistical Office	2009	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2009	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River UMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.5 Gender Ratio

Gender ratio measures the number of men for every 100 women in the population. This map illustrates the gender ratio by Province based on national censuses conducted between 2005 and 2009. Gender ratios in most Provinces in Cambodia and Lao PDR are less than 100, indicating that women outnumber men. However, in the Central Highlands of Viet Nam, parts of central and northern Lao PDR and a few Provinces in Cambodia and the Delta, there are more men than women.

Past wars and economic forces affect gender ratio in the Lower Mekong Basin. In Cambodia, and to a lesser extent in Lao PDR, many more men than women died in conflicts that occurred from the early 1970s, which, in the case of Cambodia, did not finish until the 1990s. This is reflected in the lower numbers of men in most urban and rural areas in most of Cambodia and several regions of Lao PDR.

Economic forces drive domestic migration for employment. While men have traditionally been more likely to migrate for economic reasons, women are observed to be increasingly migrating to urban centres to work in the manufacturing (generally textiles) and service sectors (such as hotels and restaurants). This may, in part, explain the very low gender ratio (a much larger number of females than males) in Phnom Penh city and its surrounding area.

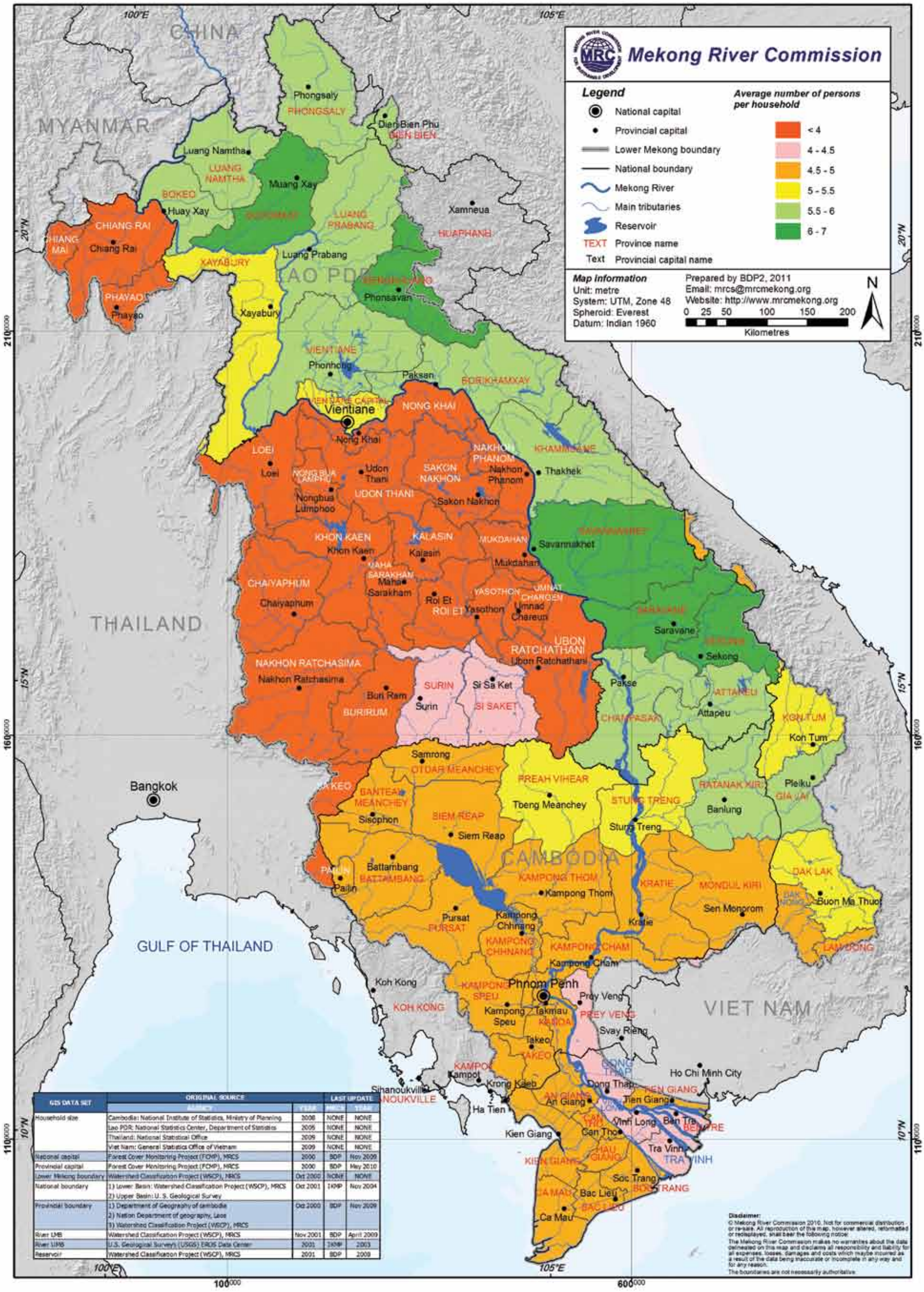
Provinces or regions where the number of men greatly outweighs the number of women are usually associated with construction or extractive industries. For example, Pailin district in western Cambodia with a gender ratio of 117 is the centre of logging and mining industries. In the Central Highlands of Viet Nam, government programmes to promote economic development have resulted in the in-migration of labourers who are disproportionately male.

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2008	Region	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	Province	General Statistics Office of Viet Nam

- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.
- Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Household size



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Household size	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: National Statistical Office	2009	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2009	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IWMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IWMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2009

2.6 Household Size

The traditional household in rural areas of the Lower Mekong Basin is typically large, often including several generations. Having many children helps adults to produce food and meet other family needs. As adults, children ensure the care of their parents and grandparents when they can no longer work.

This map shows the average number of people per household by Province in 2005-2009. The average household size in Lao PDR is six persons, while in Cambodia and Viet Nam it is 4.8 persons. Average household size is larger in remote areas of northern and central Lao PDR with, on average, six to seven persons per household, while Vientiane Capital and Xayabury Provinces have smaller average household sizes of 5.0 - 5.5 persons.

In Cambodia, households are larger than the national average of 4.8 in the more remote northern and eastern parts of the country (five to six persons) and smaller in the south, particularly in Prey Veng Province where the average household size is 4.2 persons. Interestingly, Phnom Penh Province has an average household size of 5.0, which is larger than most rural Provinces in the central and southern parts of the country (4.5-4.8). The same trend was reported for the previous census in 1998 and was attributed to relatives who have migrated from rural areas in Cambodia in search of employment and education opportunities in the city.

In the nine to ten year period between the two most recent national censuses (1995-2000 and 2005-2009), average household size in Lao PDR, Cambodia and Thailand declined slightly by 0.1, 0.7 and 0.4 persons respectively. Household size in 1995-2000 in Viet Nam has remained stable, as reported by Hook (2003). Basin wide, household size has declined by 0.3 persons. This decline in household size has been influenced by several factors including specific government policies encouraging smaller families, greater economic and education opportunities, especially for women, and gradually improving incomes. Reductions in infant and child mortality rates in Cambodia and Lao PDR may encourage families to have fewer children (Hook 2003).

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2009	Province	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	Province	General Statistics Office of Viet Nam

- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.
- Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Female head of household

2.7 Female Head of Household

This map describes the proportion of households headed by women by Province in Lao PDR, Cambodia and Viet Nam according to the most recent national population censuses of each country conducted between 2005 and 2008. Data for Thailand is from the year 2009 at the regional level only. A household with a female head is one in which a woman identifies herself as heading the household and is accepted as the head of household by other members of the household. While the proportion of households headed by a woman is often used elsewhere as a measure of progress in gender equality, in the Lower Mekong Basin (LMB) it most often represents women who are widowed or divorced, or married women whose husbands are away working (Hook 2003; Messerli 2008).

Men head most households in the LMB as indicated by the relatively low percentages of females heading households, ranging from less than 3% to 35%. Nationwide in Lao PDR, 10% of total households were headed by women, ranging from less than 3% to over 18%. Above average percentages of female-headed households are found in Provinces along the Mekong River, and in particular in Vientiane Capital, Savannakhet and Khammuan Provinces. In general, percentages tend to be greater in the southern and central parts of country than in the north. Messerli et al. (2008) suggest that greater rates of migration of Lao males seeking employment in Thailand may be responsible for these spatial trends and recommends that female household headship should be analysed together with gender ratio, out-migration and marital status. A tendency for higher divorce rates in urban versus rural area may also account for the spatial differences, especially since large towns and cities tend to be concentrated along the Mekong River where female head of household headship is greatest.

In Cambodia, 23% of total households are headed by women, a much higher proportion than found in Lao PDR, Thailand or Viet Nam. This probably reflects the large number of women widowed during the war in Cambodia between 1985 and 1990 and is supported by the low gender ratio (fewer men then women) in Cambodia as illustrated in Map 2.5. There is a general spatial trend of lower proportions (10-20%) of female-headed households in the more remote and poorer northern and western regions of the country and higher proportions (20-35%) in the central, eastern and southern regions. This corresponds to a similar spatial trend in gender ratio across the country with fewer males as a proportion of females in the central and southern regions. The close correspondence of these two indicators suggests that the high rates of female household headship are not due to better gender equality but rather the combination of out-migration of men seeking employment and death of men during the war.

In northeast Thailand, 29.6% of household are headed by women. In northern Thailand the rate is slightly higher at 32.4% and again higher in two Provinces in the eastern region of the country (Chantaburi and Sa Keo), where 40.1% of households are headed by women. In the Mekong Delta and Central Highlands of Viet Nam, the proportion of female-headed households ranges from 7% to 29%, with an average of 17.8%. The lowest proportions occur in the five Provinces in the Central Highlands, which may reflect a combination of these Provinces having largely rural populations and, secondly, a large in-migration of men seeking employment in the construction industry and the extensive agricultural plantations found in the area (see description of Gender Ratio Map 2.5).

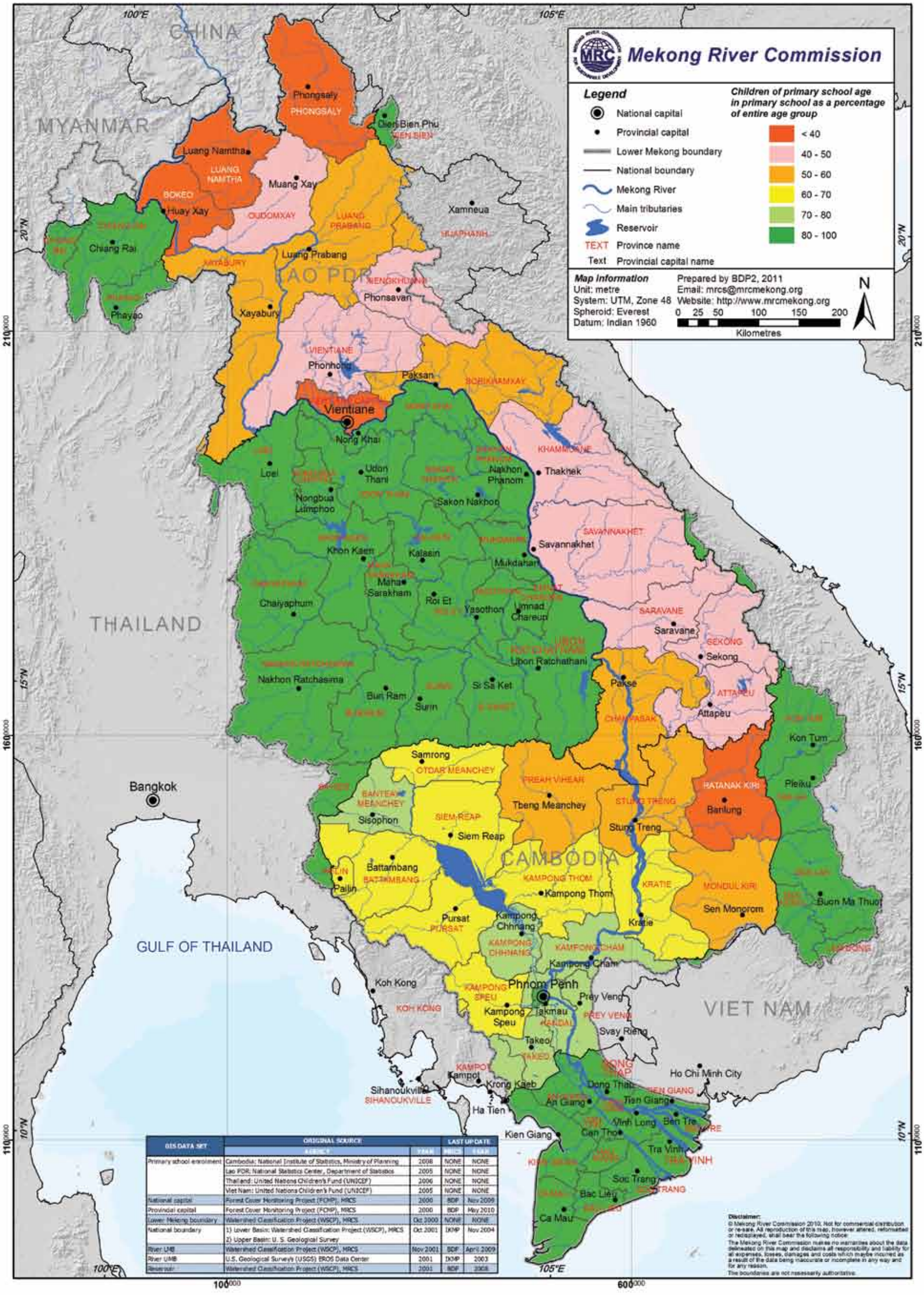
REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2009 Thailand statistical yearbook	2009	Province	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	2009 Population and Housing Census	2009	Province	General Statistics Office of Viet Nam

Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.

Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Primary school enrolment



GIS DATA SET	ORIGINAL SOURCE: AGENCY	YEAR	LAST UPDATE: MRCS	YEAR
Primary school enrolment	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: United Nations Children's Fund (UNICEF)	2006	NONE	NONE
	Viet Nam: United Nations Children's Fund (UNICEF)	2005	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	DMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Surveys (USGS) EROS Data Center	2001	DMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.8 Primary School Enrolment

Primary school enrolment refers to the proportion of children of primary school age who are enrolled in primary school. This map depicts the primary school enrolment rate by Province for Lao PDR and Cambodia and by country for Thailand and Viet Nam. Data for Lao PDR and Cambodia are from national population censuses conducted in 2005 and 2008, respectively, while for Thailand and Viet Nam, data are available from the United Nations Childrens' Fund (UNICEF) for the years 2006 and 2005, respectively.

The map shows very large differences in primary school enrolment rates between Lao PDR and eastern Cambodia on the one hand, which have low school enrolment rates ranging from 30-55 %, and much higher enrolment rates in Thailand and Viet Nam on the other hand, where 90% and 86.5% of primary age school children attend primary school respectively. Southern Cambodia has intermediate enrolment rates of 60-80%.

Nationwide in Lao PDR, only 46% of primary school aged children attend primary school. Three Provinces in the far north of the country (Bokeo, Luang Namtha and Phongsaly) have enrolment rates of only 30-40%. Vientiane, Xeng Khuang and most Provinces in the south of the country have slightly higher enrolment rates of 40-50%, while Xayabouri, Luang Prabang and Champasak Provinces have the highest national rates of 50-60%.

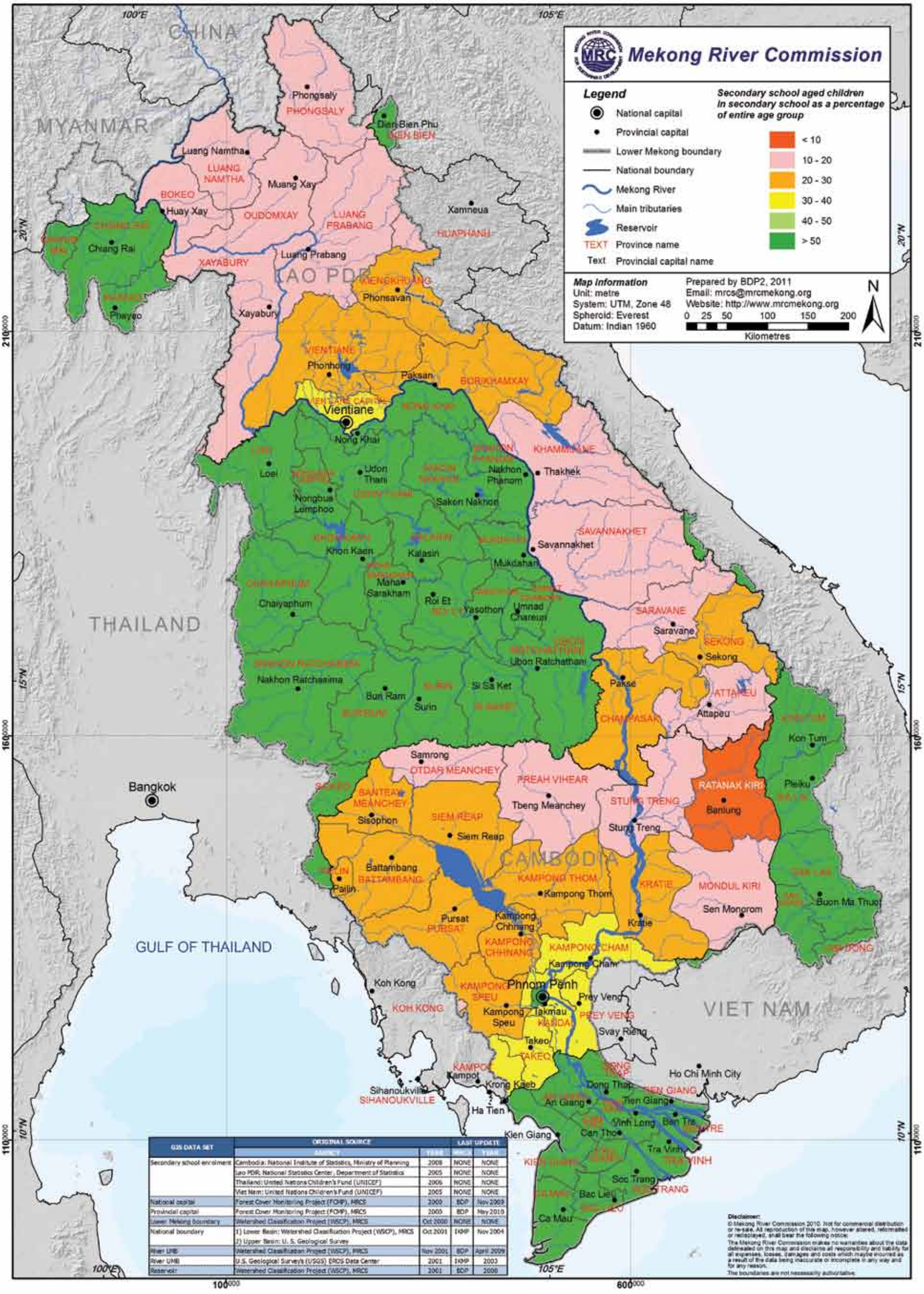
In Cambodia, the average primary school enrolment rate is 67%, although this varies widely across the country. There are large disparities between the remote eastern Province of Ratanakiri where enrolment rates are only 33% and Phnom Penh Province where Phnom Penh city is located, which has an enrolment rate of 82%. Provinces in the Tonle Sap Basin tend to have low to moderate enrolment rates of 50-60%.

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	UNICEF Education Statistics for Thailand	2006	Country	UNICEF, Division of Policy and Practice, Statistics and Monitoring Section, http://www.childinfo.org/files/EAPR_Thailand.pdf
Viet Nam	UNICEF Education Statistics for Thailand	2005	Country	UNICEF, Division of Policy and Practice, Statistics and Monitoring Section, http://www.childinfo.org/files/EAPR_Viet_Nam.pdf

- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.
- Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Secondary school enrolment



2.9 Secondary School Enrolment

Secondary school enrolment refers to the proportion of children of secondary school age who are enrolled in secondary school. This map depicts the secondary school enrolment rate by Province for Lao PDR and Cambodia and by country for Thailand and Viet Nam. Data for Lao PDR and Cambodia are from national population censuses conducted in 2005 and 2008, respectively, while for Thailand and Viet Nam, data are available from the United Nations Childrens' Fund (UNICEF) for the years 2006 and 2005, respectively.

Secondary school enrolment rates are moderate to high in Thailand and Viet Nam. In Thailand, 71% of secondary school aged children are enrolled in secondary school, while in Viet Nam the enrolment rate is 68.5%. Enrolment rates are much lower in Lao PDR and Cambodia. The average secondary school enrolment rate in Lao PDR is 18% and in Cambodia 26%. This is less than half of primary enrolment rates (see previous Map 2.9) in the same countries.

The spatial trends in Lao PDR and Cambodia are similar to that of primary-school enrolment with lower rates in far northern and central-southern Provinces of Lao PDR; and northern and eastern Provinces of Cambodia, particularly Ratanakiri Province with an enrolment rate of only 9.4%. A much higher proportion (53%) of children is enrolled in secondary school in Phnom Penh Province where Phnom Penh city is located, and in the far south towards the Delta where enrolment rates are 30-40%.

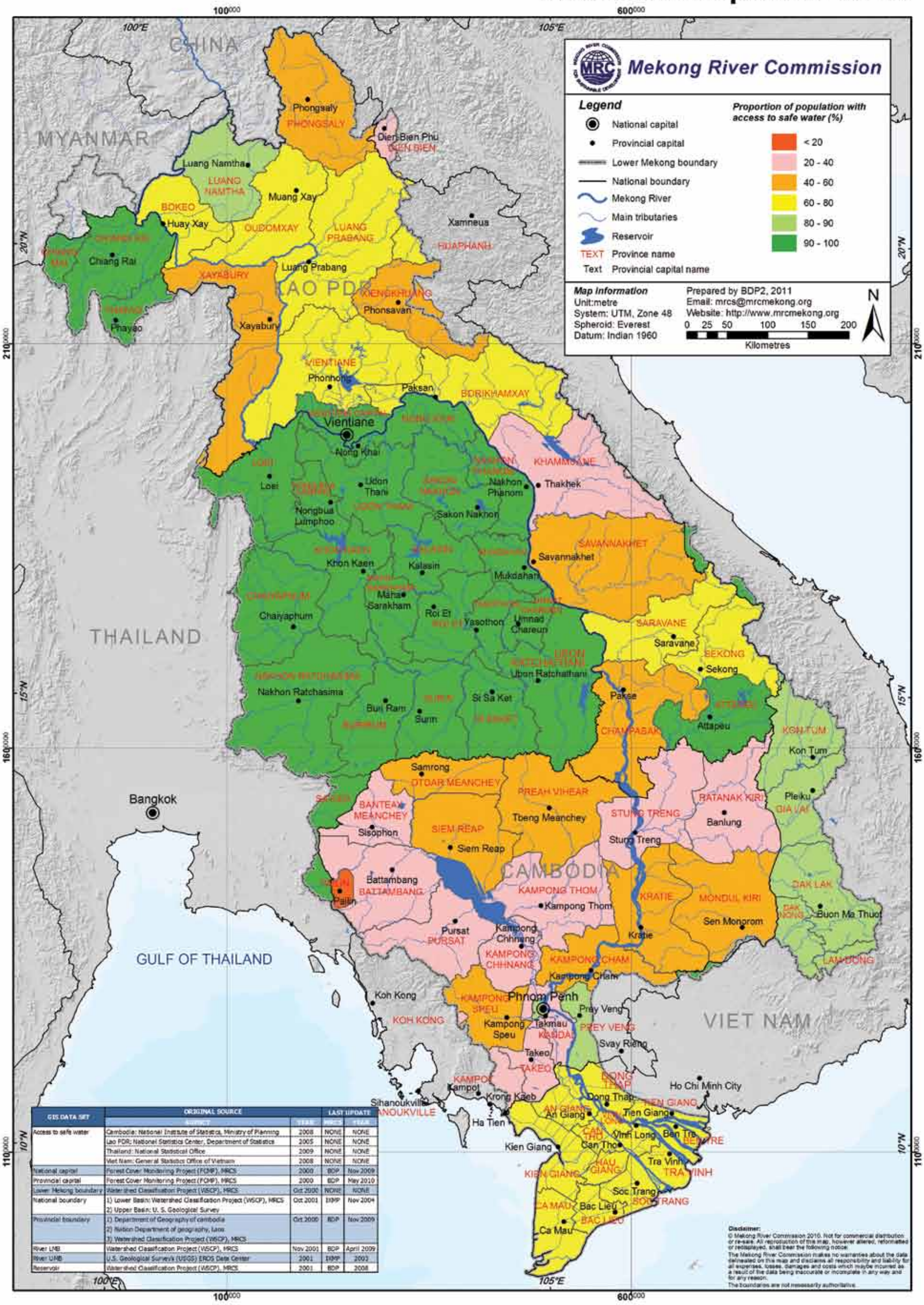
REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	UNICEF Education Statistics for Thailand	2006	Country	UNICEF, Division of Policy and Practice, Statistics and Monitoring Section, http://www.childinfo.org/files/EAPR_Thailand.pdf
Viet Nam	UNICEF Education Statistics for Thailand	2005	Country	UNICEF, Division of Policy and Practice, Statistics and Monitoring Section, http://www.childinfo.org/files/EAPR_Viet_Nam.pdf

Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.

Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Access to improved water



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	SOURCE	YEAR	MRCS	YEAR
Access to safe water	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: National Statistical Office	2009	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2008	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IWMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River LNB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IWMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.10 Access to Improved Water

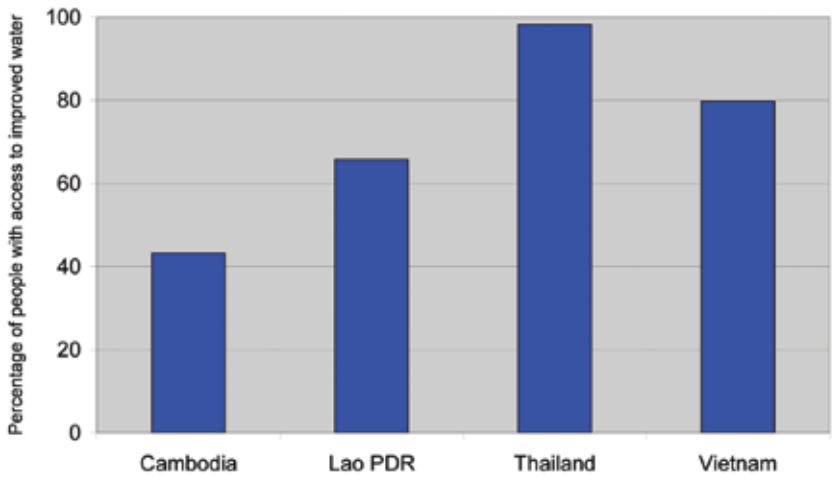
This shows the proportion of the population with access to an 'improved' water source for drinking and domestic use, by Province for Lao PDR and Cambodia, and by region for Thailand and Viet Nam. An 'improved' water source is defined as one that "*by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter*" (WHO and UNICEF 2010). The map shows a large disparity between Thailand where 98% of the population of northeast and northern Thailand have access to an improved water source, and Cambodia, where only 43% of people have access. In Lao PDR and Viet Nam, 80% of people residing within the lower Mekong Basin have access to an improved water supply.

The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation monitors progress towards the Millennium Development Goal (MDG) related to drinking water and sanitation, which is to: "Halve, by 2015, the proportion of people without sustainable access to safe drinking-water and basic sanitation". Improved water sources included private or public taps from a piped water system, rainwater and protected groundwater wells, either drilled or dug, where the well is protected from runoff and bird droppings and animals. The adjacent map is based on data on 'access to safe water' or 'main drinking water source' from national censuses or household living standard surveys in the four lower Mekong countries. These censuses and surveys do not distinguish between improved and non-improved water sources according to the WHO/UNICEF definition, however best care has been taken to include only those water sources which fit the above definition of an 'improved' water source (Table 4). In the case of Thailand and Viet Nam, protected and unprotected wells are not distinguished in the results of household surveys but these have been included in the regional average access rates presented in this map.

Table 4 Sources of water included in the 'access to improved water' definition for each country.

Country	Sources of water included in the 'access to improved water' definition for each country
Cambodia	Piped water, tube or pipe well, protected dug well
Lao PDR	Piped water, protected well
Thailand	Inside piped water supply, inside piped water sourced from groundwater, piped water – public shared tap, groundwater well
Viet Nam	Private tap, public tap, drilled well with pump, hand-dug or constructed well (without pump) and rainwater

Figure 2 Percentage of people residing within the LMB with access to improved water, by country.



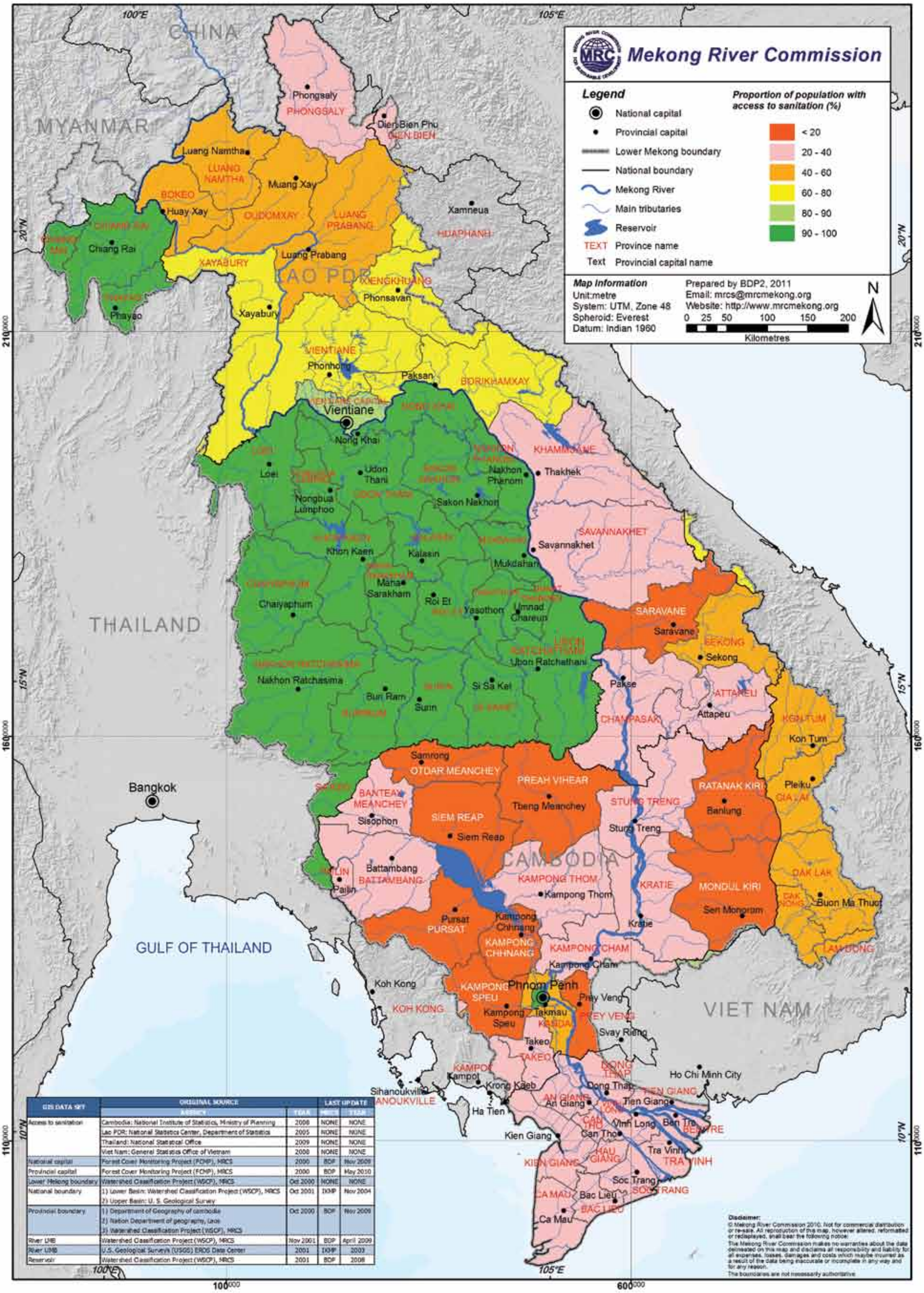
In Cambodia, access to improved water ranges from 19% in Pailin Province in the far west and 86% in Phnom Penh Province where the city of Phnom Penh is located. Most other Provinces have access rates of between 20-50%. In Lao PDR, Khammuan Province has the lowest rate of access to improved water of 37% while Vientiane Capital, Luang Namtha and Attapeu Provinces have access rates of >80%. In urban areas, piped water systems and centralised treatment plants increase the availability of safe drinking water. In the Delta in southern Viet Nam, 79.5% of the population has access to an improved water supply for drinking, while 81.2% have access in the Central Highlands.

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2010 Thailand Statistical Yearbook (Special edition)	2009	Region	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	Results of the Survey on Household Living Standards	2008 2008	Region	General Statistics Office of Viet Nam, Ministry of Planning and Investment (Published in 2010)

- WHO and UNICEF (2010) WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation.
- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin, Mekong River Commission*, Phom Phen. p 154 pp.

Access to sanitation



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Access to sanitation	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: National Statistical Office	2009	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2008	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.11 Access to Sanitation

Access to sanitation refers to the proportion of the population with access to a flush or non-flush toilet in or near the house, or a traditional pit latrine (see Table 5 below for country specific definitions). Access to sanitation has a large influence on human health and is an important indicator of socio-economic development. This map illustrates the proportion of the total population with access to sanitation by Province.

Overall, 99% of people in northeast and northern Thailand have access to sanitation, while the access rates are less than half that in the other three countries: 48% in Lao PDR, 38% in Viet Nam and 32% in Cambodia (Figure 3). In Cambodia, fewer than 20% of people in nine Provinces have access to a toilet or latrine, including Ratanakiri and Mondul Kiri Provinces in the far east of the country, six Provinces in the Tonle Sap Basin and two Provinces in the south of the country. The remaining Provinces have access rates of less than 40% with the exception of Phnom Penh Province where Phnom Pehn city is located, with a much higher rate of access of 68%, and the nearby Province of Kandal where 46% of people have access to sanitation.

In Lao PDR, the proportion of people with access to sanitation varies from high rates of 86% in Vientiane Capital Province to less than 17% in Saravan Province in the south of the country. The central-northern Provinces of Xayaburi, Vientiane, Xiang Khuang and Borikhamxay have moderately high rates of access of between 60-80%. In Viet Nam, only regional data is available. On average, 63% of people living in the Mekong Delta have access to sanitation; while in the Central Highlands 80% of people have access.

Table 5 Definition of the indicator 'access to sanitation' in each country. See reference list below for data sources.

Country	Type of toilet/latrine included in national indicator definitions
Cambodia	Flush or non-flush toilets and traditional pit latrines with or without connection to a central sewer or septic tank
Lao PDR	Flush toilet or traditional mould (pit) latrine
Thailand	Flush toilet or traditional mould (pit) latrine
Viet Nam	Flush or non-flush toilet with connection to a sewer or septic tank, and double vault compost latrines

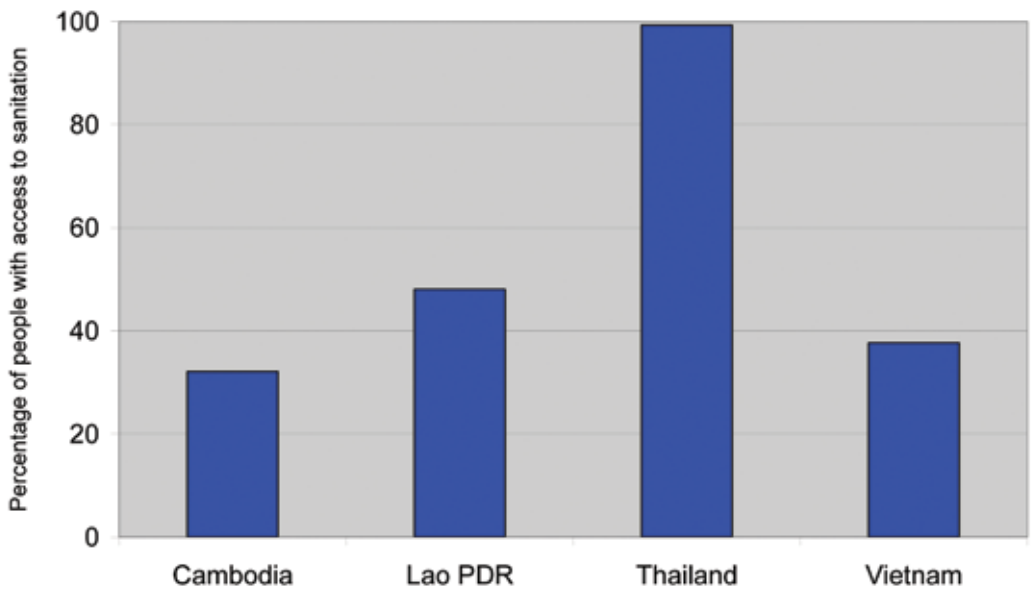


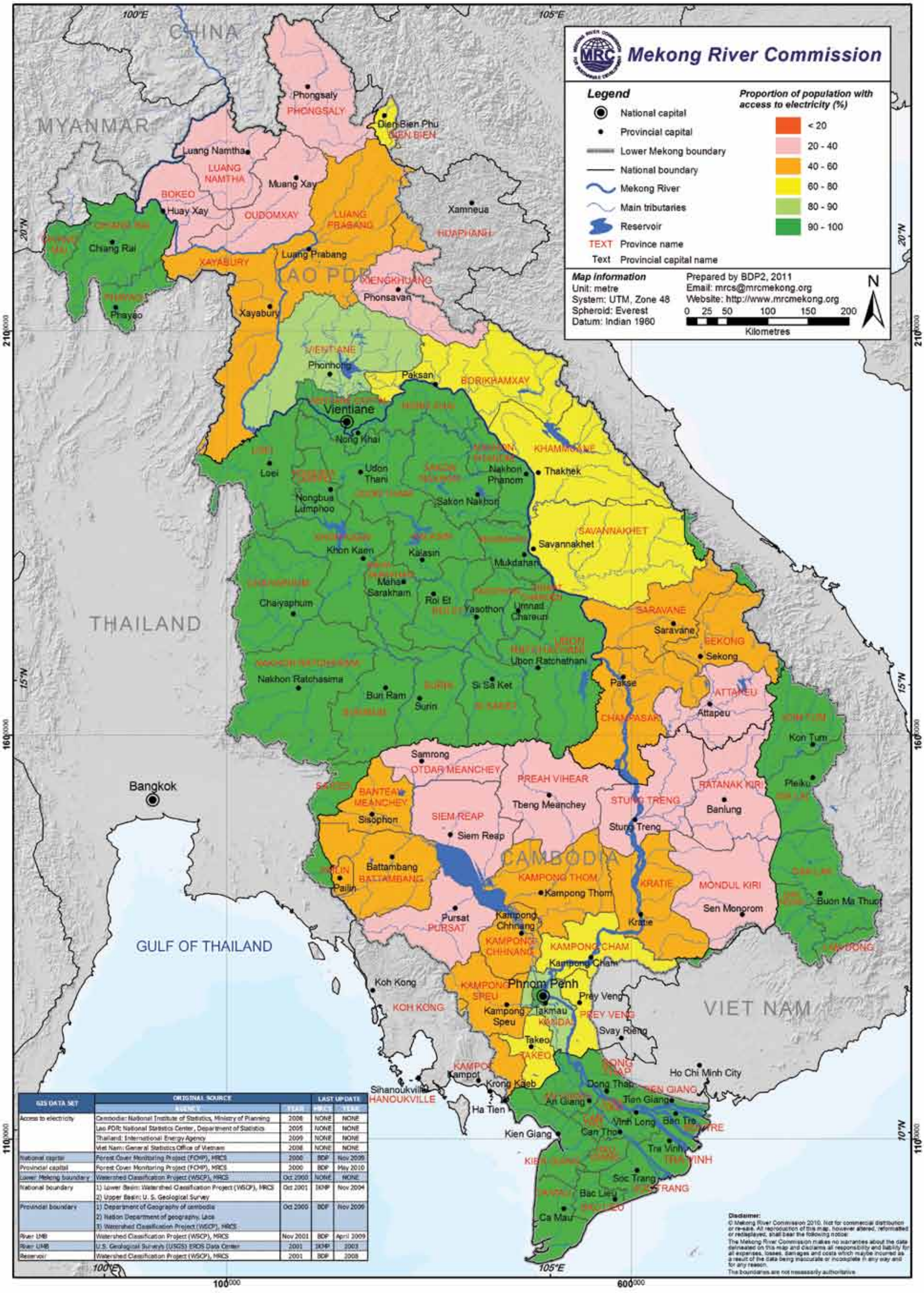
Figure 3 Percentage of people residing within the LMB with access to sanitation, by country.

REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005	2005	Province	National Statistics Center, Department of Statistics, Ministry of Planning and Investment
Thailand	2010 Thailand Statistical Yearbook (Special edition)	2009	Region	National Statistical Office, Ministry of Information and Communication Technology
Viet Nam	Results of the Survey on Household Living Standards	2008 2008	Region	General Statistics Office of Viet Nam, Ministry of Planning and Investment (Published in 2010)

- Hook, J., Novak, S. and Johnson, R. (2003) *Social Atlas of the Lower Mekong Basin*, Mekong River Commission, Phnom Penh. p 154 pp.
- Messerli, P., Heinimann, A., Epprecht, M., Souksavath, P., Chanthalanouvong, T. and Minot, N. (2008) *Socio-Economic Atlas of the Lao PDR: An Analysis based on the 2005 Population and Housing Census Swiss National Center for Competence in Research* (NCCR) North-South, University of Bern, Bern and Vientiane: Geographica Bernensia.

Access to electricity



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Access to electricity	Cambodia: National Institute of Statistics, Ministry of Planning	2008	NONE	NONE
	Lao PDR: National Statistics Center, Department of Statistics	2005	NONE	NONE
	Thailand: International Energy Agency	2009	NONE	NONE
	Viet Nam: General Statistics Office of Vietnam	2008	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
Provincial boundary	1) Department of Geography of cambodia 2) Nation Department of geography, Laos 3) Watershed Classification Project (WSCP), MRCS	Oct 2000	BDP	Nov 2009
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Surveys (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

2.12 Access to Electricity

This map shows the proportion of the population with access to electricity by Province in Lao PDR, Cambodia and Viet Nam. Data for Thailand is at the national level. The map shows a large contrast between high rates of access in Thailand (99.3%) (IEA, 2009) and Viet Nam (97.5% - average for the Delta and Central Highlands) on the one hand and much lower access rates in Cambodia (59%) and Lao PDR (58%) (Figure 4). The above country or regional averages for Viet Nam, Cambodia and Lao PDR are based on census data at the provincial level (see data sources below) and calculated by taking into account the proportional population of each Province relative to the total country population residing within the lower Mekong Basin.

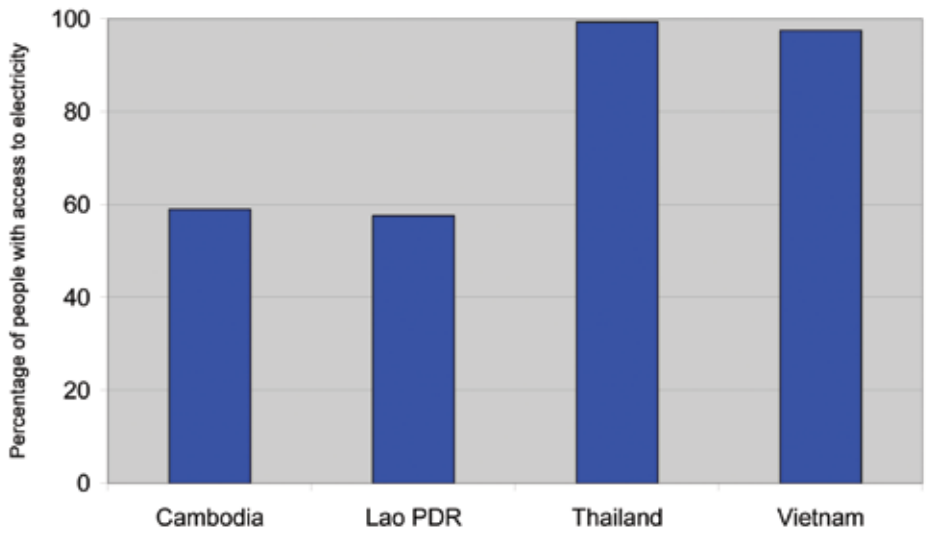
Across Lao PDR, access to electricity is generally better in the central and southern Provinces (40-80%) compared with the north where several Provinces have access rates of less than 20%. In the southern region, Saravane and Attepeu Provinces also have low rates of 33% and 15%, respectively. In Vientiane Province (excluding Vientiane city), 68% of the population has access to electricity, owing largely to electricity generated by Nam Ngum I dam.

In Cambodia, several Provinces have access rates of less than 10%. These include Ratanakiri, Stung Treng and Preah Vihear Provinces in the remote northern and eastern parts of the country; but also Kampong Thom and Siem Reap Provinces located near Tonle Sap Lake. Access rates are higher in the municipal centres of Phnom Penh (90%) and Vientiane (95%). In the Delta and Central Highlands of Viet Nam, all Provinces have access rates of more than 93%. One Province (Dien Bien) in northern Viet Nam has lower electricity access (71.7%).

Table 6 Definition of the indicator 'access to electricity' in each country. See reference list below for data sources.

Country	Electricity sources included in national indicator definitions
Cambodia	Power grid, generator, battery
Lao PDR	Power grid (direct access or shared with neighbors) , generator
Thailand	Power grid
Viet Nam	Power grid, generator, battery

Figure 4 Percentage of people residing within the LMB with access to electricity, by country.



REFERENCES AND FURTHER READING

Country	Source	Year	Data level	Agency
Cambodia	General Population Census of Cambodia 2008	2008	Province	National Institute of Statistics, Ministry of Planning
Lao PDR	Lao Population Census 2005 Ministry of Planning and Investment	2005	Province	National Statistics Center, Department of Statistics,
Thailand	World Energy Outlook 2009	2008	Country	International Energy Agency (IEA) http://www.worldenergyoutlook.org/2009.asp
Viet Nam	Results of the Survey on Household 2008 Living Standards 2008		Province	General Statistics Office of Viet Nam, Ministry of Planning and Investment (Published in 2010)

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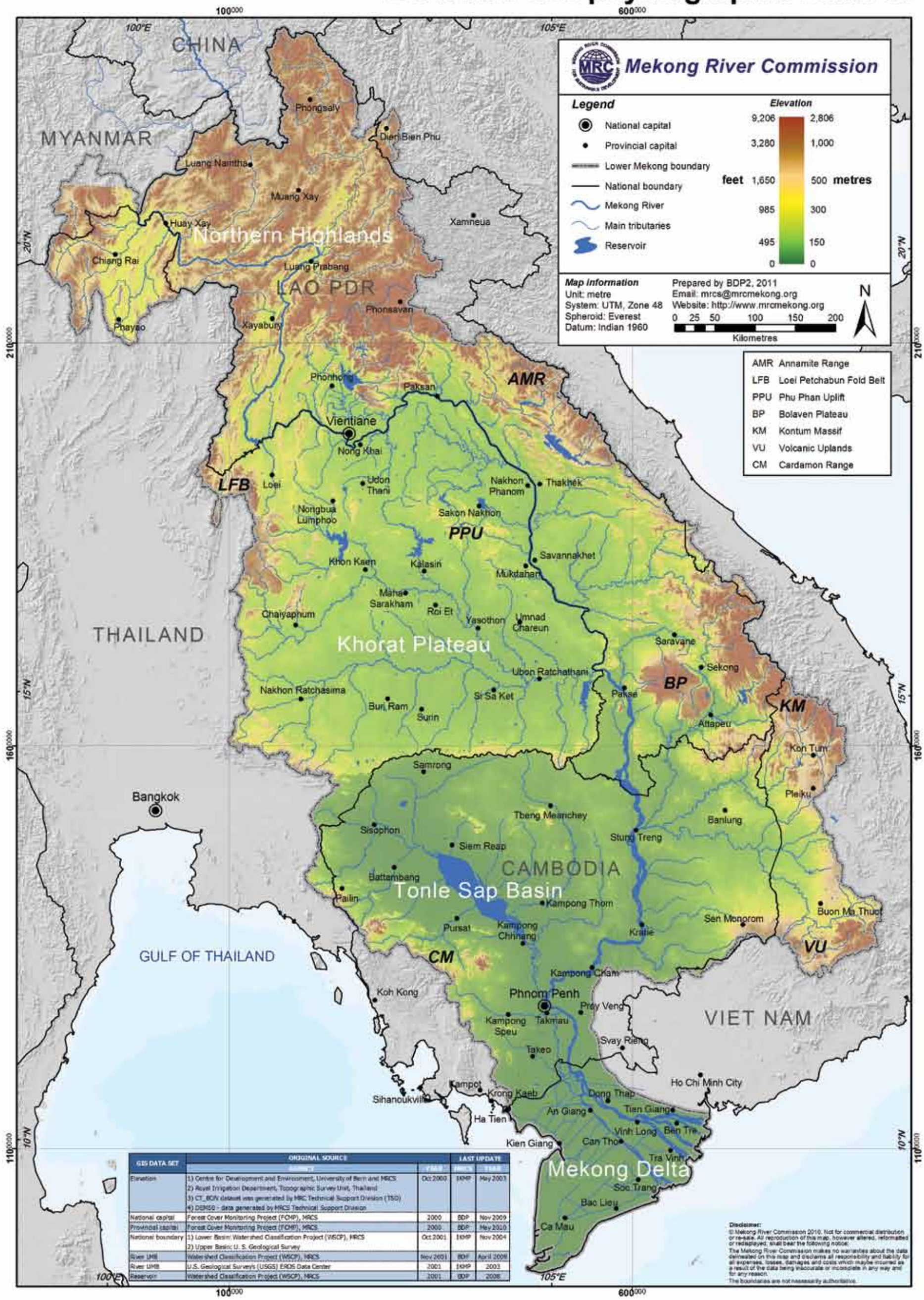
3 Physical Landforms and Transport Infrastructure

Elevation and physiographic features



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Elevation	1) Centre for Development and Environment, University of Bern and MRCS 2) Royal Irrigation Department, Topographic Survey Unit, Thailand 3) CT_BDN dataset was generated by MRC Technical Support Division (TSD) 4) DEM50 - data generated by MRCS Technical Support Division	Oct 2000	IKMP	May 2003
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Surveys (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

3.1 Elevation and Physiographic Features

The elevation of the Lower Mekong Basin ranges from just over 2,800 m above mean sea level (amsl) to zero at the coast in the Delta in Viet Nam. This map shows land surface elevation throughout the basin along with major topographic features and broad physiographic regions as described in the most recent State of the Basin Report (MRC 2010d). Mountain ranges are found throughout the basin and are evidence of a long and complex tectonic history (Brookfield 1998; Carling 2009a; Workman 1975). The key characteristics of the four physiographic regions (MRC 2010d) are described below.

Northern Highlands

The Northern Highlands include the upland areas of northern Lao PDR and northern Thailand. In this region the Mekong River as well as its major tributaries are constrained in steep-sided valleys. Many of these valleys and their associated mountain ranges, especially in the western portion of the Northern Highlands, are part of the Loei-Petchabun fold belt, a major regional structural feature. In isolated places the Mekong River, such as near Chiang Saen and Huay Xai, and its tributaries broaden and have developed floodplains.

Khorat Plateau

The Khorat Plateau is a basin that has been uplifted and tilted such that it now lays perched at an elevation of about 300 m amsl. Along its western and southern boundaries, the Plateau is rimmed by a sharp ridge of higher elevation formed by highly resistant sandstones. The Plateau is bound by the Annamite Mountains in the east and a small mountain range: the Phu Phan Uplift: is located in the central eastern area. The Phu Phan Uplift divides the Khorat Plateau into two sub-basins: the Sakhon Nakhon/Savannakhet Basin to the north, and the Min/Chi Basin to the south. Most of the central region of the Khorat Pleteau however is flat or gently folded. The major rivers draining this area (Songkhram, Chi and Mun rivers) have low-gradients and wide floodplains. On the eastern side of the Mekong River, land elevation rises more rapidly away from the Mekong River to the Annamite Range: a major mountain range that runs north-south along the Lao PDR – Viet Nam border.

Tonle Sap Basin

The Tonle Sap Basin is a "large dome like geological structure that has been 'unroofed' through erosion, leaving a rim of hills standing above the alluvial plains in the centre of the basin" (MRC 2010d). The western and central parts of the basin are characterised by a low-gradient and low-relief landscape. The Tonle Sap basin is bounded in the north by the ridge that forms the southern edge of the Khorat Plateau and the Cardamon Range in the southwest. Extensive basaltic lava flows form upland areas in the southern part of the LMB. These include the Bolaven Plateau east of Pakse and upland areas north of Ho Chi Minh City.

The Mekong Delta

The Mekong Delta plain covers an area of 62,520 km^2. The Delta begins at Phnom Penh where the Mekong River splits into two main distributary channels: the Mekong and Bassac rivers, which further downstream split into nine smaller channels that discharge into the South China Sea (Nguyen et al. 2000). The Delta plain can be divided into two regions: the inner delta plain located upstream and dominated by fluvial (river) processes, and the outer delta plain located nearer the sea and subject to marine processes such as the influence of tides, waves and ocean currents (Nguyen et al. 2000; Ta et al. 2002). The outer delta is of slightly higher elevation than the inner delta due to the formation of sand dunes and ridges near the coast.

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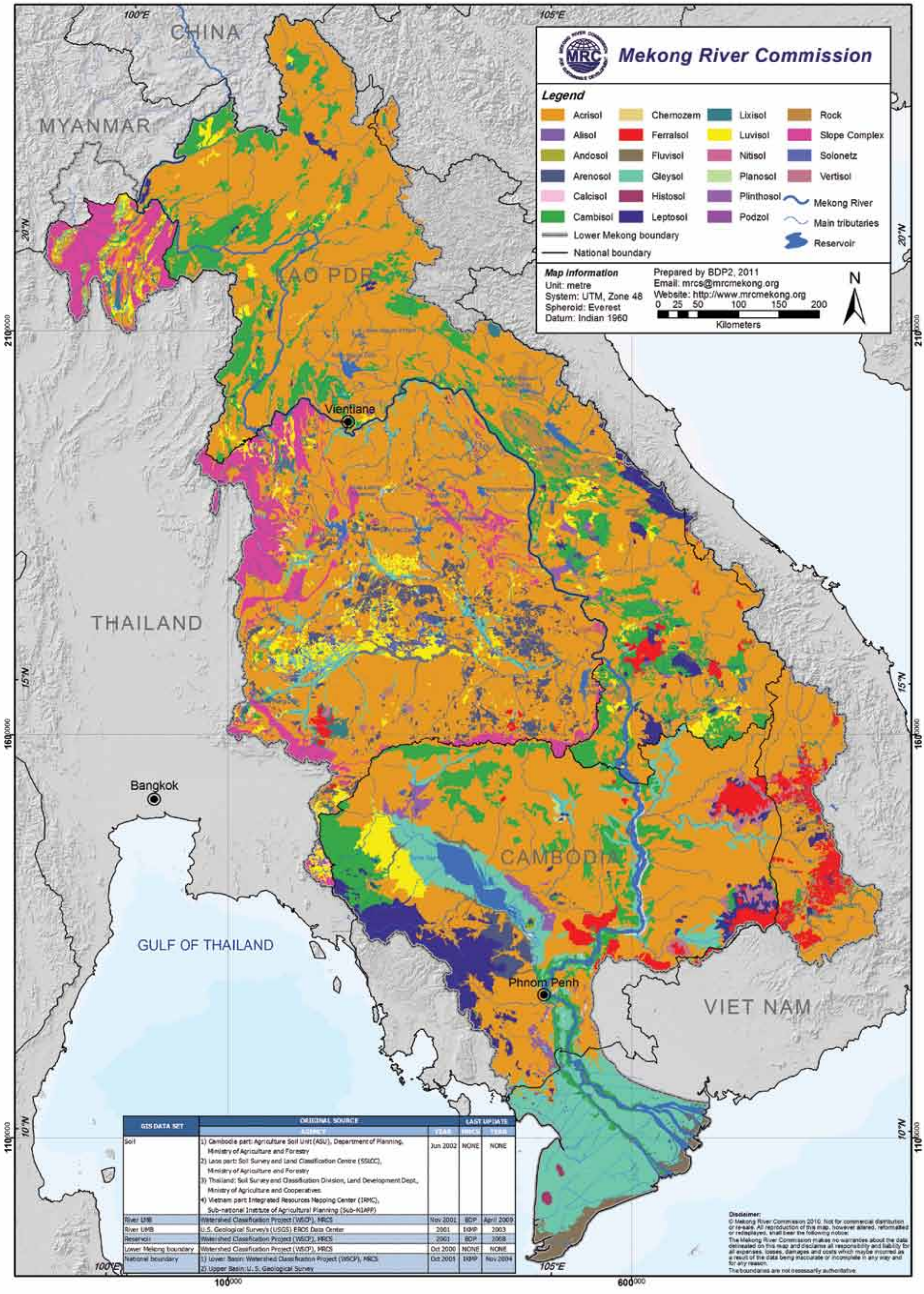
Soils



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Soil	1) Cambodia part: Agriculture Soil Unit (ASU), Department of Planning, Ministry of Agriculture and Forestry 2) Laos part: Soil Survey and Land Classification Centre (SSLCC), Ministry of Agriculture and Forestry 3) Thailand: Soil Survey and Classification Division, Land Development Dept., Ministry of Agriculture and Cooperatives. 4) Vietnam part: Integrated Resources Mapping Center (IRMC), Sub-national Institute of Agricultural Planning (Sub-NIAPP)	Jun 2002	NONE	NONE
River UMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2005	IKMP	Nov 2004

3.2 Soils

This map illustrates the distribution of major soil types in the LMB and has been compiled by the MRC from soil classification maps of the four lower Mekong countries. The soil classification follows the international standard taxonomic soil classification system: the World Reference Base for Soil Resources (WRB) first developed in 1998 (IUSS Working Group WRB 2006).

Overall, the soils of the Lower Mekong Basin have low fertility owing to the tropical monsoon climate, which results in high weathering rates and the associated rapid leaching of nutrients from soils. However, fertile soils are also found under these tropical conditions. Soil fertility is determined not only by weathering rate but also importantly by geology (which defines the parent material of the soil), management practices and proximity to rivers and the sea.

For example, soils in northeast Thailand as well as much of the Mekong corridor in Lao PDR downstream of Vientiane, much of the upland areas in southern Lao PDR and parts of Cambodia are derived from sandstone. Sandstone is low in minerals so these soils are poor in macro and micro-nutrients, perhaps most critically phosphorus. Conversely, soils in volcanic areas, such as the Bolaven Plateau west of Pakse are much more fertile due to the high mineral content of the parent volcanic (basalt) rocks. The soils of northern Lao PDR and northern Thailand are also generally more fertile as they are derived from a mix of parent materials.

The main risk to soil fertility in upland areas is soil loss through erosion and nutrient depletion through continuous cropping. Alluvium and organic matter are major ameliorators of soil fertility along rivers and streams and more broadly around the Tonle Sap Lake and in the Delta. These floodplain areas receive periodic inputs of nutrients from overbank flooding from rivers and the Tonle Sap Lake, which is most prevalent in the southern part of the LMB (see Map 4.4). Proximity to the sea can influence the sulfur content of soils, which tends to be quite low in Lao PDR and northeast Thailand but higher nearer the coasts. The Delta in Viet Nam is affected by salt water intrusion and acid sulfate soils, which require particular management.

Distribution of key soil types

The table below provides a brief description of the nine most common soil types and their coverage of the LMB and individual countries. Acrisols are the most common soil type in the LMB overall and in each country where they comprise between 36% and 70% of total land area. These intensely weathered soils, common to humid tropical climates, are clay-rich, acidic and with typically low nutrient levels. Their low fertility, acidity and often high amounts of aluminium pose limitations for agriculture. These soils are commonly forested, although acid-tolerant cash crops such as tea, coffee, rubber and pineapples can be grown with some success (IUSS Working Group WRB 2006). Cambisols are the second most common soil type in the LMB, especially in Lao PDR and Cambodia where they occur along river valleys. Although also typically poor in nutrients, they are more fertile than Acrisols and under the influence of abundant rainfall and surface runoff in alluvial plains they are highly productive paddy soils.

Fertile luvisols are found in alluvial valleys, particularly in the Chi-Mun River Basin in northeast Thailand, in northern Thailand, the Tonle Sap Basin and southern and central Lao PDR. Small but important pockets of these fertile soils are also found adjacent to small rivers and streams in the northern uplands of Lao PDR, where lowland rice can be cultivated, taking an enormous pressure off the upland areas. Also fertile ferralsols and vertisols are found in regions with a volcanic history: on the Bolaven Plateau in southern Lao PDR, the mid and upper part of the Se San and Sre Pok catchments in eastern Cambodia and Viet Nam, and along the Mekong River corridor itself in southern Cambodia. Steep terrain in northern Thailand and along the cuestas (escarpments) that rim the Khorat Plateau in northeast Thailand have not been surveyed for soil type and is marked as 'slope complex' on the map. Shallow soils underlain by bedrock (leptosols) are common in lowland areas of the Chi-Mun catchment in northeast Thailand and extensively in highland areas in southwestern Cambodia. These soils are particularly susceptible to erosion. Gleysols, soils that form in wetlands and seasonally inundated areas are the dominant soil type in the Mekong River delta and within the wet season inundated area of Tonle Sap Lake.

Soil type	Description	Area (km²)	Percent of LMB area	Percent coverage of country area (%)			
				Cambodia	Lao PDR	Thailand	Viet Nam
Acrisol	Clay rich soil with high acidity and low fertility developed in areas of intense weathering.	369,760	59.7	55.33	69.09	61.48	35.63
Cambisol	Soils with the beginnings of horizon differentiation in the subsoil. Generally low in clay, organic matter and Al/Fe compounds.	64,430	10.4	11.86	20.58	0.46	3.28
Gleysol	Wetland soils that are saturated with groundwater for long periods.	47,549	7.7	9.49	0.14	3.63	38.17
Slope Complex	Steep terrain (>35% slope), soils have not been surveyed.	29,423	4.7	-	-	15.64	-
Luvisol	Soil with a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (clay migration). Clay in subsoil is highly-active.	21,152	3.4	2.46	2.67	6.24	-
Leptosol	Shallow soil over bedrock or soil that is extremely gravelly and/or stony, common in mountains regions.	18,794	3	8.03	2.52	0.01	1.45
Ferralsol	Deeply weathered red to yellow soil rich in iron and aluminium; form in humid tropical climates.	14,584	2.4	3.71	0.83	0.44	9.28
Arenosol	Sandy soil with limited profile development	13,608	2.2	1.58	0.12	5.57	0.59
Fluvisol	Young soils developed in alluvial deposits: flood plains of in river valleys but also lake and marine deposits.	9,730	1.6	0.87	0.2	1.5	7.66
Total		589,030	95.1	93.3	96.2	95.0	96.1

Table 7 Description and coverage of the nine major soil types in the lower Mekong Basin and each of the four riparian countries.

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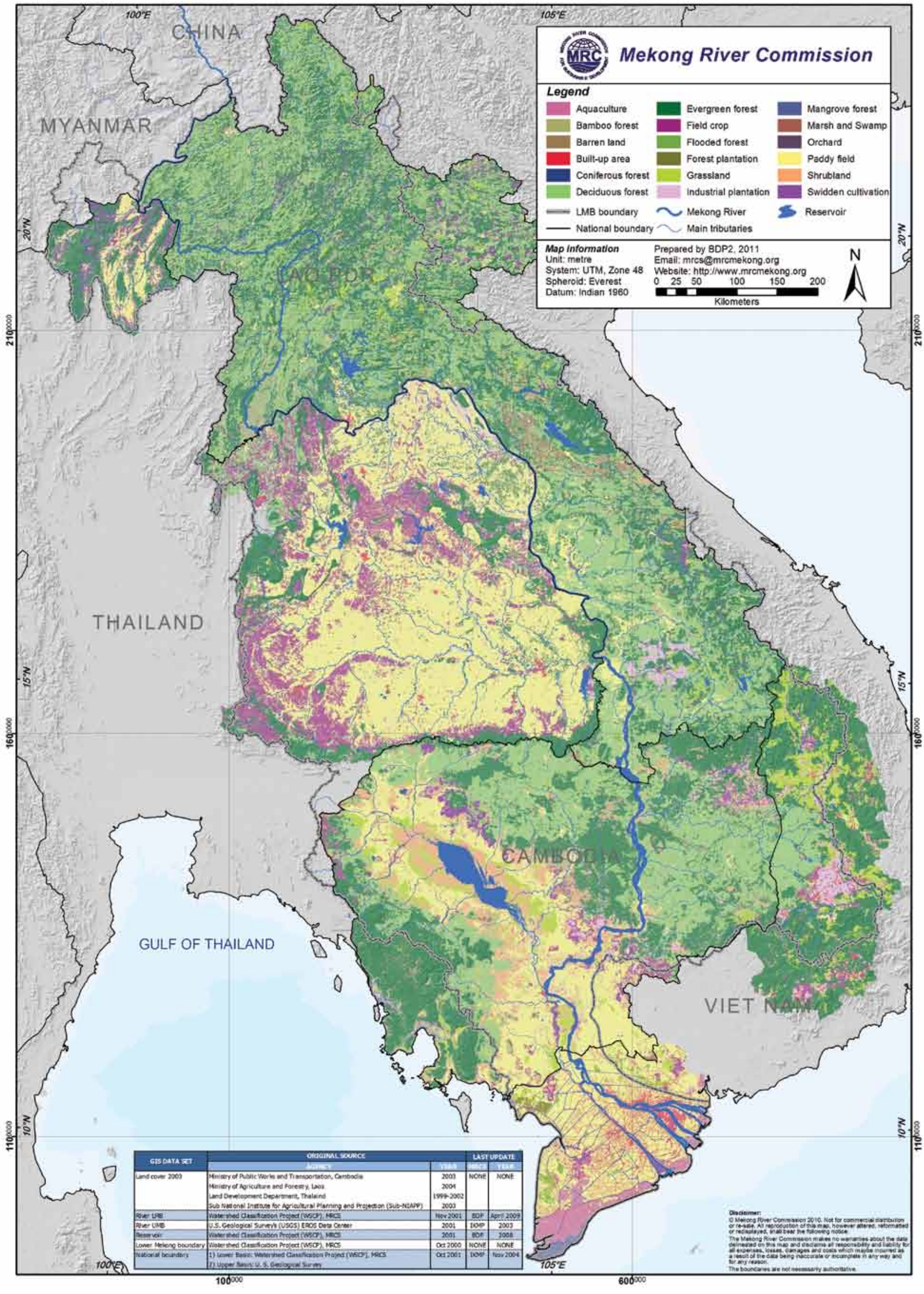
Land cover 2003



3.3 Land Cover 2003

Land-use in 2003 has been classified from satellite imagery with field verification, as undertaken by individual countries in 2002-2003 and compiled by the Food and Agriculture Organisation (FAO). Land use can be broadly divided into three major components: paddy, forested land and land cultivated for field (cash) crops. More recent satellite imagery from 2009 is currently been analysed by the MRC but was not available at the time of publication of this Atlas.

Lowland rice paddy production (yellow colour on map) covers 24% of the LMB area, dominating the vast low-lying alluvial plains of the Chi-Mun Basin in northeast Thailand, the Vientiane plain in Lao PDR, the Tonle Sap Basin in Cambodia and the delta in southern Viet Nam. Narrower river valleys in northern Thailand and central and southern Lao PDR are also utilised for paddy. Smaller paddy areas adjacent to rivers and streams in northern Lao PDR are too small to map but are nonetheless highly economically important in the otherwise steep topography of northern Lao PDR. The gently sloping upland areas of the Chi-Mun Basin are extensively cultivated with field (cash) crops as marked by the purple shading. Fertile soils in areas with a volcanic history: the Bolaven Plateau in southern Lao PDR, in isolated pockets throughout Cambodia and the upper catchment of the Sre Pok River in Viet Nam, are also utilised for field crops such as coffee and industrial plantations.

The large majority of Lao PDR and Cambodia is covered by forest, a mixture of evergreen and deciduous forest types. However, this land-use map does not differentiate between primary and secondary forests nor does it indicate forest crown density. In many parts of Lao PDR, much of the classified forest areas have very low crown density due to logging, shifting agriculture or other disturbances. In 2002, dense forest cover was lowest in the north (27.9%), 46.1% in the central region and highest in the south (56.5%) (GOL, 2005). The extensive coverage of deciduous forests is an adaptation to low water availability during the long annual dry season and probably also low limited groundwater storage in surface aquifers.

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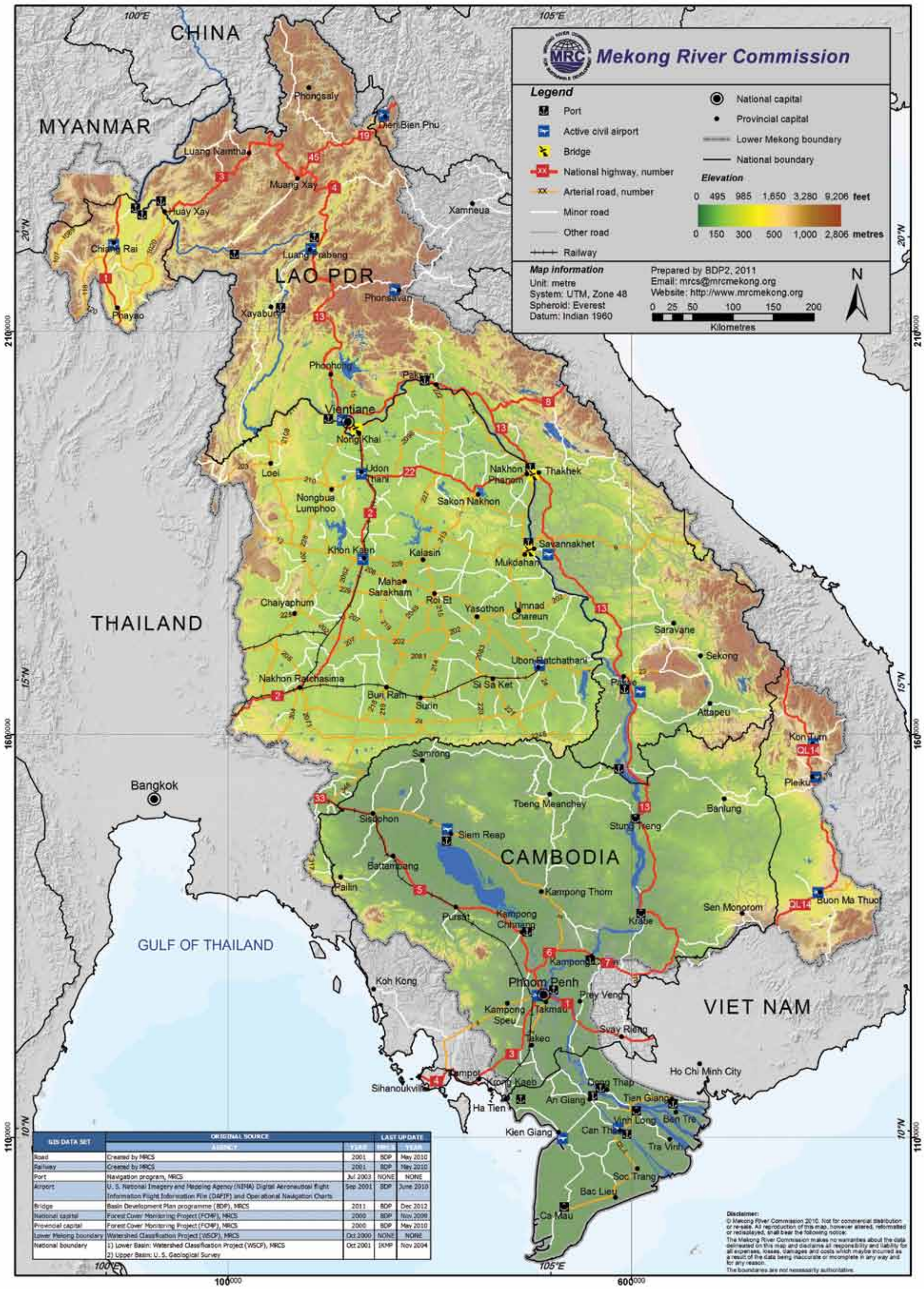
Transportation



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Road	Created by MRCS	2001	BDP	May 2010
Railway	Created by MRCS	2001	BDP	May 2010
Port	Navigation program, MRCS	Jul 2003	NONE	NONE
Airport	U. S. National Imagery and Mapping Agency (NIMA) Digital Aeronautical flight Information Flight Information File (DAFIF) and Operational Navigation Charts	Sep 2001	BDP	June 2010
Bridge	Basin Development Plan programme (BDP), MRCS	2011	BDP	Dec 2012
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004

3.4 Transportation

Whilst the natural focus of MRC is on the water and water-related resources of the Mekong River Basin, many sectoral activities within the basin are influenced by externalities arising from outside the basin. Transportation is one such sector. Transport is an essential foundation to economic development. Farmers, fish producers, manufacturers, traders and consumers rely on access to markets to buy and sell their goods. Businesses and tourism prosper only if good transport and communication links are available. Transportation networks within the basin must be linked to centres outside the basin.

The Asian Development Bank undertook an important study in 2004 to develop a clear vision and comprehensive strategy for development of a transport network within the Greater Mekong Sub-region (GMS). The GMS comprises Cambodia, Yunnan Province and Guangxi Zhuang Autonomous Region of PR China, Lao PDR, Myanmar, Thailand and Viet Nam. The study was aimed at promoting sub-regional connectivity and competitiveness, towards an eventual GMS-wide multimodal transport system. The study recognised 12 important corridors in which transport links need to be developed (see map). These included the development of an integrated network of road, rail, air and water borne transport systems.

Existing and Proposed GMS Corridors

For the MRC, the main form of transport of interest is water-borne transport, referred to as "navigation" by MRC, which it views as potentially important but largely undeveloped as an integrated transport sector. The Mekong River has provided a means of transportation for thousands of years. Transportation on the river is presently segmented by natural barriers. Sea-going vessels up to 5,000 deadweight tonnes entering from the South China Sea can only travel slightly upriver from Phnom Penh, with the Sambor Rapids and Khone Falls hindering travel upstream into Lao PDR. Upstream of Phnom Penh, inland barge size is entirely dependent on the season, with access in the dry season between 50 and 300 tonness, and in the wet season between 150 and 400 tonness.

The main obstacle to river transport between Phnom Penh and the South China Sea has been a lack of proper all-weather and night time navigation aids. This situation is now being rectified by the MRC's Navigation Programme (NAP) with the installation of channel markers, buoys, beacons and shore marks. Plans are also under consideration to dredge and widen the Bassac River (a major branch of river in the Mekong Delta) to allow 10,000 to 20,000 tonne ships to transit Tra Vinh Province (Viet Nam).

Navigation of the Lancang Jiang, as the Mekong is known in China, began in 1990 when China deployed five barges on a mission to chart the river downstream to Vientiane. China has since initiated a program of dredging and removal of rapids, reefs and shoals. China expects Xiaowan, Manwan and other Lancang hydro-electric dams will stabilize downstream water levels, decrease currents and increase depth of the river which will all improve navigability, notwithstanding the decreases observed during initial reservoir filling. The goal is to eventually enable vessels of 500 DWT to ply between Simao in Yunnan and Luang Prabang, Lao PDR, with some twelve other ports in between. However, critics contend that the destruction of natural rapids, reefs and shoals will impact negatively on the many species of fish which depend on these habitats for essential parts of their lifecycles. Plans to canalize the route will only further modify the river's natural flow regime. Increased river traffic also raises the risk of greater pollution.

Thailand has responded to increased river trade by improving facilities at Chiang Khong and construction of a new port at Chiang Saen, now known as Chiang Saen 2. Myanmar and Lao PDR have also increased their efforts to benefit from growing river trade. Myanmar's Wan Seng and Wan Pong ports are already entry points for Chinese goods. China's Xishuangbanna Petroleum Company recently signed an MOU with a Lao company to import diesel and gasoline via Lao PDR, and it is speculated that the village of Xiengkok will be transformed into a modern port.

Rapid regional economic growth in the Mekong region, combined with national strategic interests and expanding commercial opportunities and investments, are driving developments on the Mekong River. Efficient transport of goods and materials is vital to sustaining growth, and the demand for water-borne transport is likely to increase, along with other transport forms, such as road and rail. Predicting future navigation requires not only a regional perspective of multi-modal transport demand growth but also prudent balancing of competing demands on the river to ensure acceptable environmental and socio-economic outcomes.

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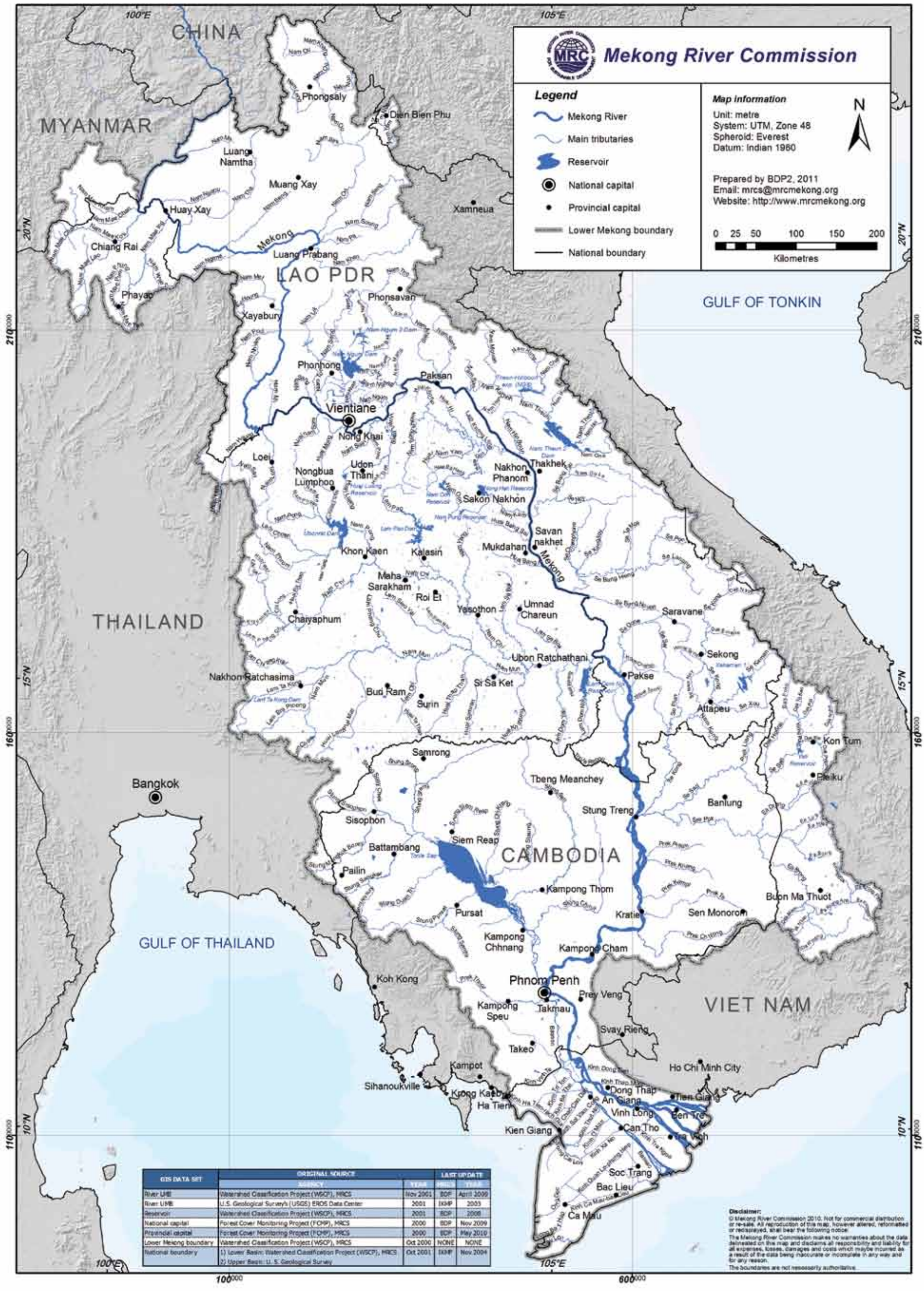
4 Water Resources

Rivers


Mekong River Commission
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Mekong River
Main tributaries
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Email: mrcs@mrcmekong.org
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Muang Xay
Huay Xay
Xamneua
Chiang Rai
Luang Prabang
Phayao
Phonsavan
Xayabury
Phonhong
Paksan
Vientiane
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Loei
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Nongbua Lumphoo
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Kampong Chhnang
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Koh Kong
Phnom Penh
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Takmau
Svay Rieng
Takeo
Kampot
Ho Chi Minh City
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Vinh Long
Ben Tre
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2) Upper Basin: U. S. Geological Survey
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4.1 Rivers

This map illustrates the drainage pattern of the Lower Mekong Basin including the path of the Mekong River and the drainage networks of major and minor tributaries. Small streams that branch off the tributary rivers are not shown for the purpose of clarity. The longest tributaries are the Mun and Chi rivers in northeast Thailand, the Nam Ou in northern Lao PDR, and the Se Kong, Se San and Sre Pok rivers in the southern part of the basin.

There is a wide variety of drainage patterns in the LMB, including simple dendritic tributary networks that resemble a branching tree (e.g. the Chi and Mun rivers in northeast Thailand), very straight rivers (e.g. Nam Beng in northern Lao PDR) and a variety of irregular patterns characterised by rivers with abrupt changes in course, 90° turns and even u-turns). These drainage patterns reflect different geological settings and tectonic influences on the landscape (Twidale, 2004). Dendridic (tree-like) drainage patterns form where the underlying geological structure is fairly homogeneous and stable. Many of the large river systems such as the Amazon, Congo and Mississippi have dendritic drainage patterns (MRC 2010d). The high sinuosity (meandering nature) of the Nam and Chi rivers in these stable alluvial basins is a result of the low lying topography, whereby rivers increase their length in order to reduce their gradient. Very straight or irregular drainage patterns reflect highly heterogeneous geology, river displacement by lava flows or the influence of tectonic processes which have altered the path of rivers. Some rivers have cut paths conforming to pre-existing structures.

Straight rivers often indicate the presence of an underlying fault or fold axis, which locks in the path of the river. Volcanic regions such as the Bolaven Plateau often exhibit radial drainage patterns, ones that radiate outward from the ancient volcanic eruption centre. The curved arc shape of the Se Done River in southern Lao PDR is a good example of a river deflected by lava flows on the Bolaven Plateau (see Map 3.1). The Nam Kading – Nam Thuen river system in central Lao PDR is characterised by straight reaches separated by abrupt bends and smaller tributaries often enter the main rivers at 90° angles. These rivers are probably following the strike and dip of folded terrain in that region. A number of the rivers flow through limestone karst landscapes and some even flow underground through caves along a portion of their path, such as the Nam Hinboun, Nam Ou, Nam Song.

The Mekong itself exhibits a range of patterns along its course. In the north, long straight reaches are separated by abrupt changes in course (e.g. the u-shaped bend near Luang Prabang) as the river follows the regional structural grain (i.e. the orientation of regional folding of the land surface and underlying geological starta). The very tight s-shaped turn in the far north upstream of Huay Xai is the result of movement along a slip-fault, first in one direction and later in the opposite direction (Burnhill In Review). In its middle reaches, the Mekong is an alluvial channel but its path is nonetheless constrained by structural features of the Khorat Plateau.

The narrow winding bedrock reach between Savannakhet and Pakse corresponds with the Mekong's path across the Phu Phan Uplift (see Map 3.1) and edge of the Khorat Plateau, which comprise of a series of fold structures where resistant sandstones are exposed at the land surface. The anabranching (split-channel) reach in southern Laos and northern Cambodia has probably evolved due to incision of the Mekong into the underlying heavily fractured and faulted terrain (Carling 2009b; Meshkova and Carling In Press), which often results in such terrain as rivers carve multiple parallel channels exploiting multiple lines of weakness in the rock (Tooth and McCarthy 2004). Downstream of Kratie, the Mekong is once again an alluvial channel but its path is guided by several volcanic areas. It is not until Kampong Cham that the Mekong is free to migrate across the floodplain.

The aquatic habitats and ecology of the Mekong tributaries are defined by the underlying geology and topography of the catchments and the characteristic hydrology of each tributary. In 2009, MRC initiated some studies to determine the significance of the tributaries from different perspectives – their contribution to the hydrology of the Mekong, significance of sediment transport, aquatic and terrestrial ecology and biodiversity, fisheries, social significance and uses such as hydropower and navigation (MRC, 2009).This initiative will provide a basis for identifying the key assets of the tributaries. A classification of the river ecosystems of the Mekong tributaries has also been undertaken by WWF (Sindorf and Dang, 2011) as a means of understanding the importance of the connectivity between the Mekong River network.

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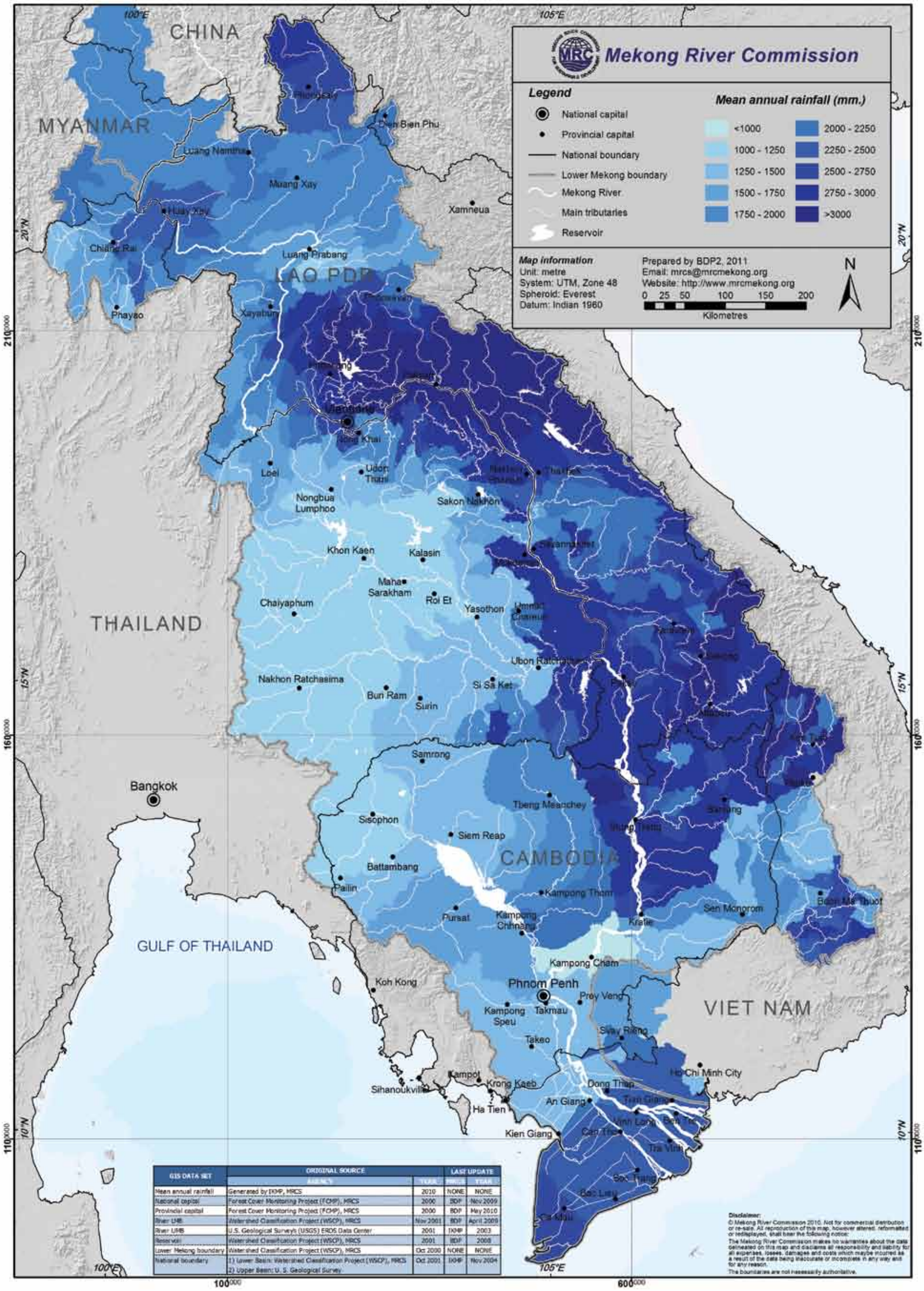
Mean annual rainfall



4.2 Mean Annual Rainfall

The distribution of mean annual rainfall over the Lower Mekong Basin is highly variable, ranging from more than 3000 mm in north-central Lao PDR to less than 1000 mm in much drier areas of northeast Thailand. This map has been produced by interpolating between rainfall measurements stations (Map 7.1), which are located in most provincial centres and some district centres and for which a long time series of daily rainfall measurements is available (typically 20-50 years).

The distribution of rainfall is primarily driven by topography and the general approach direction of the southwest monsoon and isolated tropical cyclones from the northeast across the South-China Sea and Viet Nam. Areas of very high rainfall in excess of 2500 mm (found in north-central Lao PDR and the headwaters of the Se Kong and Se San Rivers in southern Lao PDR, Cambodia and Viet Nam) generally correspond to the areas of the highest elevation along the Annamite Range (see Map 3.1). As the southwest monsoon and tropical storms approach the eastern part of the Basin from the northeast, rainfall is generated due to the forced upward movement of air over the mountains.

Mean annual rainfall decreases to the west away from the mountains, with a clear east-west rainfall gradient evident in the Chi-Min Basin in Thailand and the Tonle Sap Basin in eastern Cambodia. Rainfall is also generally low (<1750 mm) around Phnom Penh and the upper Delta in Viet Nam, but increases to 2250-2500 mm in the lower delta and up to 2750 mm on the Ca Mau peninsula, where the influence of typhoons is greater.

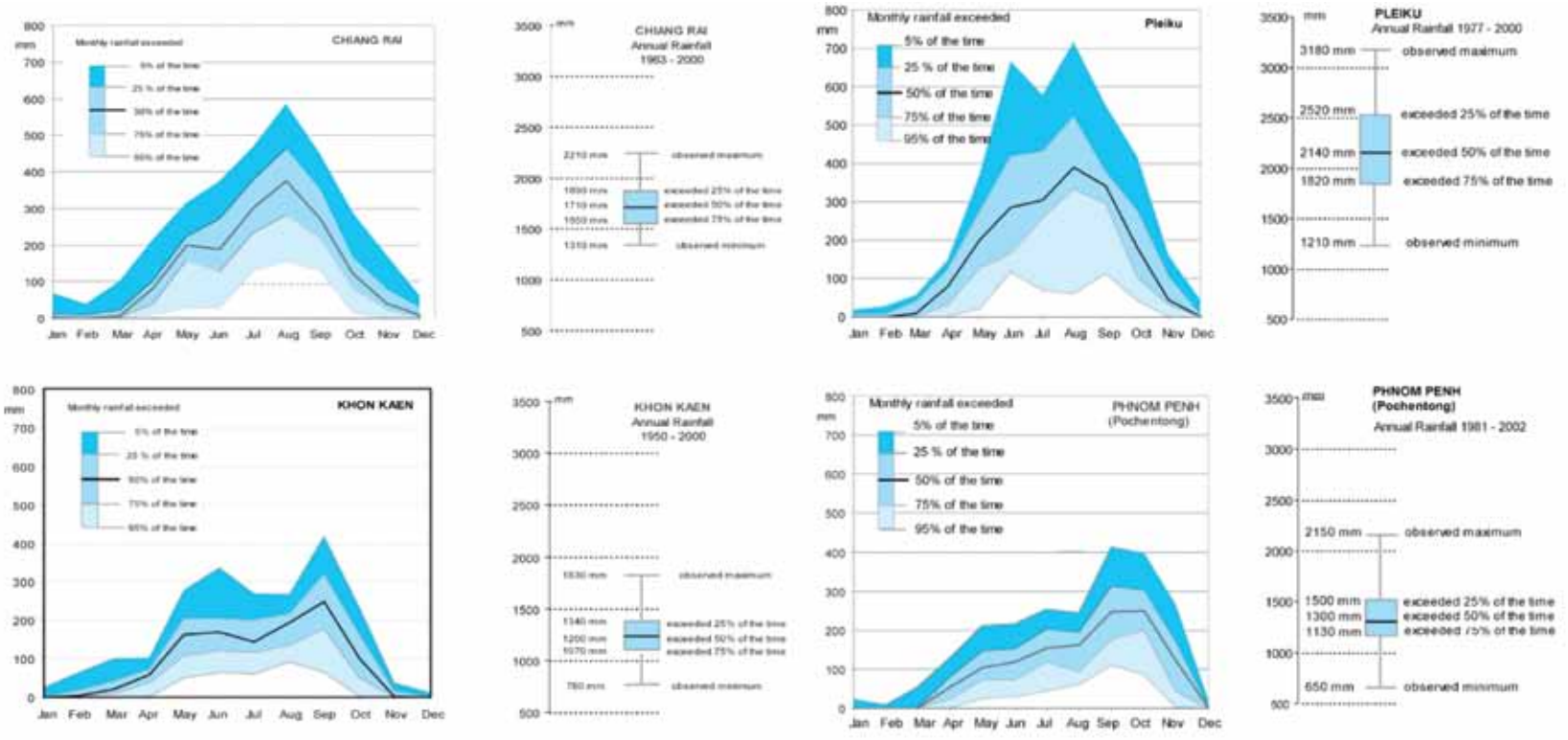
In the more temperate northern regions of Lao PDR and Thailand, rainfall is generally lower than the central highlands, but is also highly variable, ranging from 1000 mm just south of Luang Prabang to 2250-2750 mm in Phongsaly Province (headwaters of the Nam Ou River). The high variability in rainfall is due to local topographic influences.

The seasonal and inter-annual variations in rainfall at selected gauging stations in different parts of the Lower Mekong Basin are illustrated in the figure below and described in detail in (MRC 2005) . The graphs on the left plot the distribution of rainfall through the year including the median monthly rainfall and the variation of monthly rainfall from year to year over the 20-50 year observation period. On the right are box plots showing the variation of total annual rainfall over the observation period at each representative station.

The key trends in these graphs as described by MRC (2005) include:

- The highest rainfall occurs in July, August and September in most of the Basin, however there is a shift to later in the wet season in Cambodia and the delta where September and October are the wettest months.
- Monthly rainfall in the wet season and annual rainfall are most variable in the northern regions (Chiang Rai), Mekong lowlands (Pakse) and central highlands (Pluiki) where mean annual rainfall is greatest.
- A double peak of rainfall during wet years at Pakse in the Mekong lowlands and at Pluiku in the central highlands in Viet Nam. This second peak in rainfall late in the wet season is due to the action of tropical cyclones that develop in the South-China Sea during some years.

Figure 5 Distribution and range of annual and monthly rainfall at selected stations (MRC 2005).



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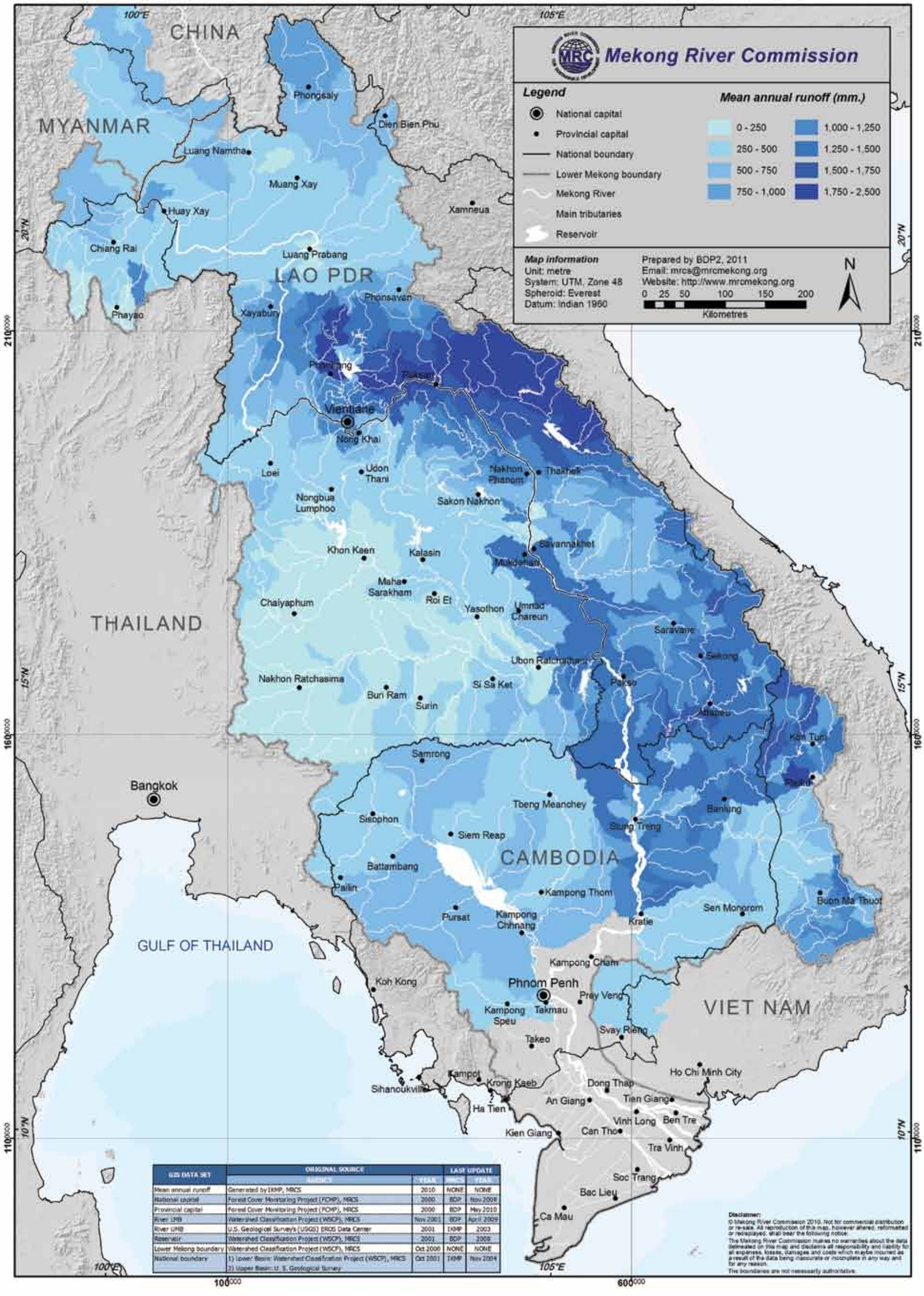
Mean annual runoff



4.3 Mean Annual Runoff

Runoff refers to water flow in streams and rivers expressed on a per unit area basis. It represents the proportion of rainfall that leaves the catchment as stream flow, with the remaining portions being stored in soils and groundwater aquifers or exported from the catchment through evapotranspiration. Mean annual runoff is reported as a depth and is calculated by dividing the mean annual stream flow (discharge) of a particular river by its catchment area.

The distribution of mean annual runoff in the Lower Mekong Basin closely reflects the spatial patterns in rainfall described for the previous map, but is also affected by topography, soil texture and vegetation type and density. In the case of topography, flatter catchments such as the Chi-Mun basin in northeast Thailand, will tend to have higher evaporation rates in part, due to the longer time taken for rainfall to reach streams, meaning that only between 25% and 50% of rainfall leaves the catchment as streamflow (Adamson and Tospornsampan 2008). Much higher proportions of rainfall (up to 75%) are translated into streamflow in steeper catchments, including the left bank tributaries of the Mekong in southern and central Lao PDR.

Of these steep and wet left bank tributaries, the Nam Ngum and Nam Kading-Nam Thuen catchments produce the greatest runoff of up to 2500 mm per year. This translates to about 6% of the total flow of the Mekong River for each catchment as shown in Figure 6 below. This graph plots catchment area versus the percentage flow contribution to the Mekong River total. The Mun-Chi and Tonle Sap basins, despite having much larger catchment areas each contribute similar proportions of between 5% and 6%, which reflects the combined effect of lower rainfall and greater evaporation rates, hence generally low runoff per unit catchment area.

The six major left bank tributaries entering the Mekong River between Vientiane and Nakhon Phanom together contribute 19% of the total mean annual flow (MRC 2005). The other major contributor is the Se Kong - Se San – Sre Pok basin which contributes 17% to the total annual flow of the mainstream. The large area of this catchment means that runoff is slightly lower than the Nam Ngum and Nam Kading-Nam Thuen catchments. Overall, the left bank tributaries of the Mekong River contribute 60% to the total flow of the Mekong compared to 24% for the right bank tributaries (Table 8). This can be attributed to the general trend for higher rainfall and steeper topography in the east of the Basin.

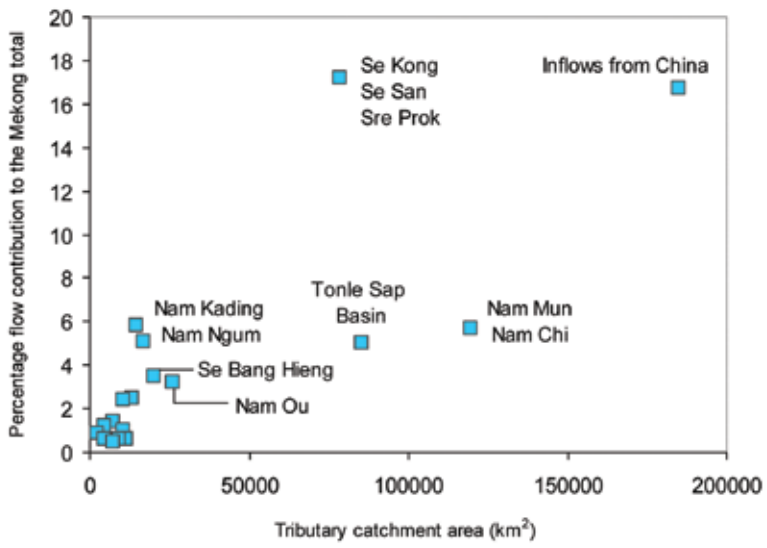


Figure 6 Percentage contribution of the major Mekong tributary systems to mainstream annual flow, as a function of catchment area (Adamson and Tospornsampan 2008).

River reach	Left bank (%)	Right bank (%)	Total (%)
China	16		16
China-Chiang Saen	1	4	5
Chiang Saen – Luang Prabang	6	3	9
Luang Prabang – Chiang Khan	1	2	3
Chiang Khan – Vientiane	0	0	0
Vientiane – Nong Khai	0	1	1
Nong Khai – Nakhon Phanom	19	4	24
Nakhon Phanom – Mukdahan	3	1	4
Mukdahan – Pakse	5	6	11
Pakse – Stung Treng	23	3	26
Stung Treng - Kratie	1	0	1
Total	60	16 24	100

Table 8 Flow contributions from tributaries entering the Mekong mainstream in various reaches (MRC 2005).

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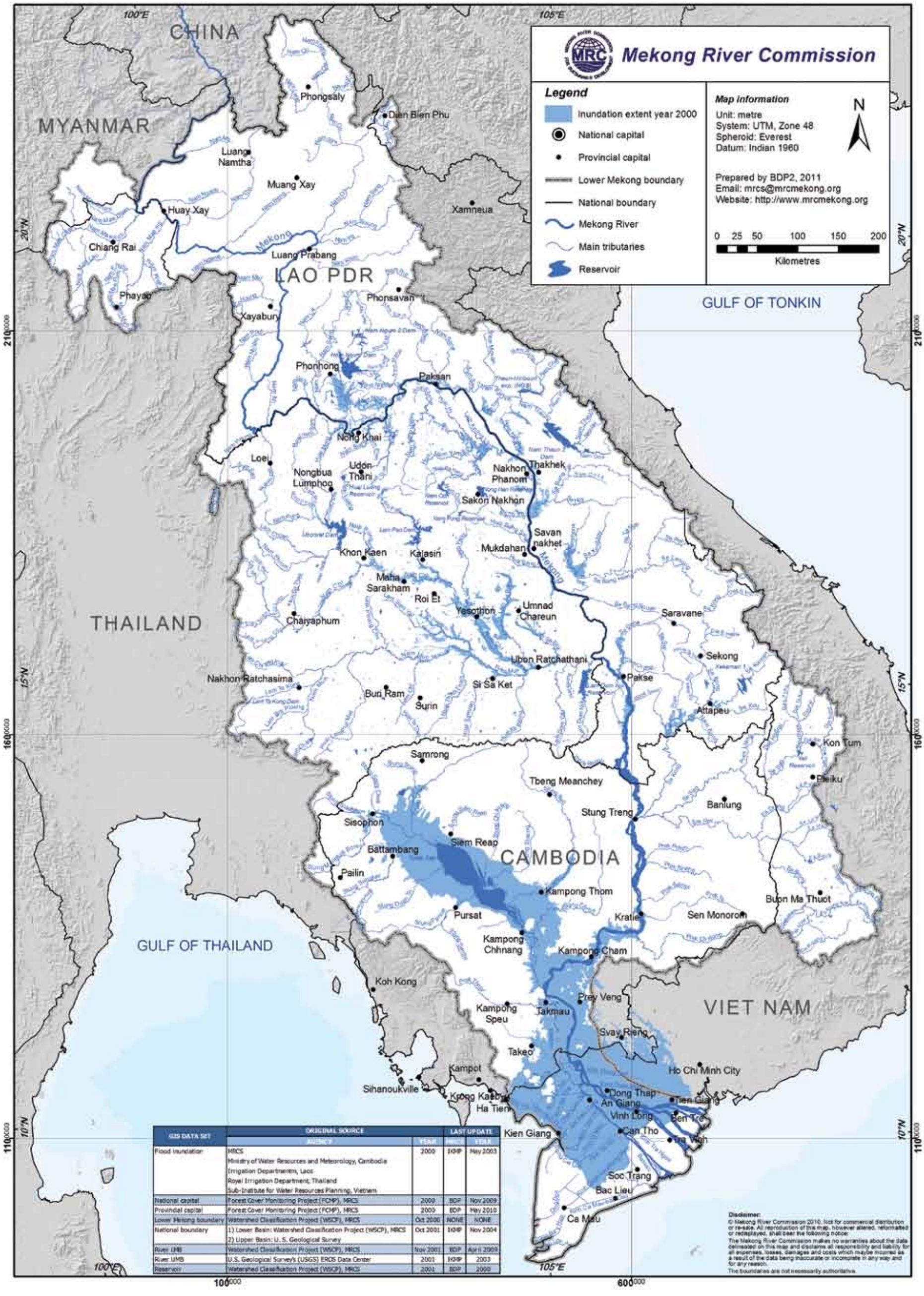
Flood inundation 2000



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	AGENCY	YEAR
Flood inundation	MRCS Ministry of Water Resources and Meteorology, Cambodia Irrigation Departments, Laos Royal Irrigation Department, Thailand Sub-Institute for Water Resources Planning, Vietnam	2000	IKMP	May 2003
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2000

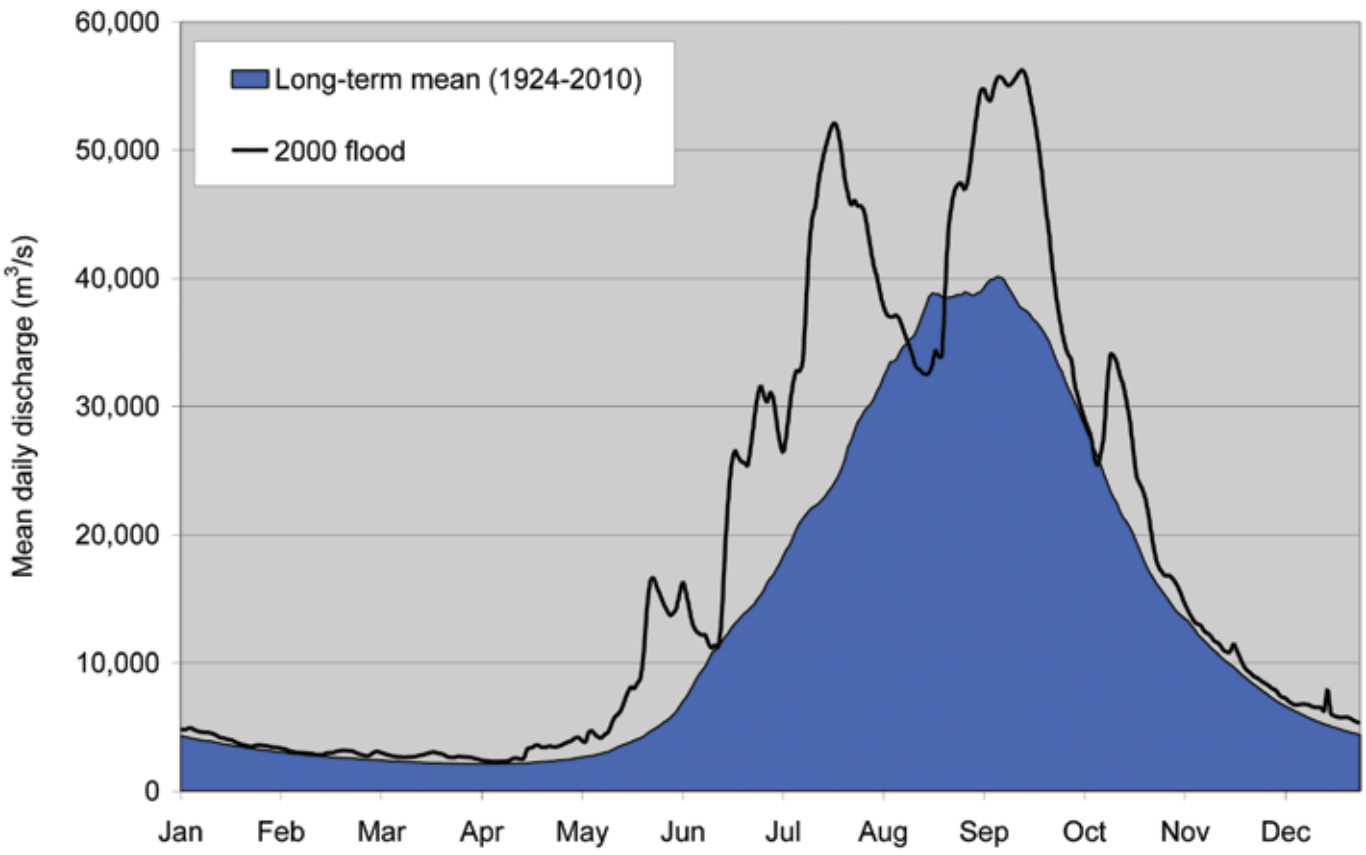
4.4 Flood Inundation 2000

The three consecutive wet seasons between 2000 and 2002 were marked by large floods in the middle and lower reaches of the Lower Mekong Basin. This map illustrates the maximum extent of inundation during the 2000 flood event, the most severe in terms of area inundated in over 70 years (MRC 2005). The peak discharge at most gauging mainstream stations during 2000 was close to average. However, the flood volume was extreme – almost 500 km^3 at Kratie, which corresponds to an average recurrence interval of 1:50 years (MRC 2005).

The large flood volume was caused by the early onset of the monsoon and associated early rise in the annual flood hydrograph by a month to six weeks. This caused saturation of soils in catchments and natural wetlands earlier than usual, such that subsequent rainfall and floodwaters arriving from upstream had nowhere to drain, causing extensive inundation of areas that do not usually flood. This was exacerbated by tropical storms from the South China Sea later the season in August-September-October that resulted in heavy rainfall in Viet Nam.
The most severally affected areas were in the low lying floodplains in southern Cambodia and the upper delta in Viet Nam where hundreds of people lost their lives. It should be noted that most of the inundated area around Tonle Sap Lake during 2000 is usually inundated under average wet season conditions.

Extensive inundation also occurred in the Chi-Mun basin and the lower parts of most tributaries entering the Mekong between Vientiane and Pakse. Flood volumes in these middle reaches of the Mekong River were also extreme, corresponding to between 1:5 and 1:20 year recurrence intervals at various stations (MRC 2005). The extent of inundation in the middle reaches however was not as large as in the Cambodian lowlands and delta due to generally steeper topography and because the Mekong River is incised into the floodplain in its middle and upper reaches (Carling 2009b). The incised nature of the River at these locations means that it rarely overtops its banks, which in turn causes large floods to be transmitted further downstream, exacerbating inundation of low lying areas downstream in Cambodia and the delta. The inundation of the lower reaches of tributary catchments between Vientiane and Pakse was caused by the high water levels in the Mekong mainstream, which caused Mekong floodwaters to back-up into the tributaries and prevented tributary floodwaters from draining downstream.

Figure 7 The 2000 flood hydrograph at Kratie compared to mean daily discharges for the period 1924-2010. While the flood peak during 2000 of 56 000 m^3/s was only marginally above the long term average annual maximum flow of 52 000 m^3/s, the seasonal volume of floodwater was the highest on record (470 km^3).



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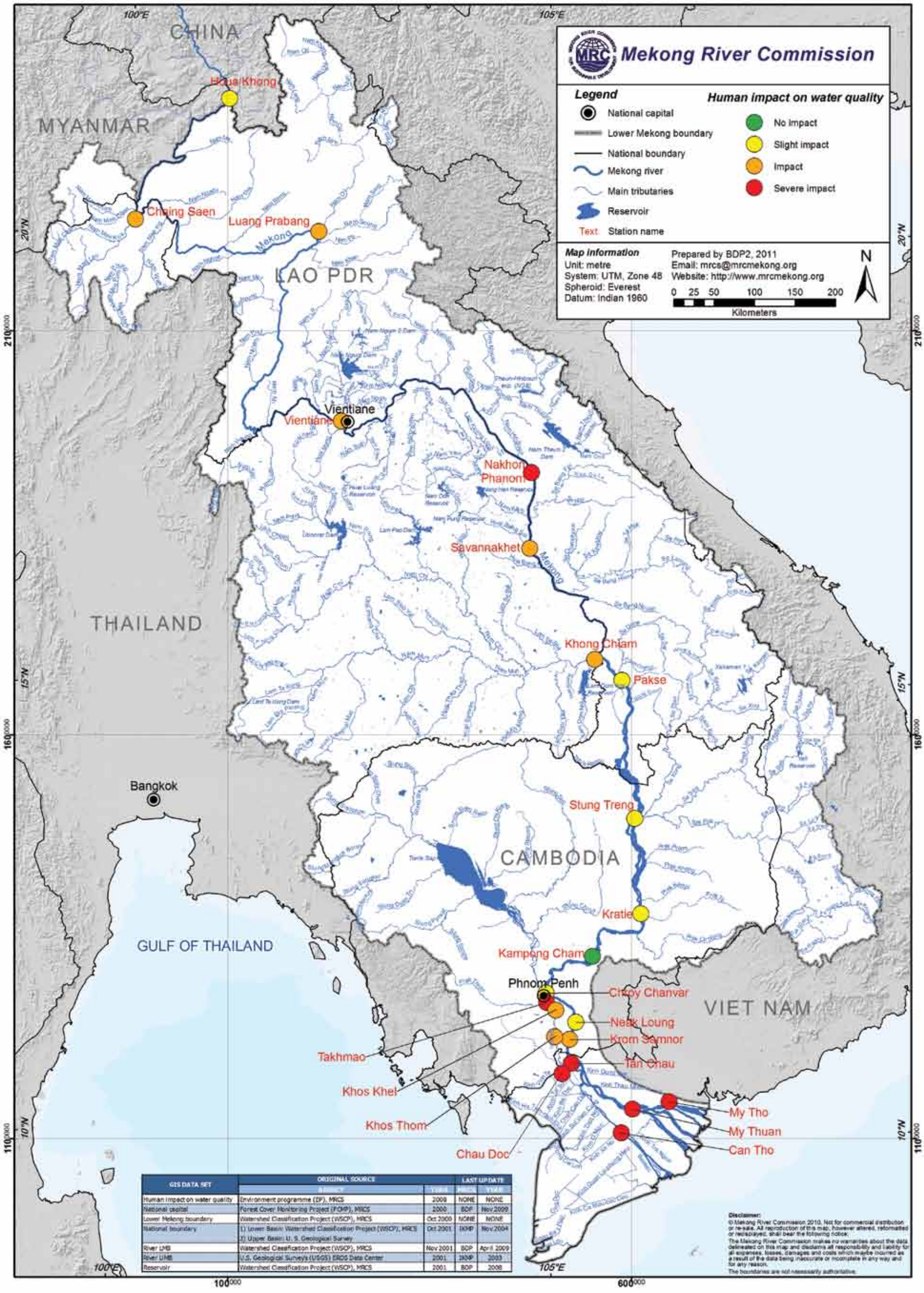
Human impact on water quality



4.5 Human Impact on Water Quality

The Water Quality Monitoring Network (WQMN) of the Lower Mekong Basin was established in 1985 and now includes regular monthly or two-monthly measurement of 11 water quality parameters at 48 permanent stations on the Mekong River mainstream and important transboundary tributaries (MRC 2008a, c, 2010c). In recent years, 17 key mainstream stations have been assessed on an annual basis for 'Human Impact on Water Quality' which is reported in this map for the year 2008 (MRC 2010c).

Classifications of 'Human Impact on Water Quality' range from 'no impact' to 'severe impact' and are based on a Water Quality Index calculated from measurements of four key parameters throughout the year at each station. These four key parameters, which are listed in Table 9, are considered to be key indicators of pressure exerted by human activities on water quality and hence also the health of aquatic life in the Mekong River. If the measured parameter value meets the guideline value (Table 9) then it is given a rating of two points, if it fails the rating is zero points. The rating points are averaged over all four parameters and all sampling days during each year to derive a final Water Quality Index score for each station (MRC 2010c). Higher index scores indicate good water quality and 'No impact', while low values indicate poor quality and are classified as 'Severe Impact' (Table 10).

According to the map which illustrates the situation in 2008, the degree of impact of human activities on water quality was low (A - no impact) at only one station (Kampong Cham in Cambodia). At six stations human activities had 'slight impact', and more considerable impact (C – impact) at six stations, located mostly in the middle reaches of Mekong in Thailand and Lao PDR. The four stations at which human activities where having severe impact (D) on water quality are located in the delta in Viet Nam (three stations) and at Nakhon Phanom located further upstream of the Thai – Lao border. Sources of pollution include domestic and industrial waste, agricultural runoff and mining activities. The severe impact on water quality in the Delta is probably the result of high population density in the Delta and around Phnom Penh city, located upstream in Cambodia (see Map 2.2 on population density). High population density and the large number of urban areas results in increased municipal wastewater discharge to the Mekong and Bassac rivers. Table 11 below describes the history of 'Human Impact on Water Quality' ratings for 17 key mainstream stations between the year 2000 and 2008 as reported in the most recent Report Card on Water Quality (MRC 2010c). The table shows a clear trend of increasing human impact and declining water quality during this nine year period at all stations.

Table 9 Water quality parameters used in the classification system for 'Human Impact of Water Quality'

Parameter	Guideline value (mg/L)
Dissolved Oxygen	≥ 6
Chemical Oxygen Demand	< 4
Ammonium	< 0.05
Total Phosphorus	< 0.08

Table 10 Classification system for 'Human Impact on Water Quality'

Class	WQI Rating Score
A – No Impact	10 ≥ WQI ≥ 9.5
B – Slight impact	9.5 > WQI ≥ 8.5
C – Impact	8.5 > WQI ≥ 7
D – Severe Impact	WQI < 7

Table 11 History of 'Human Impact of Water Quality' ratings at 17 Mekong River mainstream stations 2000-2008 (MRC 2010c)

No.	Station Name	Country	Class								
			2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Houa Khong	Lao PDR	ND	ND	ND	ND	B	C	B	B	B
2	Chiang Saen	Thailand	B	B	B	C	B	C	C	B	C
3	Luang Prabang	Lao PDR	B	B	B	C	D	C	B	C	C
4	Vientiane	Lao PDR	B	C	B	C	C	C	B	C	C
5	Nakhon Phanom	Thailand	C	B	B	B	D	C	D	C	D
6	Savannakhet	Lao PDR	ND	B	B	B	B	C	C	C	C
7	Khong Chiam	Thailand	C	B	B	C	D	B	C	B	C
8	Pakse	Lao PDR	B	B	B	B	C	B	B	B	B
9	Stung Treng	Cambodia	ND	ND	ND	ND	ND	C	B	B	B
10	Kratie	Cambodia	B	A	A	A	A	C	B	B	B
11	Kampong Cham	Cambodia	B	C	B	A	A	B	B	B	A
12	Chroy Chanvar	Cambodia	B	B	A	A	A	B	B	C	B
13	Neak Loung	Cambodia	B	B	A	A	B	C	C	C	B
14	Krom Samnor	Cambodia	ND	ND	ND	ND	ND	C	B	B	C
15	Tan Chao	Viet Nam	C	B	C	B	B	D	D	C	D
16	My Thuan	Viet Nam	B	B	C	C	C	C	D	D	D
17	My Tho	Viet Nam	ND	B	C	B	D	C	D	D	D

Note: ND: No data

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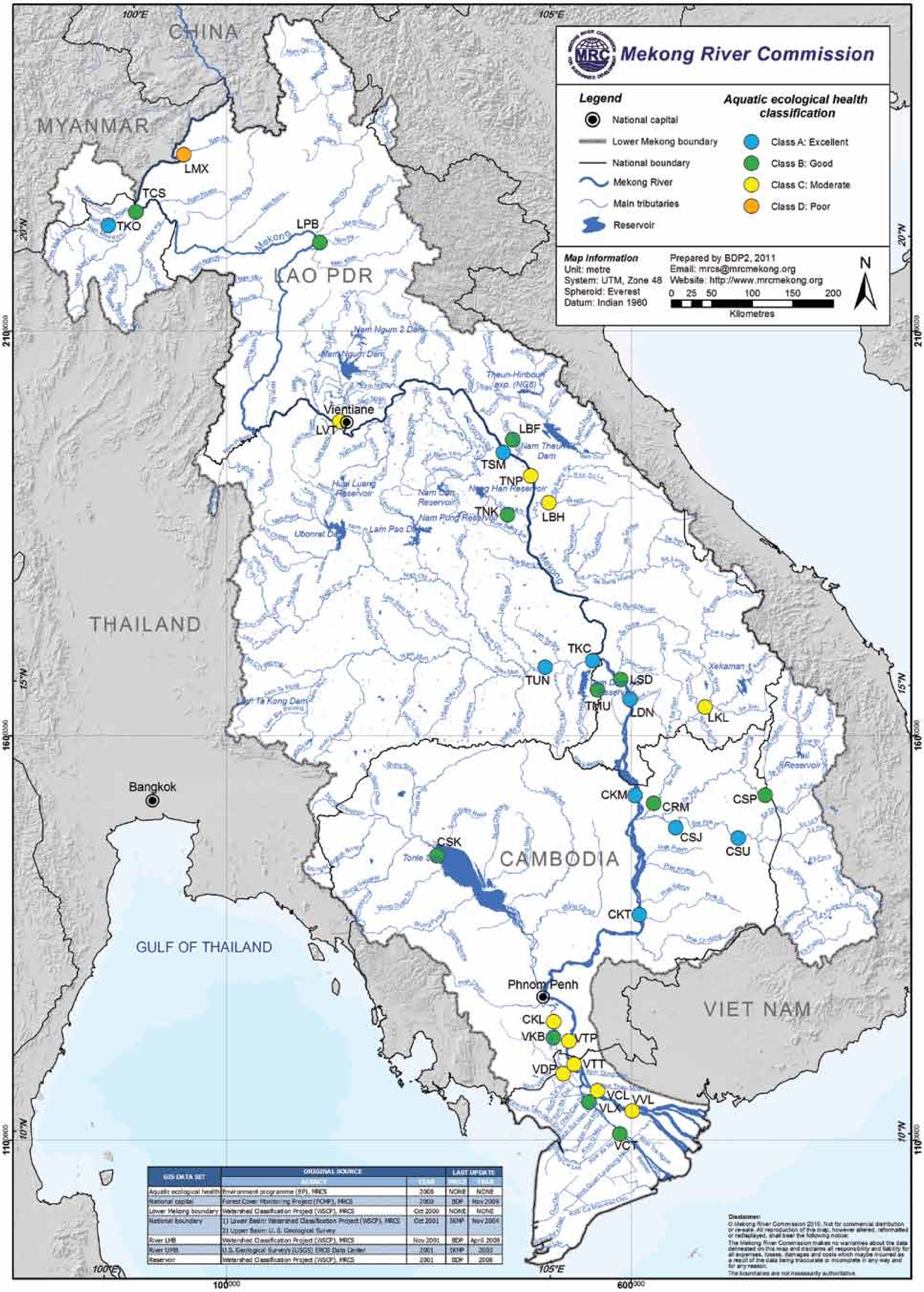
Aquatic ecological health



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	[illegible]	YEAR
Aquatic ecological health	Environment programme (EP), MRCS	2008	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2009	BDP	Nov 2009
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

4.6 Aquatic Ecological Health

Water quality measurements indicate the chemical characteristics of river water at a point in time, however they may not capture episodic or intermittent pollution, which may have lasting impacts on the health of aquatic organisms. A more direct way of measuring the ecological health of a river system is to measure the abundance of key functional groups of organisms living in rivers. This is referred to as 'biomonitoring' and was initiated in the lower Mekong Basin in 2003. The key functional groups surveyed include: (i) benthic diatoms (microscopic algae attached to a substrate); (ii) zooplankton (microscopic animals that float or drift in the river water); (iii) benthic macroinvertebrates (animals such as insects, snails and worms that live on, or in, the riverbed); and (iv) littoral macroinvertebrates (animals, as above, that live in shallow water at the shoreline of rivers and lakes). Rich species diversity and high abundances of indicator species reflect good river health, while low diversity and abundances indicate poor health.

Table 12 Temporal changes to ecological health at 32 key monitoring sites during 2004-2008.

Site code and location		Site assessment by year				
		2004	2005	2006	2007	2008
Cambodia						
CKT	Mekong River, Kampi	A		A		A
CMR	Mekong River, Stung Treng Ramsar site		B	A	B	B
CSJ	Se San River, Sesan		A	B	A	A
CKM	Se Kong River, Ramsar site		A	B	B	B
CSP	Sre Pok River, Ratanakiri	A	A	A	A	B
CSU	Se San River, Lum Phat		A	B	B	A
CKL	Bassac River, Koh khel			B		C
CSK	Stoeng Sangke River, Prek Toal			C		B
Lao PDR						
LDN	Mekong River, Done Nguei				A	A
LSD	Se Done River, Ban Hae				B	B
LKL	Se Kong River, Ban Xou		A		C	C
LBH	Se Bang Hieng River, under bridge				A	C
LBF	Se Bang Fai River, under bridge				B	B
LVT	Mekong River, Ban Huayhome	C			B	C
LMX	Mekong River, Ban Xiengkok		C			D
LPB	Mekong River, Done Chor	A	A			B
Thailand						
TNP	Mekong River, Nakorn Panom					C
TSM	Junction of the Songkram & Mekong Rivers				C	A
TNK	Nam Kam River, Mukdaharn				C	B
TMU	Nam Mun River, Ubon Rachathani	B				B
TKC	Junction of the Nam Mun & Mekong rivers					A
TUN	Nam Mun River, Ubon Rachathani					A
TCS	Mekong River, Chiang San, Chiang Rai					B
TKO	Nam Kok River, Chiang Rai	B	A			A
Viet Nam						
VCT	Bassac River, Phu An, Can Tho			C		B
VLX	Bassac River, Long Xuyen, An Giang			C		B
VDP	Bassac River, Da Phuoc, An Giang					C
VKB	Bassac River, Khanh Binh, An Giang					B
VTP	Mekong River, Thuong Phuoc, Dong Thap					C
VTT	Mekong River, Thuong Thoi, Dong Thap					C
VCL	Mekong River, Cao Lanh, Dong Thap			C		C
VVL	Mekong River, My Thuan, Vinh Long					C

This map illustrates the results of biomonitoring surveys conducted at 32 sites in 2008 (MRC 2008c; 2009). The surveys were conducted by a team of biologists and ecologists from the four MRC Member Countries. The colour of each point indicates how the characteristics of biota at that site compares with guidelines established at a set of 14 'reference sites' considered to have 'baseline' (excellent) water quality and ecological health (MRC 2008b). Three characteristics were used to assess the ecological health of sites: species richness (number of species or species groups); abundance (number of individuals); and Average Tolerance Score per Taxon. The third characteristic is an indicator of the tolerance to pollution of plant and animal groups (taxa) found at each site and reflects how disturbed the site is (MRC 2008b). The surveyed sites included the Mekong mainstream and tributary rivers and covered a range of physical river environments (bedrock and alluvial channels) and levels of disturbance from human activities.

Of the 32 sites surveyed in 2008, nine were in Class A (excellent ecological health), 12 in Class B (good), 10 in Class C (moderate) and one in Class D (poor). Apart from the Delta, where there is a higher proportion of 'moderate' ratings and no 'excellent' ratings, the upper, middle and lower parts of the Basin show a near-equal mix of better and worse ecological health ratings. Most surveyed tributary sites have an 'excellent' or 'good' rating. Sites on the Mekong River mainstream range from 'poor' to 'excellent'.

Sites showing signs of stress include the junction of the Nam Ma and Mekong rivers (LMX) near Xiang Kok in northern Lao PDR which rates as poor; and the Mekong River at Vientiane and Nakhon Phanom both of which are large urban areas. Moderate ecological health is also found in the lower reaches of the Se Bang Fai (LBH), upper reaches of Se Kong (LKL), and at several sites downstream of Phnom Penh and in the Delta, where population density is greatest and water quality has been impacted by human activity (see previous map). Note that in the Delta, the ecological health is generally better on the Basaac River distributary compared with the Mekong River distributary.

Table 12 (left) summarises the results of ecological health monitoring between 2004 and 2008 at the 32 key monitoring sites. Stability in site classifications in more than half of the sites and improvement in some sites particularly in the Mekong Delta are positive signs for the health of the Mekong River. Some locations indicate improvement while others show degradation (MRC 2009).

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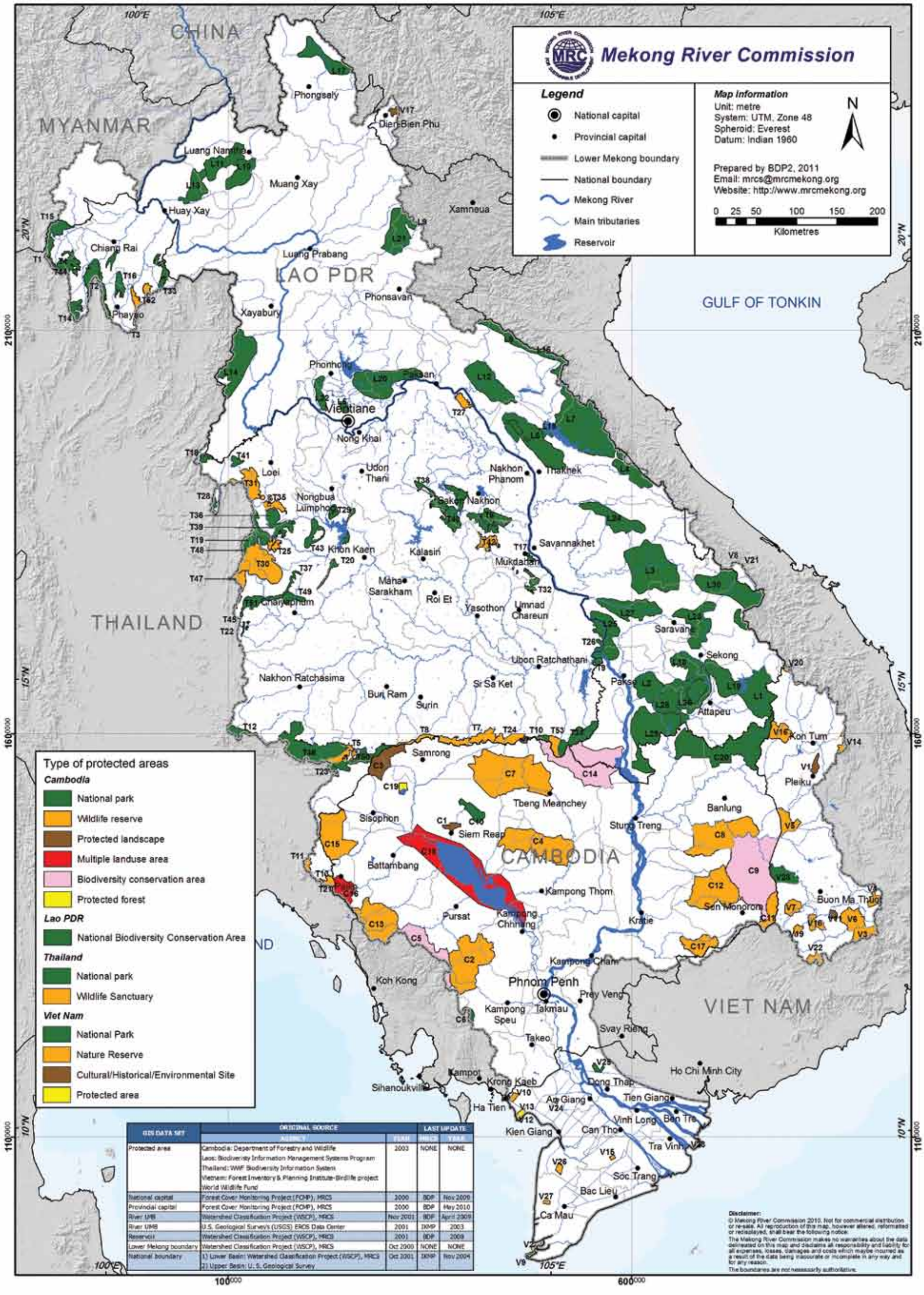
5 Environment

Protected areas



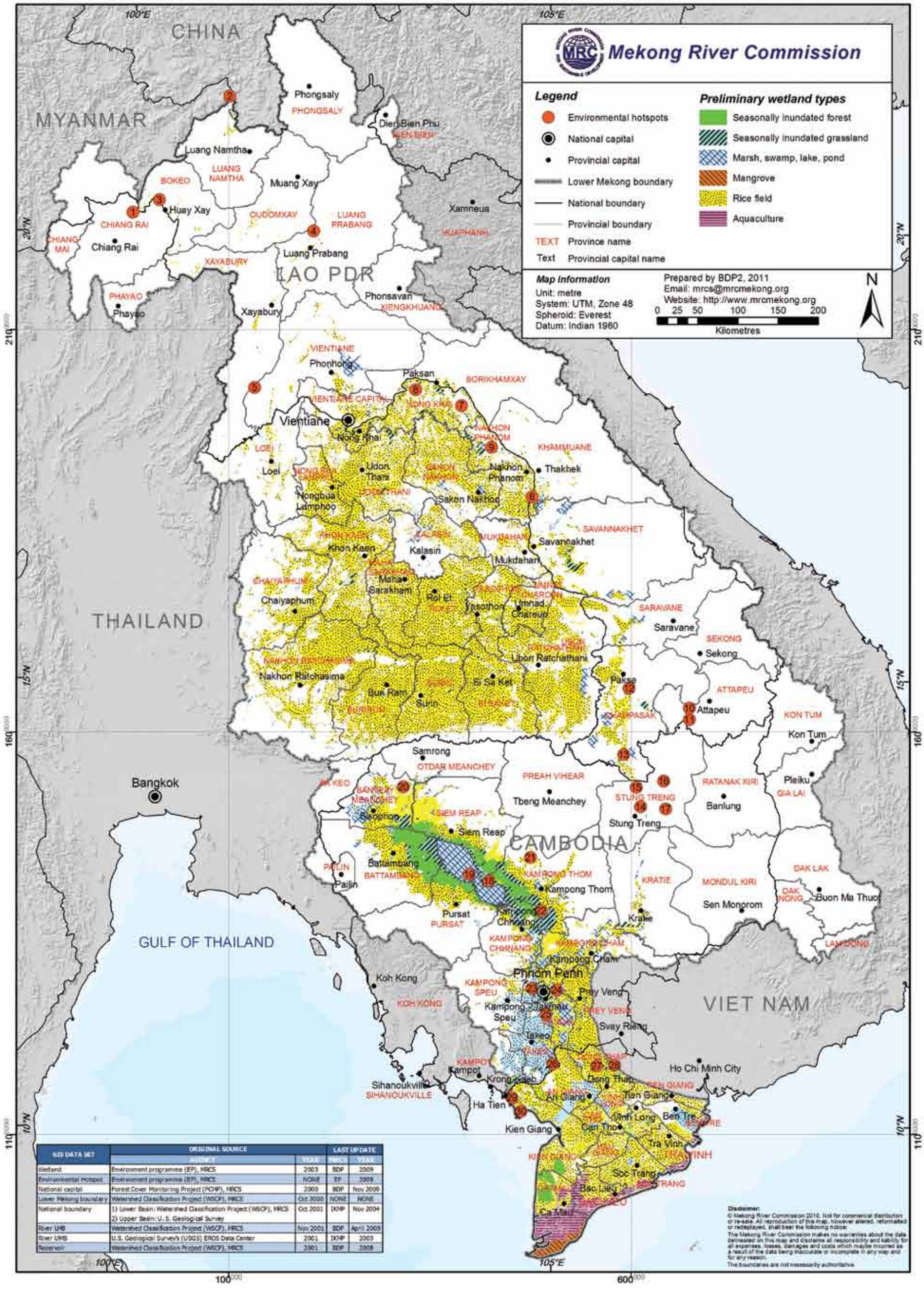
5.1 Protected Areas

This map illustrates the location of all protected areas officially designated by each of the MRC member countries. These include national parks, wildlife reserves and sanctuaries, nature reserves, cultural and historical sites and biodiversity conservation areas. The classification of protected areas is specific to each country as shown in the legend key of the map. The surface area of each protected area is given in Table 13 below. In the lower Mekong Basin, protected areas cover a total of 100,728 km^2. Cambodia has 20 protected areas of which the largest are the Tonle Sap Multiple Land Use Area, Kulen Promtep Wildlife Reserve and Mondulkiri Biodiversity Conservation Area: all with areas greater than 4,000 km^2. In Lao PDR there are 30 National Biodiversity Conservation Areas (NBCA). Nakai-Nam Theun NBCA, which borders the new Nam Thuen II reservoir is the largest followed by Gi Do NBCA, located in the Xe Bang Hieng catchment southeast of Savannakhet. Thailand has 53 protected areas in the north and northeast parts of the country which fall within the Lower Mekong Basin. Some of these, like Kao Yai National Park, extend outside the boundaries of the LMB but this area is not included in Table 13. The largest protected areas in Thailand are Tablarn National Park located south of the city of Nakhon Ratchasima and Pu Kiew Wildlife Sanctuary located west of Khon Kaen. In Viet Nam there are 28 protected areas within the LMB: small areas in the delta, larger areas in the headwaters of the Se San and Se Prok catchments and one in the north of the country near Dien Bien Phu.

Table 13 List of protected areas and their size by country (areas are in km^2)

Cambodia			Lao PDR			Thailand			Viet Nam		
Code	Name	Area	Code	Name	Area	Code	Name	Area	Code	Name	Area
C1	Angkor	138	L1	Dong Ampham	1,758	T1	Chiang Dao	67	V1	Bac Pleicu	140
C2	Aural	2,575	L2	Dong Hua Sao	947	T2	Doi Luang	746	V2	Bai Boi	56
C3	Banteay Chmar	848	L3	Gi Do	3,065	T3	Doi Pu Nang	38	V3	Bi Dup Nui Ba	434
C4	Beng Per	2,486	L4	Hin Namnu	840	T4	Doi Vieng Pa	474	V4	Chu Hoa	187
C5	Cardamom Mountain	1,165	L5	Houay Nhang	124	T5	Dong Yai	322	V5	Chu Prong	479
C6	Kirirom	140	L6	Khammouane Limestone	2,172	T6	Huiy Huad	793	V6	Chu Yang Sin	584
C7	Kulen Promtep	4,028	L7	Nakai-Nam Theun	3,720	T7	Huiy Sala	364	V7	Dak Mang	299
C8	Lomphat WS	2,507	L8	Nam Chuan	656	T8	Huiy Tabtan-Hadsamran	462	V8	Dak Rong	0.1
C9	Mondulkiri	4,285	L9	Nam Et	5.1	T9	Kang Tana	84	V9	Dat Mui	63
C10	Phnom Kulen	365	L10	Nam Ha (East)	790	T10	Khao PraViharn	134	V10	Ha Tien	70
C11	Phnom Nam	538	L11	Nam Ha (West)	915	T11	Khao Soi Dao	119	V11	Ho Lak	93
C12	Phnom Prich	2,206	L12	Nam Kading	1,598	T12	Khao Yai	329	V12	Hon Chong	19
C13	Phnom Samkos	1,930	L13	Nam Kan	749	T13	Klong Kruewai Chalermprak	179	V13	Kien Luong	75
C14	Preah Vihear BGCA	3,227	L14	Nam Phoun (Poui)	1,924	T14	Kun Jae	285	V14	Kon Ka Kinh	147
C15	Roniem Daun Sam	1,737	L15	Nam Theun Corridor	227	T15	Mae Phang	527	V15	Lung Ngoc Hoang	28
C16	Samlot	591	L16	Nam Theun Ext.	426	T16	Mae Puem	354	V16	Mom Ray	487
C17	Snuol WS	751	L17	Phou Dene Dinh	946	T17	Mukdahan	50	V17	Muong Phang	92
C18	Tonle Sap	5,957	L18	Phou Kateup	731	T18	Na Haow	106	V18	Nam Ca	245
C19	Trapeang Thmor	129	L19	Phou Kathong	1,569	T19	Nam Nao	668	V19	Nam Nung	105
C20	Virachey	3,349	L20	Phou Khao Khoay	1,888	T20	Nam Pong	224	V20	Ngoc Linh KTum	80
Total area		38,954	L21	Phou Loeuy	1,430	T21	Nam Tok Kaw	1.7	V21	Phong Dien	6.6
			L22	Phou Pha Nang	361	T22	Pa Him Ngam	72	V22	Ta Dung	189
			L23	Phou Theung	1,374	T23	Pang Sida	112	V23	Thanh Phu	77
			L24	Phou Xang He	1,169	T24	Panom Dong Rak	332	V24	Tinh Doi	21
			L25	Phou Xiang Thong	1,091	T25	Paphung	178	V25	Tram ChimTam Nong	80
			L26	Phu Luang (Bolavens)	1,001	T26	Pha Tam	355	V26	U Minh Thuong	80
			L27	Xe Bang Nouan	1,358	T27	Pu Hao	189	V27	Vo Doi	34
			L28	Xe Khampho	1,138	T28	Pu Hin Tongkla	94	V28	Yok Don	557
			L29	Xe Pian	2,443	T29	Pu Kao Pupankam	295	Total area		4,729
			L30	Xe Sap	2,264	T30	Pu Kiew	1,577			
			Total area		8,675	T31	Pu Luang	709			
						T32	Pu Sa Dok Boa	207			
						T33	Pu San	283			
						T34	Pujong-Nayoy	688			
						T35	Pukaw - Pukratae	237			
						T36	Pukradeung	255			
						T37	Pulan Ka	201			
						T38	Pupalek	425			
						T39	Pupamarn	361			
						T40	Pupan	713			
						T41	Purua	120			
						T42	Pusithan	308			
						T43	Puvieng	323			
						T44	Sri Lanna	38			
						T45	Sub Lanka	1.5			
						T46	Tablarn	1,655			
						T47	Tabo-Huiyyai	319			
						T48	Tad Mok	42			
						T49	Tadtone	217			
						T50	TaPhrya	618			
						T51	Tri tong	333			
						T52	Vieng Law	308			
						T53	Yod Dome	243			
						Total area		18,334			

Preliminary wetland map and environmental hotspots



GIS DATA SET	ORIGINAL SOURCE		LAST UP DATE	
	AGENCY	YEAR	MRCS	YEAR
Wetland	Environment programme (EP), MRCS	2003	BDP	2009
Environmental Hotspot	Environment programme (EP), MRCS	NONE	EP	2009
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

5.2 Preliminary Wetland Map and Environmental Hotspots

This map shows the location and extent of wetlands in the Lower Mekong Basin and the location of 32 environmental hotspots. The wetland map is based on an original wetland classification of the LMB compiled from country data by the Environment Programme in 2003. The wetland classification was simplified into six classes, as shown here, by the Basin Development Plan (BDP) Programme as part of the Assessment of Basin-wide Development Scenarios (MRC 2010b). The extent of wetlands in the LMB is currently being updated by the Environment Programme. The environmental hotspots are ecologically sensitive areas of national, regional or international significance. They are areas containing rich biodiversity, a large number of important species at risk, areas important for migrating species or supporting key ecological processes (MRC 2010b). Hotspots include designated Ramsar Sites, Biosphere Reserves, Protected Areas, Important Bird Areas and Greater Mekong Subregion (GMS) Hotspots (Table 14).

Wetlands provide important habitat for flora and fauna, including many fish species that seasonally migrate to wetlands for spawning and feeding (MRC 2010d). Wetlands are important for conserving biodiversity and are also critical to the food security and livelihoods of local communities. They provide important sources of food, water, wood and fibrous plants for building material and traditional medicines. Wetlands also play a major role in mitigating costly flood damages and removing contaminants from surface waters. The water purification function is important particularly in urban and peri-urban areas (Gerrard 2004). In coastal areas, mangrove forests trap sediments and nutrients and protect the coastline from the erosive action of storms. In the Lower Mekong Basin, wetlands include areas heavily utilised by humans including rice fields and aquaculture ponds.

Rice fields constitute 84% of the total wetland area in the LMB and cover a large proportion of northeast Thailand. While rice field wetlands may be subject to several pressures including the use of herbicides, pesticides and fertilisers, they remain important habitat for many aquatic organisms including as a spawning and feeding ground for fish during the annual flood season (Poulsen et al. 2002b). Marshes, swamps, lakes and ponds make up 6% of the total wetland area and are scattered throughout the lower part of the LMB, in southern Lao PDR and Cambodia, particularly along the Mekong and Tonle Sap river corridors. Many of these marshes, swamps, lakes and ponds are of high biodiversity value and several are included in the listing of environmental hotspots below in Table 14. Seasonally inundated forest and grasslands make up 3.3% and 3.6% of the total wetland area, respectively and are found predominantly surrounding the Tonle Sap Lake and in the Delta. Mangrove forests constitute 1% of all wetland areas in the LMB. Mangroves are confined to coastal areas in the Ca Mao Peninsula in the southwest of the Mekong Delta in Viet Nam where the Delta is predominantly tidally influenced and has extensive tidal flats (Nguyen et al. 2000). Mangroves are largely absent from the eastern coast of the Delta due to increasing aquaculture development but more importantly, because of the influence of waves, ocean currents and a smaller tidal range, which favour the formation of beaches and sand dunes behind narrow tidal flats (Nguyen et al. 2000). Aquaculture (artificial ponds used for rearing fish and prawns) make up 2.1% of the total LMB wetland area, mainly in the southwest of the Delta and coastal areas further to the east.

ID	Name	Country	Description and conservation status
1	Nong Bong Kai Non-Hunting Area	T	Ramsar Site, Protected Area, Important Bird Area
2	Golden Triangle (China, Myanmar, Thailand, Lao PDR)	C/M/T/L	GMS Hotspot – Wetlands and protected areas
3	Mekong River corridor between Chiang Saen and Chiang Khong	T/L	Ecosystem habitats of biodiversity conservation importance
4	Mekong channel upstream of Luang Prabang	L	Location of clusters of alternating shallow rapids and deep pools: important for fish conservation. IBA*.
5	Mekong channel between Luang Prabang and Vientiane	T/L	Diverse bedrock-alluvial channel ecosystem with several clusters of alternating shallow rapids and deep pools, IBA*
6	Mekong River between Vientiane and Mun River confluence	T/L	Wide, alluvial river channel with floodplains - Important Bird Area
7	Bun Khong Long Non-Hunting Area	T	Permanent freshwater lake surrounded by seasonally inundated floodplain. High diversity of wetland wildlife. Ramsar site, Protected Area and Important Bird Area.
8	Kut Ting Marshland	T	Habitat for numerous species at risk, Ramsar Site, Protected Areas, IBA*
9	Lower reaches of the Songkhram River	T	Seasonally inundated forests and floodplains. Potential future Ramsar Site. Fish Conservation Zones.
10	Xe Khampho-Xe Piane National Protection and Conservation Areas	L	Freshwater lakes, ponds, marshes and seasonally flooded grassland. Protected area and IBA
11	Xe Kong Plains	L	Important Bird Area and habitat for numerous fish, reptile and mammal species at risk
12	Mekong River between Savannakhet and Khone Falls/Siphandon	L	Site of alternating shallow rapids and deep pools. Important Bird Area and habitat for numerous species at risk.
13	Khone Falls – Siphandon	L	Complex river ecosystems with numerous river channels, islands, rapids, waterfalls, deep pools and seasonally inundated forests. Habitat for numerous species at risk and IBA.
14	Mekong River from Lao PDR border to Kratie	C	As above but also includes a Ramsar site upstream of Stung Treng (see no.15)
15	Mekong River north of Stung Treng (37km stretch)	C	Ramsar Site, Protected Area & Important Bird Area
16	Se Kong River	C	GMS hotspot and Important Bird Area
17	Se San River	C	GMS hotspot and Important Bird Area
18	Boeng (Lake) Chhmar and river system at the edge of Tonle Sap Lake	C	Ramsar Site, Protected Area and Important Bird Area
19	Tonle Sap Lake, Tonle Sap River, Prek Toal	C	UNESCO Biosphere Reserve, GMS Hotspot, Protected Area and Important Bird Area
20	Ang Trapeang Thmor Sarus Crane Reserve	C	Seasonally flooded grassland. Protected Area and Important Bird Area.
21	Stoung/Prasaat Balang	C	Dipterocarp forest, seasonally inundated grasslands and seasonal pools and streams. Important Bird Area.
22	Stung Sen / Lower Stung Sen / northern Santuk / Baray	C	Streams, seasonally inundated grassland and open forest. Protected Area and Important Bird Area
23	Basset Marsh	C	Permanent lake and extensive marshes, seasonally inundated when Tonle Sap Lake floods. IBA*
24	Boeung Veal Swamp	C	Permanent lake and seasonally inundated forest and marshes. Important Bird Area
25	Bassac Marsh	C	Extensive wetland areas between the Mekong and Bassac rivers. Important Bird Area.
26	Boeung Prek Lapouv	C	Seasonally inundated grasslands. Important Bird Area
27	Tram Chim National Park	V	*Melaluca* swamp, seasonally inundated grassland, lotus swamp. Rremnant of the Plain of Reeds. Protected Area, IBA
28	Lang Sen Wetland Reserve	V	As above but also the only remaining site in the Delta where natural *Melaluca* forest occurs along a natural river
29	Ha Tian Plain and Phu My Grassland	V	One of the last remaining extensive areas of seasonally inundated grassland in the Mekong Delta. IBA*.
30	Kien Luong	V	As above for no. 29. Located in the south of the Ha Tien Plain at an elevation of 0-2m above sea level.
31	Tra Su	V	*Melaluca* forest plantation, seasonally inundated grasslands and swamps. IBA, Bird Sanctuary, production forest.
32	Tinh Doi	V	*Melaluca* forest plantation and seasonally inundated grasslands. IBA, production forest.

Table 14 Description and location of environmental hotspots. More detailed information available from MRC (2010b). *Important Bird Area.

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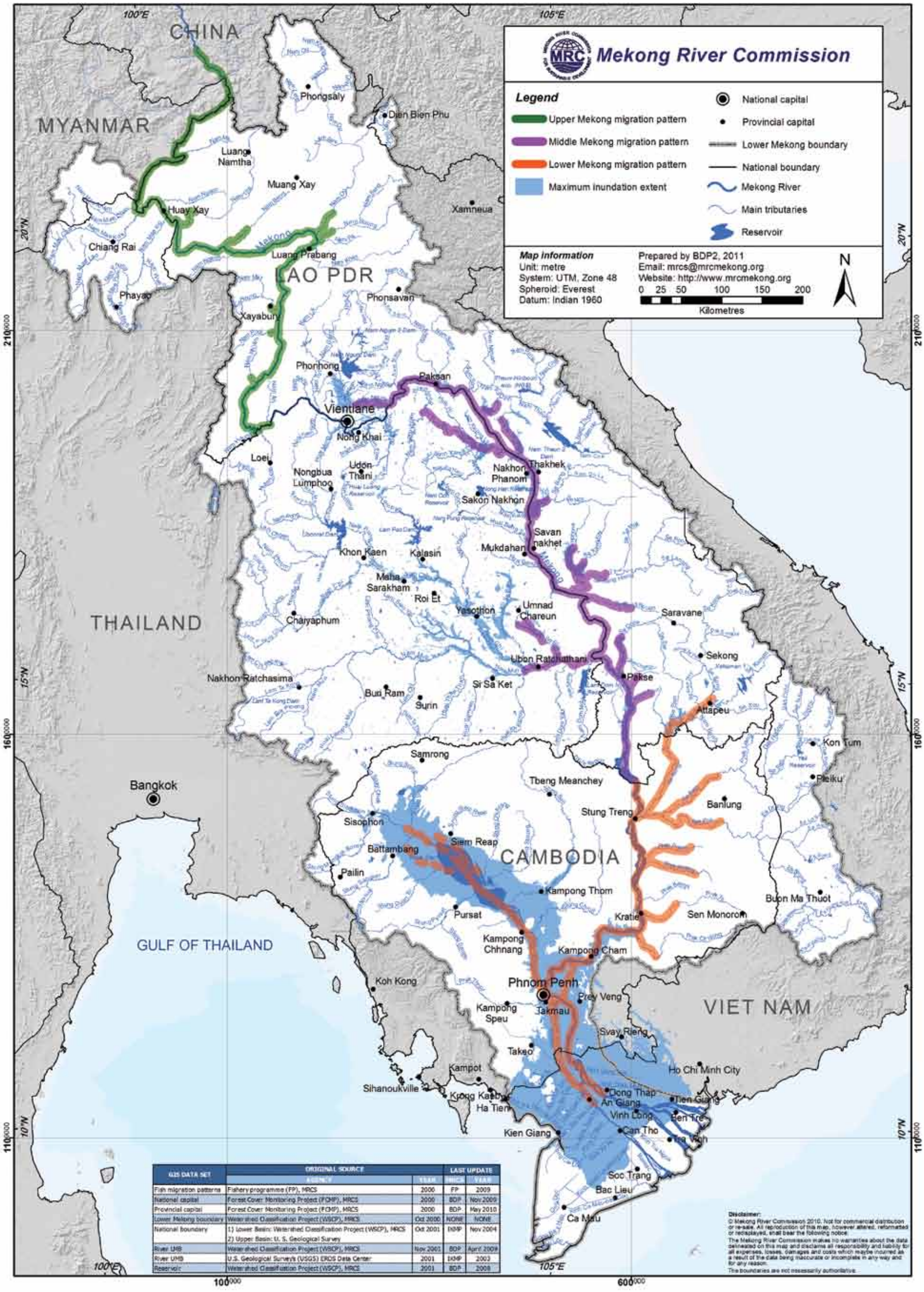
Fish migration patterns



5.3 Fish Migration Patterns

The vast majority (87%) of the 189 fish species in the Lower Mekong Basin (LMB) for which migratory status is known, are migrant species (165) while the remaining 23% (14) are non-migrant (Baran 2006). Fish migration includes longitudinal movement of up to hundreds of kilometres along the river channels of the Mekong River and its tributaries, but also 'lateral' migration from the main river channels onto floodplains, and back again when the water recedes. Fish migrate for feeding and breeding, because the habitats essential for their reproduction and food availability are separated in time and space (Poulsen et al. 2002b). For example, when fish migrate upstream for breeding, their newly hatched larvae and juvenile fish will drift with the rising flows at the start of the rainy season onto floodplains where they become most productive and accessible as a food source to other fish (Baran 2006).

Fisheries ecologists have distinguished three main fish migration systems in the LMB as illustrated in the adjacent map: the Lower Mekong (altitude 0-150 m above sea level), the Middle Mekong (altitude 150-200 masl) and the Upper Mekong (altitude 200-500 masl) (Poulsen et al. 2002b). Although the systems have distinct geographical areas and are defined based on land elevation (as it represents the presence and extent of floodplains adjacent to river channels), the systems are not closed. They are strongly interconnected and many species migrate from one system to another.

In the Lower Mekong migration system, fish move from their dry-season refuges (for example deep pools) in the Mekong River mainstream between the Khone Falls and Kratie downstream to the floodplains in southern Cambodia and Mekong Delta in Viet Nam for feeding. These vast floodplains are inundated with floodwaters during each wet season (Poulsen et al. 2002a). Fish then return upstream to their dry season habitats at the end of the wet season. Some species extend their dry-season migration into the Se Kong - Se San - Sre Pok river system. However, this large tributary basin also has its own migration system. The Tonle Sap – a vast complex of rivers, lakes and floodplains – is another integral part of this Lower Mekong migration system and one of the most productive fisheries in the LMB. At the onset of the wet season, flow in the Tonle Sap River changes direction, flowing from the Mekong into the Tonle Sap River and filling the Tonle Sap Lake. Fish larvae and juveniles are able to migrate upstream into the Lake from the Mekong by drifting with the flow (Poulsen et al. 2002b).

In the Middle Mekong migration system, fish move upstream as water levels rise in the wet season, entering tributaries and adjacent floodplains for feeding. The Songkhram and Nam Mun rivers in northeast Thailand and the Nam Ngum, Nam Hin Boun, Xe Bang Fai, Se Done and Xe Bang Hieng – Xe Champhone river systems in Lao PDR are of particular importance owing to the low-lying topography of their lower catchments and hence the presence of large floodplain areas and rainfed paddy fields. As water levels recede, fish return to dry-season refuges in the Mekong River.

Owing to the steep topography and hence limited floodplain areas, the Upper Mekong migration is predominantly confined to longitudinal movements of fish along the Mekong River main channel and lower parts of some tributary rivers. Fish migrate upstream to spawing habitats in the wet season and later return to dry season refuges, often deep water pool as in other parts of the Mekong River.

The environmental conditions which trigger fish migration in the LMB are known for only 30 of the 165 known migrant species (Figure 9) (Baran 2006). The most common trigger, to which 80% of species respond, is changes to river water levels, either when water levels are rising at the start of the wet season, falling at the end of the wet season or both. The abrupt increase in rainfall at the start of the wet season, together with changes in water colour due to increased turbidity as fine sediment is washed from the land surface into rivers with the first rains, are the next most significant migration triggers, providing migration cues for 30% of migrant species. Abrupt increases and/or decreases in discharge (river flow) at the start and end of the wet season, and sharp increases in the abundance of insects (a key food source for fish) are also important triggers. Some species have a single trigger, while others rely on multiple cues. Since water levels and discharge are strongly correlated, it can be seen that 90% of fish species (for which migration cues are known) are sensitive to variations, or thresholds, in water level and discharge (Baran 2006).

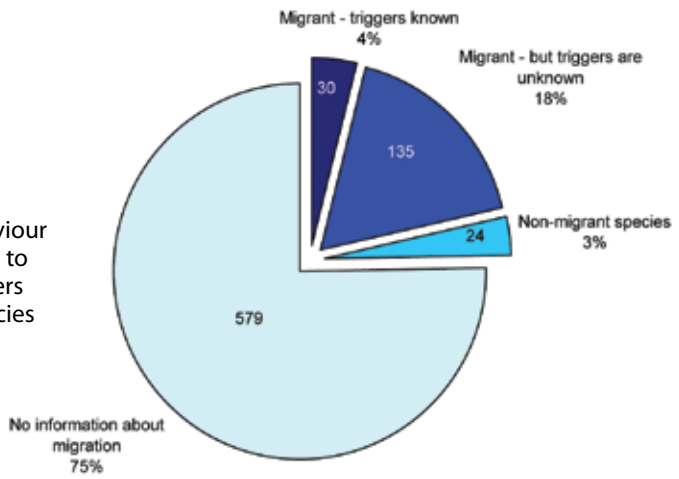


Figure 8 Migratory behaviour and sensitivities to migration triggers among 768 species (Baran 2006).

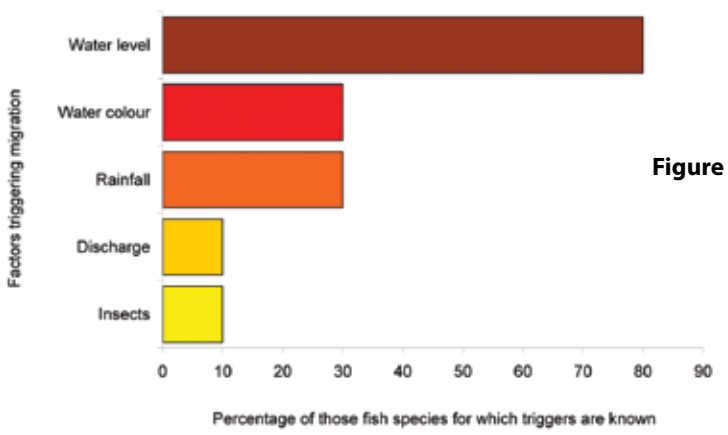


Figure 9 Percentage of fish species sensitive to migration cues that respond to a given trigger (Baran 2006).

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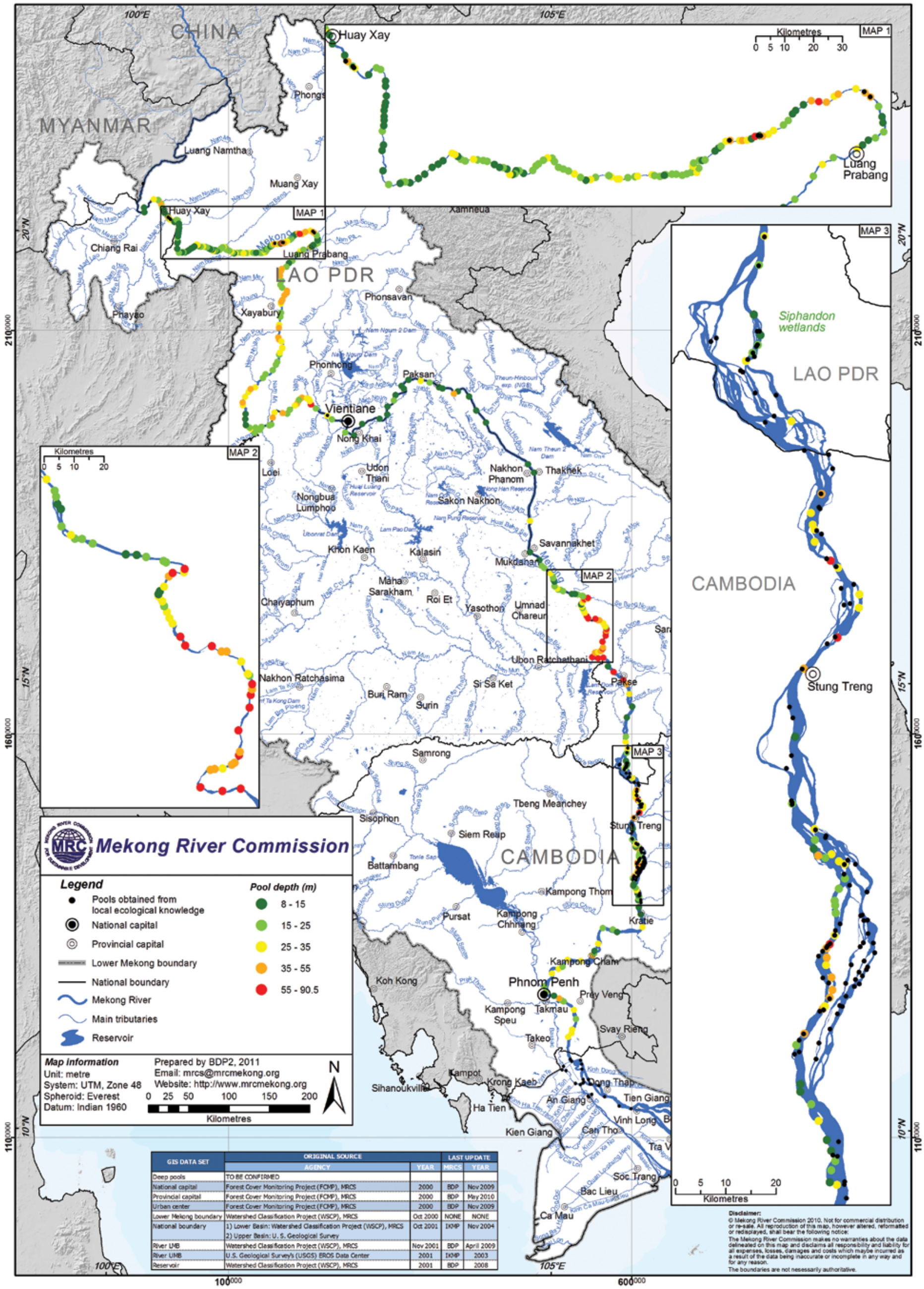
Deep pools



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Deep pools	TO BE CONFIRMED			
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Urban center	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

5.4 Deep Pools

Pools, also termed 'deep pools' are natural depressions in the bed of a river. They occur at regular intervals along most rivers and exhibit many forms including shallow, long depressions in wide alluvial channels and deep, short depressions in bedrock-influenced rivers (Figure 10). Along the Mekong mainstream and many of its tributaries, pools provide an important dry season refuge for a number of important Mekong fish species and a spawning habitat for some species (Poulsen et al. 2002a). The large water depths and slow moving water in pools in the dry season provide shelter from predators and a thermal refuge (Baird 2006) as well as a refuge for migratory species between seasonal migrations. The distribution of deep pools in the LMB is thought to have had an important influence on the evolution of the three geographically distinct migration systems in the Mekong illustrated in Map 5.3 (Poulsen et al. 2002).

This map shows the location of pools on the Mekong mainstream from two different sources:
a) Black points - pools identified from local ecological knowledge (LEK) obtained during several independent surveys conducted between 1995 and 2010 and synthesised by Halls et al. (2011). These surveys identified pools based on interviews with fisher groups in ecologically-significant areas and productive fishing grounds, often in combination with field surveys of river bathymetry (depth) and interpretation of existing bathymetric maps. Some pools identified in these surveys did not have geographic coordinates and so have not been included in this map. Only some tributaries have been surveyed.
b) Coloured circles - pools identified from a statistical analysis of the riverbed long profile (a plot of river depth along the line of deepest flow versus distance downstream) of the lower Mekong River (Conlan In prep.). Pools were identified by fitting a trend to the long profile and then selecting all depressions beneath the trend line (see Halls et al, 2009 for details of the method).

A more detailed presentation and analysis of these two datasets can be found in Halls et al (2011). The two datasets provide different but complimentary information.

The LEK-based pools indicate pools of particular ecological significance. Note that the LEK surveys were concentrated in specific areas and may not represent the true distribution of deep pools. The statistically-identified pools include all major depressions in the riverbed based on a physical (geomorphic) interpretation of the river regardless of whether the depressions are utilised as a fishing ground. The statistical method also provides an objective and consistent measure of pool dimensions (depth, length and volume). Pools on minor channels (e.g. Siphandon wetlands and northern Cambodia) and the numerous channels in the delta could not be identified using this statistical method.

In northern Lao PDR, ecologically significant (LEK) pools are located around Huay Xai and upstream of Luang Prabang. In the middle, predominantly alluvial, river reaches one pool has been identified from LEK surveys about 20km upstream of Vientiane in a constricted gorge section of the River. Between Pakse and Kratie, including the Siphandon wetlands in southern Lao PDR, there are a particularly large number of LEK-based pools. This river reach supports one of the most productive fisheries in the LMB. It is characterised by an anabranching river planform with multiple channels separated by islands and rocky outcrops. Pools in this river reach have formed at lateral channel constrictions, meander bends and downstream of islands where flow from two channels converges.

Pools identified from a statistical analysis of the river longprofile are colour coded by the maximum depth of the pool in the dry season. Pool depth ranges from 3.1 to 90.5 m, however only pools deeper than 8m are shown in this map. Pools are more closely spaced and deeper in the northern reaches between Chiang Saen and Vientiane, between Savannakhet and Pakse and from the Siphandon wetlands downstream to Kratie. These reaches are all bedrock-influenced reaches, where channel obstructions and constrictions and an overall narrow channel create deeper and more frequent pools. Conversely, the middle reaches between Vientiane and Savannakhet and downstream of Kratie are predominantly wide and shallow alluvial reaches, with fewer constrictions and obstructions. In alluvial reaches, pools form at meander bends, opposite sand bars and at occasional confluence zones downstream of islands or channel constrictions due to isolated geological structures that impinge on the river. Pools in the downstream alluvial reaches in Cambodia are deeper and larger in volume than pools in the middle alluvial reaches due to greater discharge and hence more flow energy to scour larger pools and secondly, more frequent and narrower channel constrictions downstream of the numerous large islands (Conlan In prep.). Flow convergence and acceleration in these constricted reaches scours deeper and longer pools. There are fewer islands in the middle reaches.

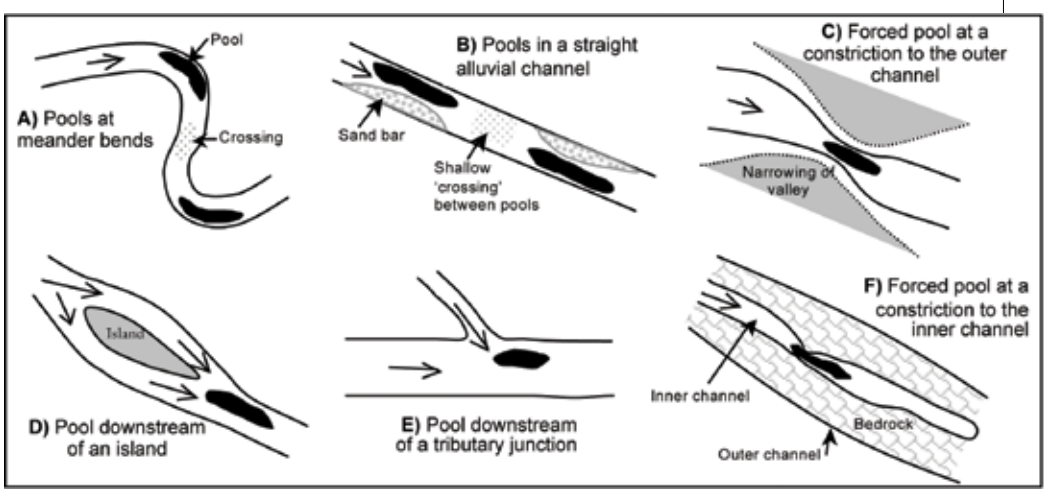


Figure 10 Major pool types found on the lower Mekong River (Conlan In prep.; Halls *et al*. 2009). Pools at constrictions (C & F) are the most common type of pool on the Mekong mainstream.

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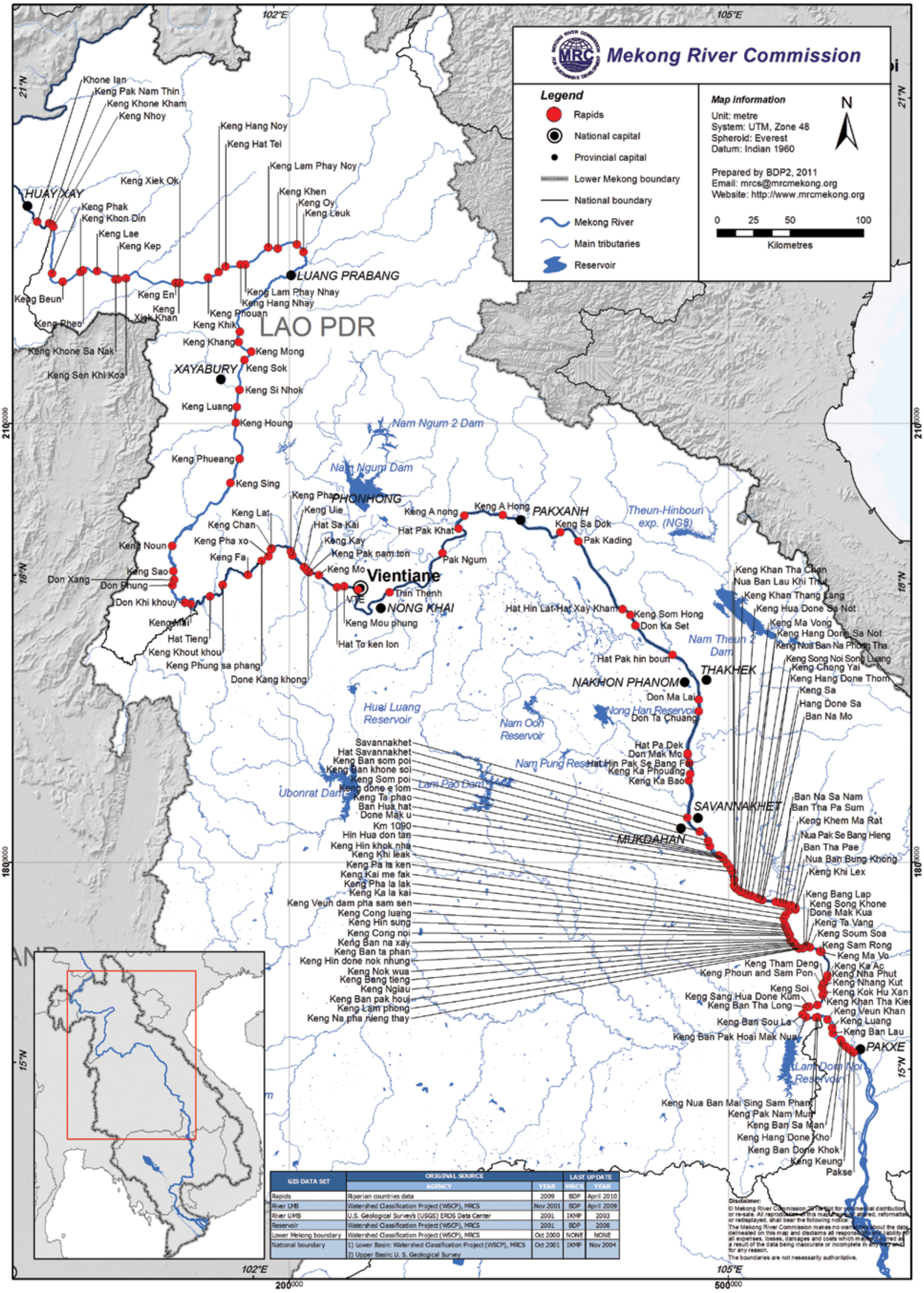
Poulsen, A.F., Poeu, O., Viravong, S., Suntornratana, U. and Tung, N., Thanh (2002a) Deep pools as dry season fish hahitats in the Mekong Basin. In: *MRC Technical Paper No. 4*, Mekong River Commission. p 22.

Rapids


Mekong River Commission
Legend
Rapids
National capital
Provincial capital
Lower Mekong boundary
National boundary
Mekong River
Main tributaries
Reservoir
Map Information
Unit: metre
System: UTM, Zone 48
Spheroid: Everest
Datum: Indian 1960
Prepared by BDP2, 2011
Email: mrcs@mrcmekong.org
Website: http://www.mrcmekong.org
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SAVANNAKHET
MUKDAHAN
PAKXE
Nam Ngum 2 Dam
Nam Ngum Dam
Theun-Hinboun exp. (NG8)
Nam Theun 2 Dam
Huai Luang Reservoir
Nam Oon Reservoir
Nong Han Reservoir
Nam Pung Reservoir
Lam Pao Dam
Ubonrat Dam
Lam Dom Noi Reservoir
Khone Ian
Keng Pak Nam Thin
Keng Khone Kham
Keng Nhoy
Keng Xiek Ok
Keng Phak
Keng Khon Din
Keng Lae
Keng Kep
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Keng Nok wua
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Keng Ngiau
Keng Ban pak houi
Keng Lam phong
Keng Na pha nieng thay
Keng Khan Tha Chan
Nua Ban Lau Khi Thut
Keng Khan Thang Lang
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Keng Hang Done Sa Not
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Keng Song Noi Song Luang
Keng Chong Yai
Keng Hang Done Thom
Keng Sa
Hang Done Sa
Ban Na Mo
Ban Na Sa Nam
Ban Tha Pa Sum
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Nua Ban Bung Khong
Keng Khi Lex
Keng Bang Lap
Keng Song Khone
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Keng Ta Vang
Keng Soum Soa
Keng Sam Rong
Keng Ma Vo
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Keng Nhang Kut
Keng Kok Hu Xan
Keng Khan Tha Kie
Keng Veun Khan
Keng Luang
Keng Ban Lau
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Keng Phoun and Sam Pon
Keng Soi
Keng Sang Hua Done Kum
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Keng Ban Sou La
Keng Ban Pak Hoai Mak Nua
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GIS DATA SET
ORIGINAL SOURCE
AGENCY
YEAR
LAST UPDATE
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YEAR
Rapids | Riparian countries data | 2009 | BDP | April 2010
River LMB | Watershed Classification Project (WSCP), MRCS | Nov 2001 | BDP | April 2009
River UMB | U.S. Geological Survey's (USGS) EROS Data Center | 2001 | IKMP | 2003
Reservoir | Watershed Classification Project (WSCP), MRCS | 2001 | BDP | 2008
Lower Mekong boundary | Watershed Classification Project (WSCP), MRCS | Oct 2000 | NONE | NONE
National boundary | 1) Lower Basin: Watershed Classification Project (WSCP), MRCS
2) Upper Basin: U. S. Geological Survey | Oct 2001 | IKMP | Nov 2004
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The boundaries are not nesessarily authoritative.

5.5 Rapids

The Mekong River is a mixed alluvial-bedrock river meaning that certain reaches are alluvial in nature, having a bed and banks composed of alluvial sediment (gravel, sand, silt and clay), while others have solid bedrock exposed in all or part of the bed and banks. Rapids occur where bedrock is exposed in the riverbed and forms obstacles to the flow. This map shows the location of 173 known rapids between Chiang Saen and Pakse. Numerous rapids also occur in bedrock reaches between Pakse and Kratie but their location is still being finalised.

The map indicates that rapids are common along the entire length of the lower Mekong River. They even occur intermittently in the predominantly alluvial reach between Vientiane and Savannakhet where structural features including faults and fold structures intersect the River. The highest density of rapids occurs in the reach between Savannakhet and Pakse where the Mekong cuts across the Phu Phan Range and the southeastern edge of the Khorat Plateau. Resistant sandstones rocks are exposed in the channel in this reach.

Typically, rapids are characterised by fast water flow and turbulence, evidence of which can be seen at the water surface as broken water (white water), standing waves, boils and eddies. The bedrock obstacles are not necessarily exposed above the water surface and often are only visible during the low flow period in the dry season. During the wet season, many rapids are completely submerged but continue to create fast flow speeds and large turbulence which can be hazardous for navigation, but important for fish and other aquatic biota. As illustrated in Map 6.7 on navigation capacity, only small vessels are able to safely navigate many reaches of the lower Mekong River due to the presence of rapids, limiting the potential of inland maritime transport in the upper and middle reaches of the River.

Rapids provide important feeding and spawning habitat for fish because of the hydraulic conditions created by them but also the rock substrate which supports food sources including plants and macro-invertebrates. The hydraulic conditions include large eddies characterised by slow recirculating water flow in the wake (immediately downstream) of large obstacles where fish can take refuge during both wet and dry seasons. The fast flow jets and turbulence generated at rapids mobilise nutrients, plants and macro-invertebrates from the riverbed into the water column, providing sources of food for fish. The importance of rapids for aquatic organisms is evidenced by the many productive fishing grounds located at or nearby rapids (Poulsen et al. 2002b; Valbo-Jørgensen and Poulsen 2000). In addition, deep pools (Map 5.4) are often found immediately downstream of rapids due to the high erosive power of the fast flow jets and turbulence exiting the rapids which scour of the bed downstream.

Figure 11 Example of a rapid, Keng Si Nhok, on the Mekong River downstream of Luang Prabang in northern Lao PDR. Keng Si Nhok is a dangerous area for navigation resulting from two bedrock islands that heavily obstruct the navigation channel. The active channel in the dry season is only 31 metres wide and 15 metres deep, which together with fast flow and turbulence makes the rapid a major hazard for commercial and tourist vessels. Nonetheless, the same conditions make it an important fishing ground *(Photo: Navigation Programme, MRC)*.

Figure 12 Fishing activity at Keng Si Nhok rapid in northern Lao PDR. Rapids are characterised by high turbulence and alternating areas of fast and slow flow, which provide important feeding and spawning habitat for many Mekong fish species *(Photo: Navigation Programme, MRC)*.

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6 Water Uses

6.1 Existing and Planned Irrigation Projects

6.2 Percentage of District Area Under Irrigation

6.3 Existing and Planned Hydropower Projects

6.4 Installed Capacity of Hydropower Projects

6.5 Live Storage of Hydropower Projects

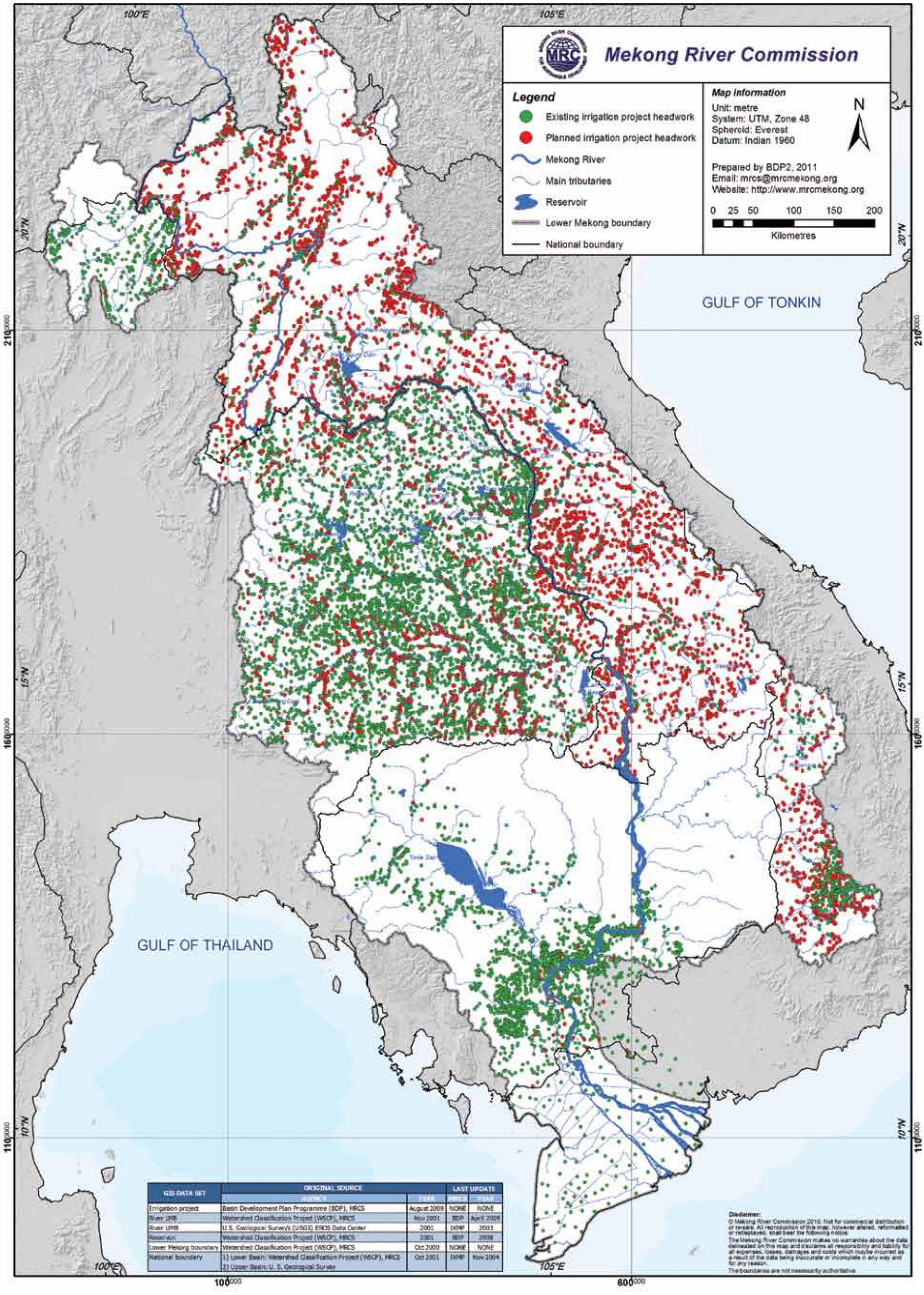
6.6 Mean Annual Energy of Hydropower Projects

6.7 Navigation

6.8 Consumption of Inland Fish and Other Aquatic Animals (kg/capita/year)

6.9 Consumption of Inland Fish and Other Aquatic Animals ('000 tonnes/year)

Existing and planned irrigation projects



6.1 Existing and Planned Irrigation Projects

The irrigation sector is the largest consumptive water user in the Basin. There are currently 11,420 projects in operation, irrigating a total of 4.0 million hectares. Of this total area, 87% is irrigated for wet season rice, predominantly as a supplement in periods of rainfall shortfalls; 31% for dry season rice cropping; 37% for rice cropping between the wet and dry seasons (the so-called '3rd season'), which mainly occurs in Viet Nam and to a smaller extent in Cambodia; and 15% for non-rice crops (Young 2009).

The adjacent map shows the distribution of existing and planned irrigation projects compiled from country data by the Basin Development Plan Programme of the MRC. The key features of this map are the large density of existing irrigation projects in northeast and northern Thailand, in southern Cambodia and the headwaters of the Sre Pok Basin in Dak Lak Province in Viet Nam; and secondly the large number of new projects planned in Lao PDR. Table 15 and Table 16 below provide details of the total irrigated areas in each country for existing and planned projects. The predicted areas of planned projects as well as expansions to existing projects are based on 20 and 50 year Basin-wide Development Scenarios (MRC 2010a) as put forward by each country and a recent irrigation sector review (Young 2009).

Thailand has the greatest number of existing irrigation projects (6,388) and the second largest area under irrigation after Viet Nam. Existing projects are located along river corridors and also the wider floodplain in northeast Thailand, surrounding large storage reservoirs and smaller weirs. Saline soils, high groundwater tables, limited tributary surface water runoff and pumping heads from the Mekong all pose major constraints for irrigated dry-season rice cropping in northeast Thailand. A further 990 projects are planned in Thailand, predominantly in the northeast region, possibly based on a series of pumped transfers from the Mekong.

Lao PDR has 2,330 existing projects but the total irrigated area and the average irrigated area of each project (71 ha) are small relative to other countries in the Basin (Table 15). This is largely due to the steep topography of the country and hence limited land area suitable for irrigation. The map here shows that existing projects are confined to narrow strips along major tributaries of the Mekong River and the Mekong River floodplain itself. Lao PDR has an ambitious plan for a further 2,768 irrigation projects in the future, focusing on irrigated non-rice crops in upland areas and dry-season rice, which under the 2030 Development Scenario are predicted to increase irrigated areas by 240% and 460% respectively (Figure 14 – see next page).

In Cambodia there are currently 2,091 projects irrigating 0.5 million hectares. Approximately equal portions of irrigated areas are for wet and dry season rice with minor irrigation of 3rd-season rice crops and non-rice crops. There are 32 new projects planned in Cambodia but these are not currently planned to be fully developed until 2060, with only a small, additional irrigated area of 6,000 ha planned for operation by 2030 (Table 16). The majority of the predicted 54% increase in annual irrigated area by 2030 is likely to come from expansion of existing projects (Table 15).

Viet Nam has fewer existing projects than any other country but each project irrigates a large area. Viet Nam has the largest annual irrigated area of 1.9 million hectares, which constitutes 48% of all irrigated land in the LMB (Table 15). Viet Nam also has the largest area in each category (wet, dry and 3rd season rice and non-rice crops) (Figure 13 – see next map). There are 339 new projects planned in the highland areas of the Sre Pok and Se San Basins, but they are small relative to existing projects (Table 16) so the predicted increase in annual irrigated area by 2030 for Viet Nam is is modest at 7%, with a focus on non-rice crops. Expansion of irrigated rice in the delta is limited by the land availability as well as environmental constraints including acid sulfate soils and saline water intrusion.

Several basin-wide constraints to irrigation development have been identified in the recent review of the LMB irrigation sector (Young 2009). These include the marginal nature of many planned sites since the best irrigation sites have been largely developed; and the extensive ongoing development of estate cash crops including oil palm and rubber which have reduced the land available for new irrigation schemes. Irrigation investments have moved towards small scale irrigation development with more involvement of water user groups. The operation of the planned new storages in the Lancang in PR China (and to lesser extent in other tributary reservoir schemes) is expected to increase the dry season flows in the Mekong mainstream substantially, making possible increased dry season abstractions for irrigation without significantly reducing historic flows into or saline intrusion within the Mekong delta, an important consideration for Viet Nam.

Table 16 Details of planned irrigation projects by country based on 2030 and 2060 Development Scenarios.

Country	No. of projects	2030 Development Scenario		2060 Long term Development Scenario	
		Annual irrigated area	Average area/project	Annual irrigated area	Average area/project
Cambodia	32	6,000	188	318,483	9953
Lao PDR	2,768	238,617	86	502,299	181
Thailand	990	946,162	956	984,904	995
Viet Nam	339	125,165	369	142,997	422
Total	4,129	1,315,944	319	1,948,683	472

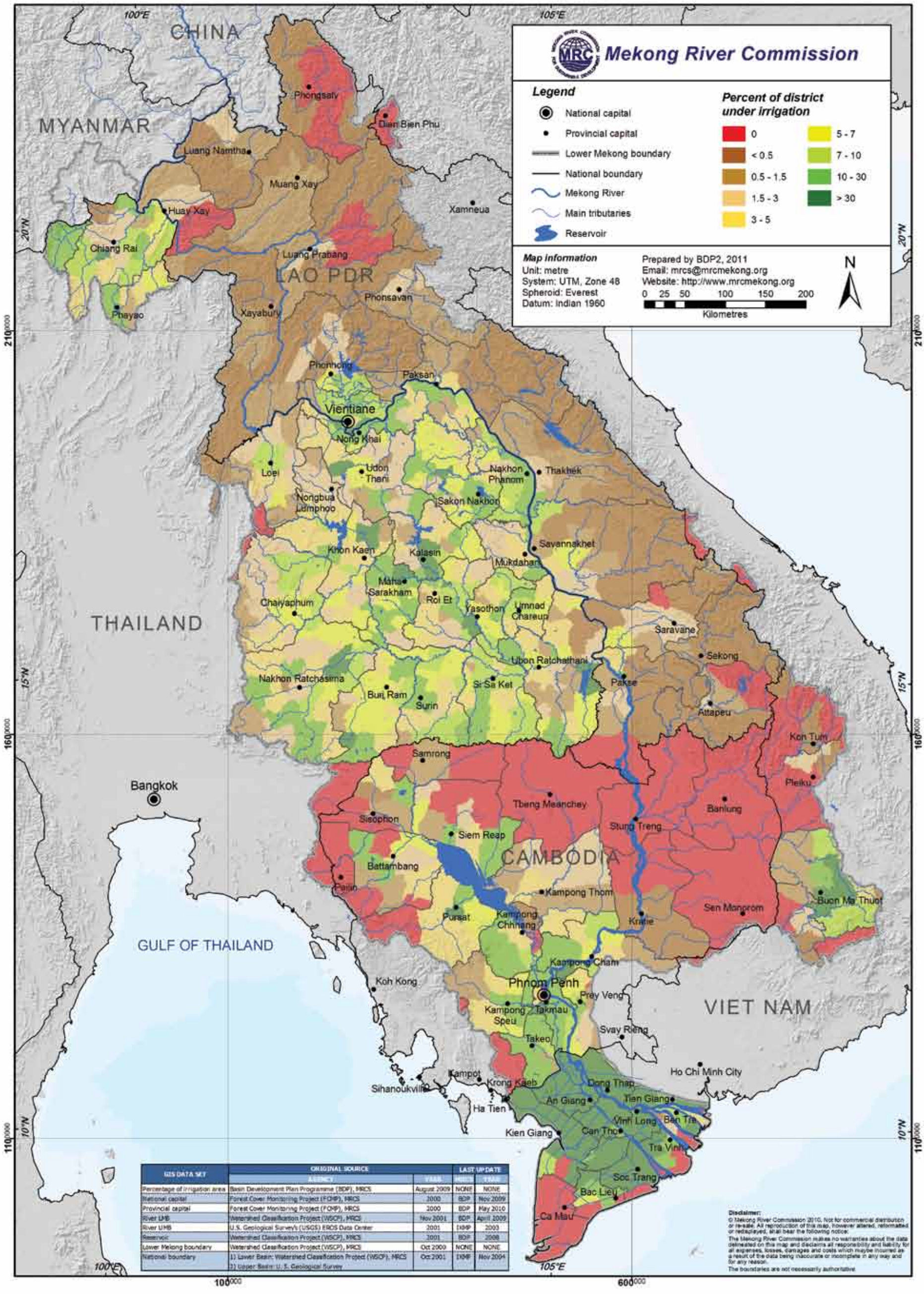
Table 15 Details of existing irrigation projects in the lower Mekong Basin by country: number of projects, total annual irrigated area, average project area and predicted expansion under 2030 and 2060 development scenarios. All areas are in hectares (ha).

Country	No. of projects	Annual irrigated area	Average area per project	2030 Development Scenario		2060 Long term Development Scenario	
				Annual irrigated area	Percent increase	Annual irrigated area	Percent increase
Cambodia	2,091	504,245	241	772,499	53%	837,542	66%
Lao PDR	2,333	166,476	71	213,062	28%	215,186	29%
Thailand	6,388	1,411,807	221	1,411,807	0%	1,411,807	0%
Viet Nam	608	1,919,623	3,157	1,919,623	0%	1,919,623	0%
Total	11,420	4,002,151	350	4,316,991	8%	4,384,158	10%

REFERENCES AND FURTHER READING

(see 6.2 References and Further Reading section)

Percentage of district area under irrigation



6.2 Percentage of District Area Under Irrigation

This is the second map in the series on irrigation and shows the percentage of each district currently under irrigation. The map shows similar spatial trends to the distribution of existing irrigation projects in the previous map, such that areas with the greatest density of irrigation projects tend to have the largest percentage of land under irrigation. These include districts in northeast and northern Thailand, southern Cambodia on the Mekong River floodplain and headwaters of the Sre Pok catchment in Dak Lak Province in Viet Nam. The exception to this correlation is the delta in southern Viet Nam, which has a lower density of irrigation projects but each project covers a large area, over 3100 ha on average, so that over 30% of most districts are under irrigation.

Lao PDR has the lowest overall proportion of land under irrigation which is largely due to the combined effect of steep topography and hence limited land area suitable for irrigation and secondly low historical investment in irrigation infrastructure. Districts with marginal areas under irrigation (1-3%) are located along the lower–lying Mekong River corridor and lower catchments of major tributaries. Much of the Se Kong- Se San - Sre Pok catchments in southern Lao PDR and eastern Cambodia also have negligible irrigated area.

Figures below shows the distribution of existing and potential irrigated areas among four main cropping patterns: wet, dry and 3rd season rice and non-rice crops: in each country. Figure 2 quantifies the predicted percentage increase in each crop type between the existing irrigated area and the development scenario for the year 2030 as discussed in the description of the previous map on irrigation projects.

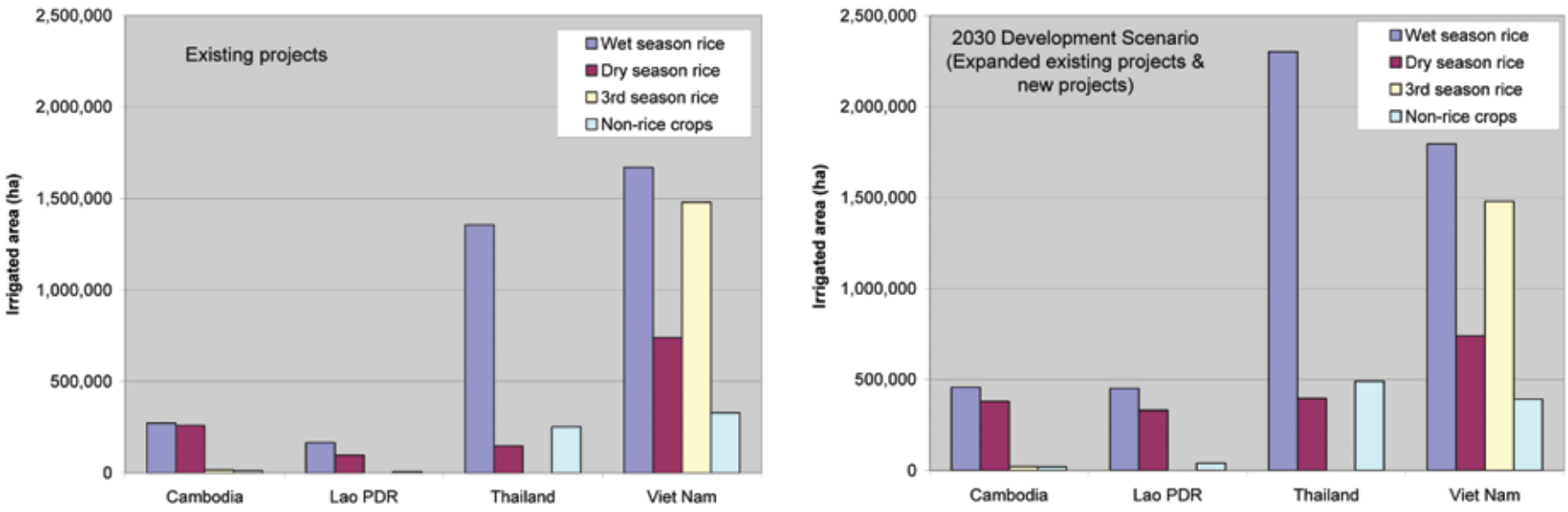


Figure 13 Irrigated area for rice crops (wet season, dry season & 3rd season) and non-rice crops under A) existing irrigation projects and B) the 2030 development scenario which includes new projects and expansion of existing projects.

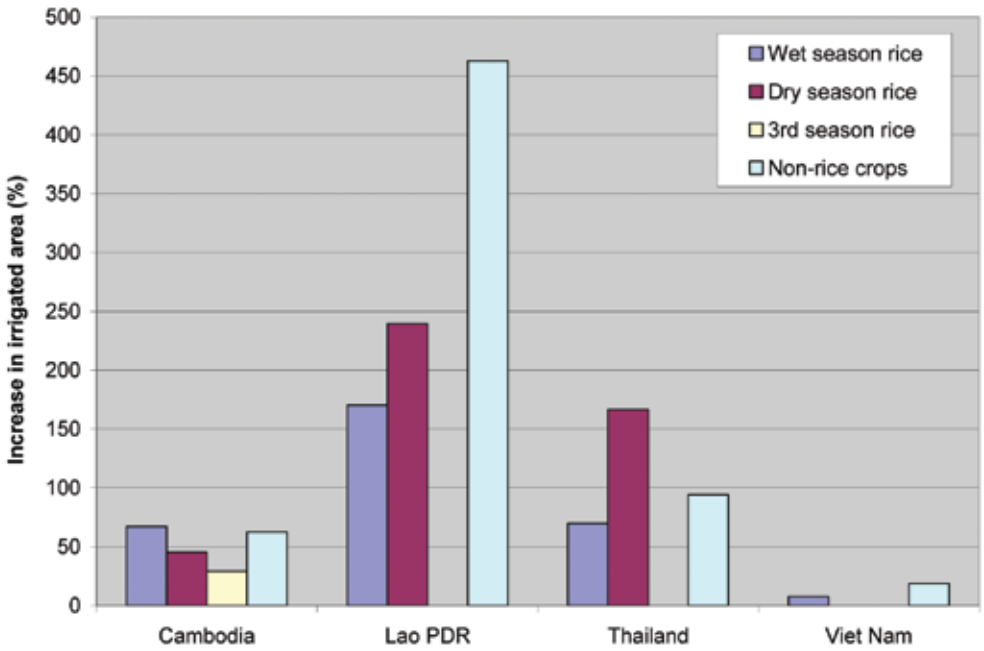


Figure 14 Predicted increases in irrigated area between the 2008 situation and the 2030 scenario for various crop types.

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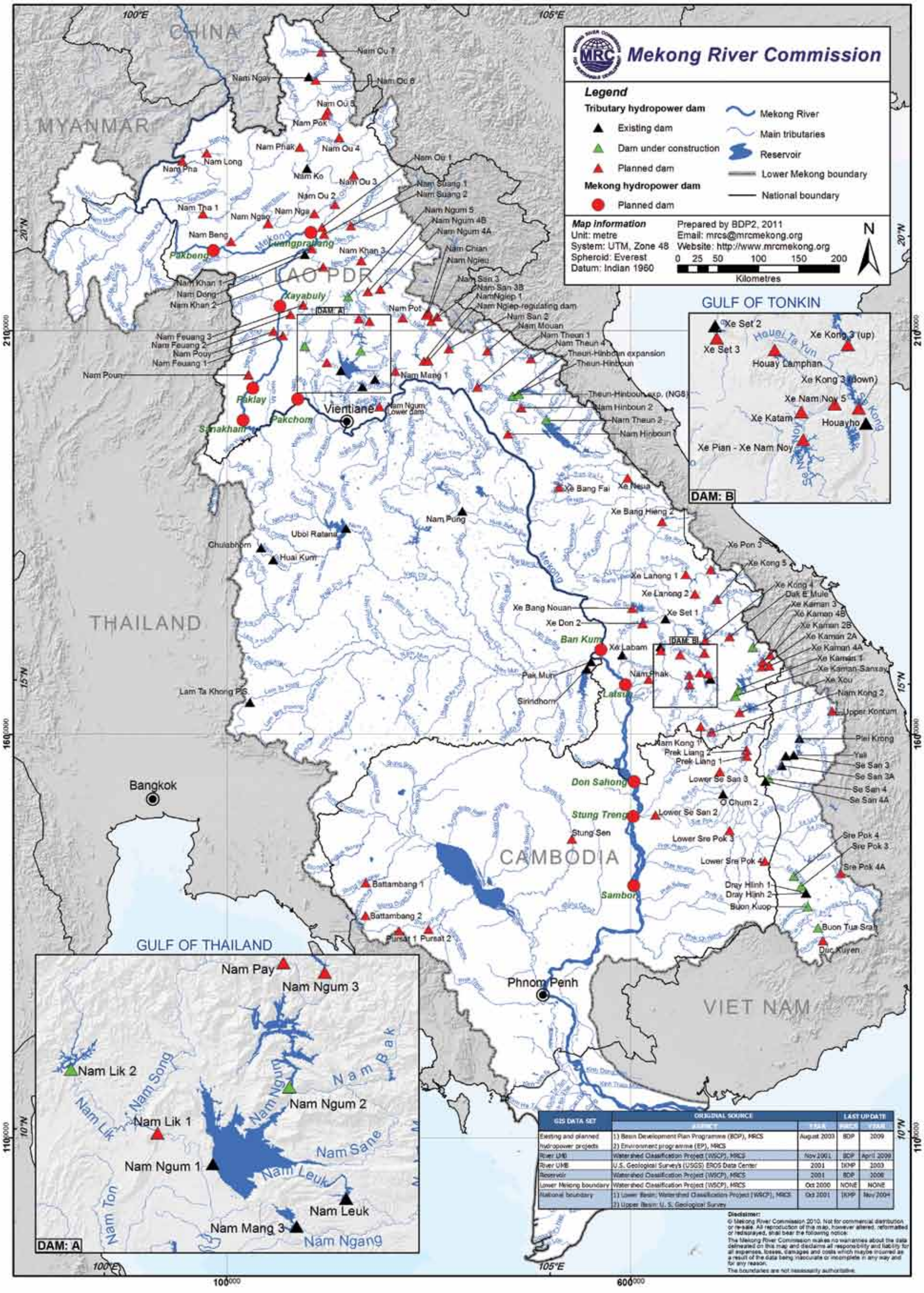
Existing and planned hydropower projects



6.3 Existing and Planned Hydropower Projects

The Mekong has become of the most active regions in the world for hydropower development with a large number of large hydropower projects planned. This is the first of four maps describing the location, storage capacity and energy production characteristics of existing and planned hydropower projects in the lower Mekong Basin.

This first maps shows the location of all existing projects in 2009, projects under construction in 2009 (some of which, like Nam Thuen 2 in Lao PDR, have now been completed), and planned projects. Table 17 below shows the number of projects in each country. The information in this map and subsequent three maps is from the MRC's Hydropower Database (MRC 2009) based on data provided by the four LMB countries and private developers. Only medium and large dams in excess of 1 MW are included in this database, which excludes for instance the numerous small dams constructed since the 1960's in the northeast of Thailand to store local supplies.

There are 26 existing medium and large dams on tributaries of the Mekong River and 13 under construction or recently completed. There are currently no dams on the Mekong mainstream downstream of PR China, but the first of 11 planned mainstream dams, the Xayaburi Dam to be located in Lao PDR, is currently in the late stages of planning and under review by the LMB countries as part of the MRC's Prior Consultation Process. This consultation process under the Procedures for Notification, Prior Consultation and Agreement (PNPCA) is a requirement of the 1995 Mekong Agreement and involves countries jointly reviewing any development project proposed for the mainstream with an aim to reach a consensus on whether or not it should proceed, and if so, under what conditions.

Of the 11 planned mainstream dams, two would be located on Thai-Lao PDR border (Pakchom and Ban Kum), seven are in Lao PDR and two in the lower reaches in Cambodia. The 11 proposed mainstream dams and 85 proposed tributary dams are at various stages of planning and have widely variable predicted start dates, ranging from projects without a feasibility study to ones at an advanced stage of planning and environmental assessment. Lao PDR have very ambitious plans for not only nine mainstream dams but an additional 71 dams on tributaries. Several large tributary basins, including the Nam Ngum catchment near Vientiane, Nam Thuen-Nam Kading catchments in central Lao PDR, the Nam Ou catchment in the north and the Se Done catchment in the south, have numerous proposed dams that would operate as a cascade. Similarly, the transboundary Se Kong – Se San –Sre Pok Basin has 24 additional planned dams including four very large dams (Lower Se San 2 & 3 and Lower Sre Pok 3 &4) which would have reservoir areas greater than 350 km^2 and larger than the area of the existing Nam Ngum dam (the large reservoir north of Vientiane).

Thailand currently has seven hydropower dams in the northeast of the country but no plans for any additional dams in the near future. Viet Nam has seven existing hydropower dams and five under construction in the Se San and Sre Pok catchments with plans for an additional three in the same catchments. The 11 tributary dams planned by Cambodia are all located in the Se Kong – Se San – Sre Pok Basin as described above.

Table 17 Number of existing, under construction and planned hydropower projects in the lower Mekong Basin by country.

Country	Mekong River	Tributary				Total
	Planned	Existing	Under construction	Planned	Tributary total	
Cambodia	2	1	-	11	12	14
Lao PDR	9*	11	9	71	91	100
Thailand	-	7	-	-	7	7
Viet Nam	-	7	5	3	15	15
Total	11	26	14	85	125	136

*Lao PDR and Thailand share borders on two of the proposed mainstream dams. These projects are included under Lao PDR in this table.

REFERENCES AND FURTHER READING

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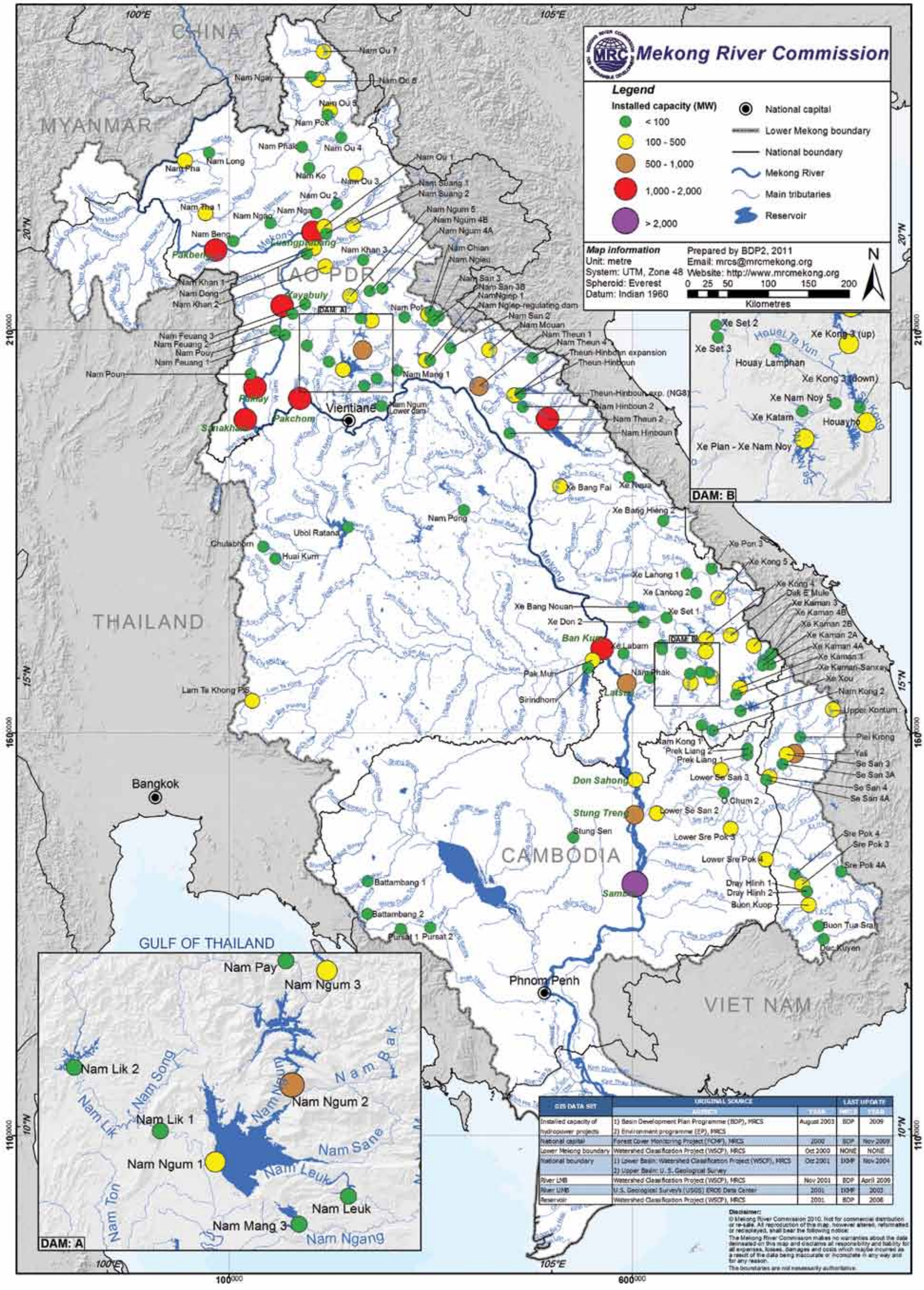
Installed capacity of hydropower projects



6.4 Installed Capacity of Hydropower Projects

Installed capacity refers to the total power output of turbines at a dam and is measured in megawatts (MW). The installed capacity is determined by the design of turbines, the number of turbines, the 'design flow' (the rate of water flow through the turbines) and the 'head' (pressure difference between the reservoir water level and the outfall level). The design flow is predominately a function of the mean flow of the river and hence also catchment (watershed) area, such that larger catchments and larger river flows allow for greater installed capacity. The close positive relationship between catchment area and installed capacity of LMB dams is illustrated in Figure 16. The design flow is also influenced by the operating procedures of the dam, for example, in response to fluctuations in energy demand.

The adjacent map shows the installed capacity of existing and planned hydropower projects and those under construction. The installed capacity is represented by the size and colour of the circles. The planned dams of the Mekong River mainstream would have the largest installed capacity (>1000 MW) owing to the large mean annual flow of the Mekong River. The largest of these is the planned Sambor dam in Cambodia with an installed capacity of 3300 MW.

Basin wide, the total installed capacity of all existing dams is just over 2,600 MW but could potentially rise tenfold to 29,700 MW if all planned dams are built. This includes 12,300 MW from planned tributary dams and 14,700 MW from the 11 planned dams on the Mekong mainstream (Table 18). Figure 15 below shows that the large majority (70%) of future potential installed capacity on both the Mekong Mainstream and tributaries is in Lao PDR. Currently, 45% of the installed capacity is in Viet Nam, generated from several dams on the upper Se San and Sre Pok rivers. Lao PDR and Thailand each have 27% of the Basin total capacity, while Cambodia currently only has one hydropower dam with an installed capacity of 1 MW. The ambitious expansion hydropower plans would see large increases in installed capacity in Cambodia (5600 fold increase) and Lao PDR (a 27 fold increase) as indicated in Table 18 below.

Table 18 Total installed capacity of existing, under construction and planned hydropower projects for the four lower Mekong Basin countries and the Basin overall.

Country	Mekong River	Tributaries				Total
	Planned	Existing	Under construction	Planned	Tributary total	
Cambodia	4,280	1		1,309	1,310	5,590
Lao PDR	10,417	738	2,764	6,847	10,350	20,767
Thailand		745			745	745
Viet Nam		1,204	1,016	363	2,583	2,583
Total	14,697	2,688	3,780	8,519	14,987	29,684

Figure 15 Total installed capacity of existing and planned projects on the Mekong mainstream and tributaries for the four lower Mekong countries. If all planned projects are built, 70% of the installed capacity will be in Lao PDR, with equal contributions from mainstream and tributary dams.

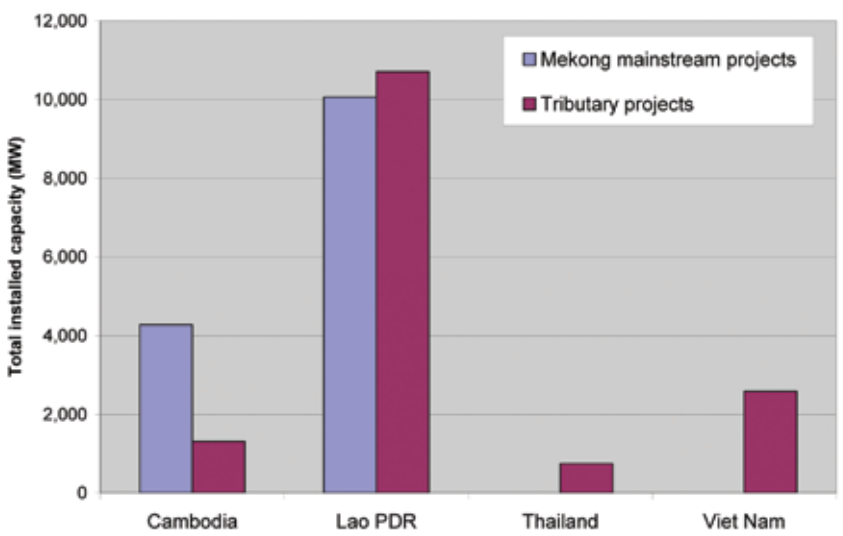
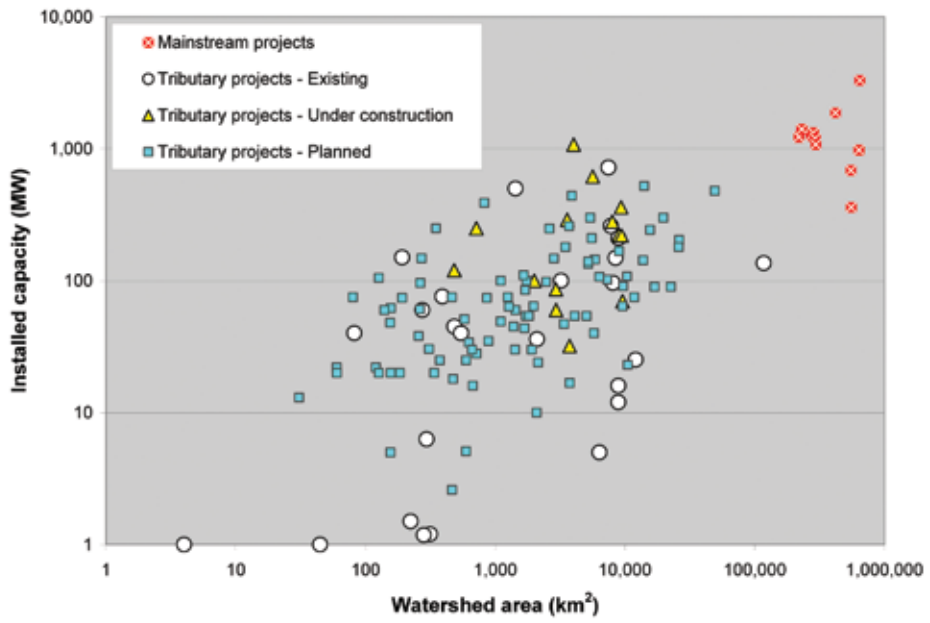


Figure 16 A plot of the watershed area versus installed capacity of existing, under construction and planned hydropower dams in the lower Mekong Basin. The installed capacity is the total power output of turbines at a dam and is a function of the design flow through the turbines, which is in turn determined by the watershed area and mean annual flow of the river entering the dam.



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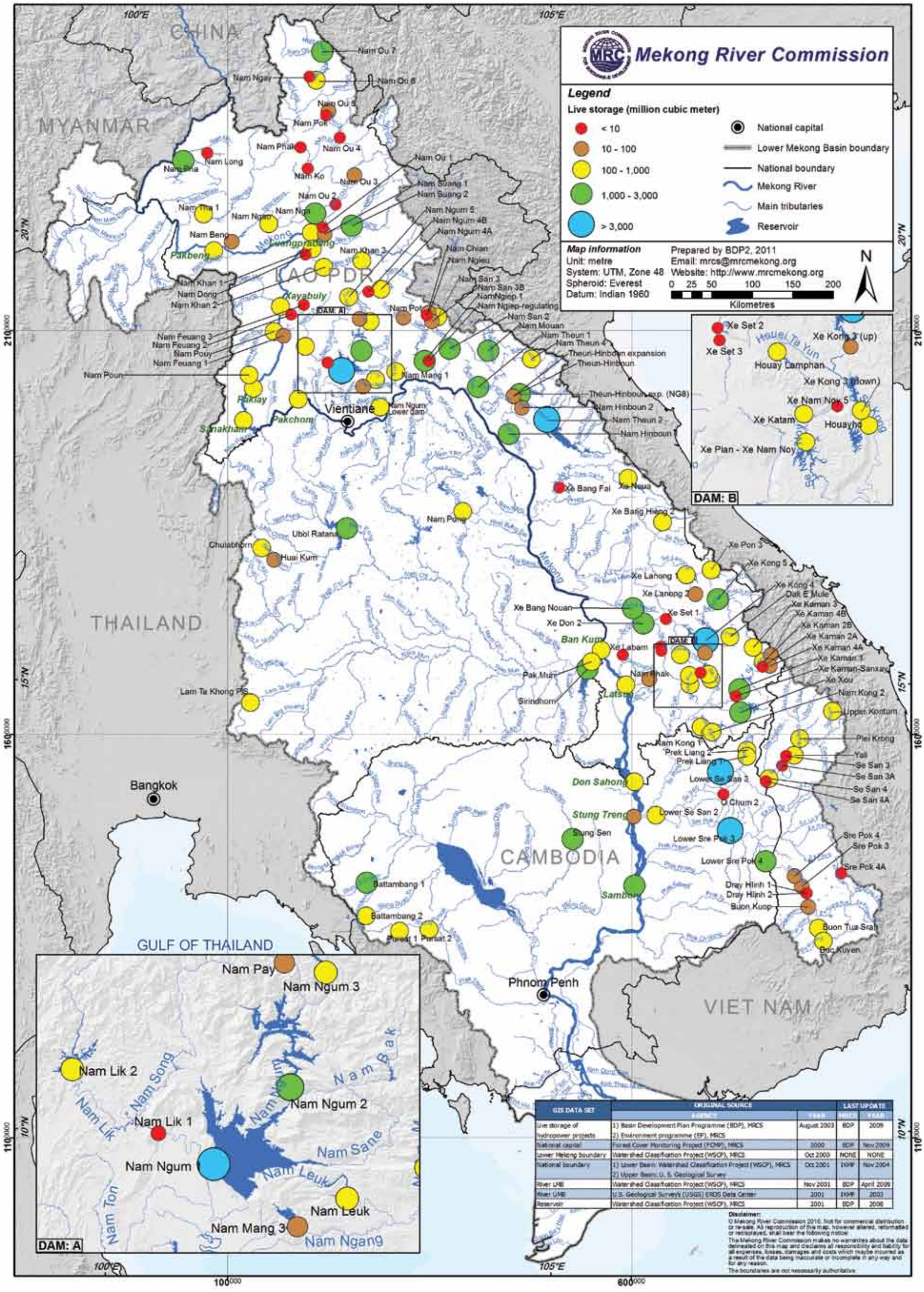
Live storage of hydropower projects



6.5 Live Storage of Hydropower Projects

Live storage, also known as 'active storage' refers to the volume of water retained by the dam (i.e. in the reservoir) under the minimum normal operating water level. Operating levels and storage volumes will fluctuate seasonally in response to changes in river flow, but also in response to energy demand. In the adjacent map, live storage of all existing, under construction and planned dams is illustrated by colour and by size of the circle. The largest existing dam in terms of live storage is Nam Ngum I located north of Vientiane in Lao PDR with a live storage of 4,700 million cubic meters (m^3). The recently completed Nam Thuen 2 dam in central Lao PDR has a similarly large live storage of 3,378 million m^3, while three planned dams in the Se Kong-Se San-Sre Pok Basin will each have a live storage greater than 3,000 million m^3. Note that the live storage of the planned dams on the Mekong mainstream is relatively low: 70 – 734 million m^3, except for Sambor in Cambodia which is 2000 million m^3.

Live storage is the major determinant of sediment trapping behind the dams. Larger reservoirs will trap a greater proportion of the incoming sediment load due to slower downstream water velocities within the reservoir. Sediment trapping limits the life of the dam and has negative consequences for turbine operation and the structural stability of the dam wall. It also has several environmental consequences including reduced supply of sediment and nutrients to the river downstream. Live storage also determines the dams capacity to re-regulate river flows, and consequently the degree to which the dam can contribute to reducing flood peaks and consequential damage to the livelihoods and property of those living downstream. Dams commonly obstruct fish migration (which in some cases for low head dams has been shown to be mitigated by fish ladders), diminishing the productivity of natural fisheries, but can also create new opportunities for fisheries development within the reservoirs.

Live storage is closely related to the area of land inundated upstream of a dam (i.e. the reservoir area), as illustrated in Figure 17 below. However, reservoir area is also determined by the land topography upstream of the dam, such that for a given volume of stored water, reservoirs in deep and narrow valleys will be deeper and smaller in area compared to reservoirs located on low lying topography which will be shallow and larger in area. Larger reservoir areas tend to displace more people and create greater losses of agricultural land and forests.

Of the existing hydropower dams, Nam Ngum 1 has the largest reservoir area of 294 km^2. The recently constructed Nam Thuen 2 dam has a similar reservoir area (Figure 17). While most planned hydropower dams, including the mainstream dams have predicted reservoir areas of less than 200 km^2, there are six planned dams in Cambodia with much larger estimated reservoir areas (>300 km^2). Two of these: Sambor dam on the Mekong mainstream just upstream of Kratie and the Lower Se San 3 dam on the middle reaches of the Se San River will each have a reservoir area of more than 1,000 km^2, which is more than three times the size of the existing Nam Ngum 1 dam and just under half the area of Tonle Sap lake during the dry season. The large reservoir area but relatively small live storage of these two dams compared with Nam Ngum 1 dam reflects that these dams will be shallow due to the low lying topography of the planned inundation area.

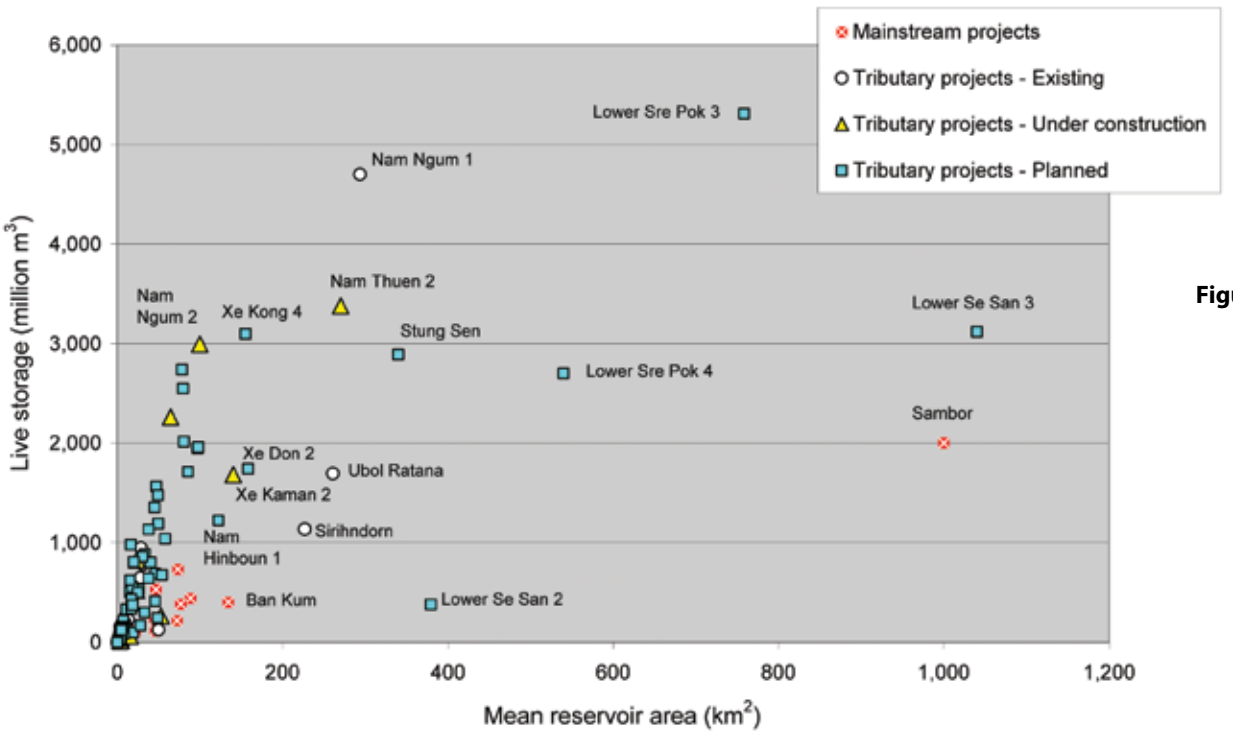


Figure 17 A plot of predicted mean reservoir area (averaged over the year) versus live storage for existing, under construction and planned hydropower projects in the lower Mekong Basin. While the majority of planned projects and those under construction have predicted reservoir areas of 10-100 km^2, 13 will have reservoirs areas larger than 100 km^2 and two dams in Cambodia will have reservoir areas larger than 1000 km^2. These latter two projects are predicted to inundate more than three times the area of the existing Nam Ngum 1 reservoir in Lao PDR.

REFERENCES AND FURTHER READING

MRC (2009), *Lower Mekong Basin Hydropower Database*. Mekong River Commission, Vientiane.

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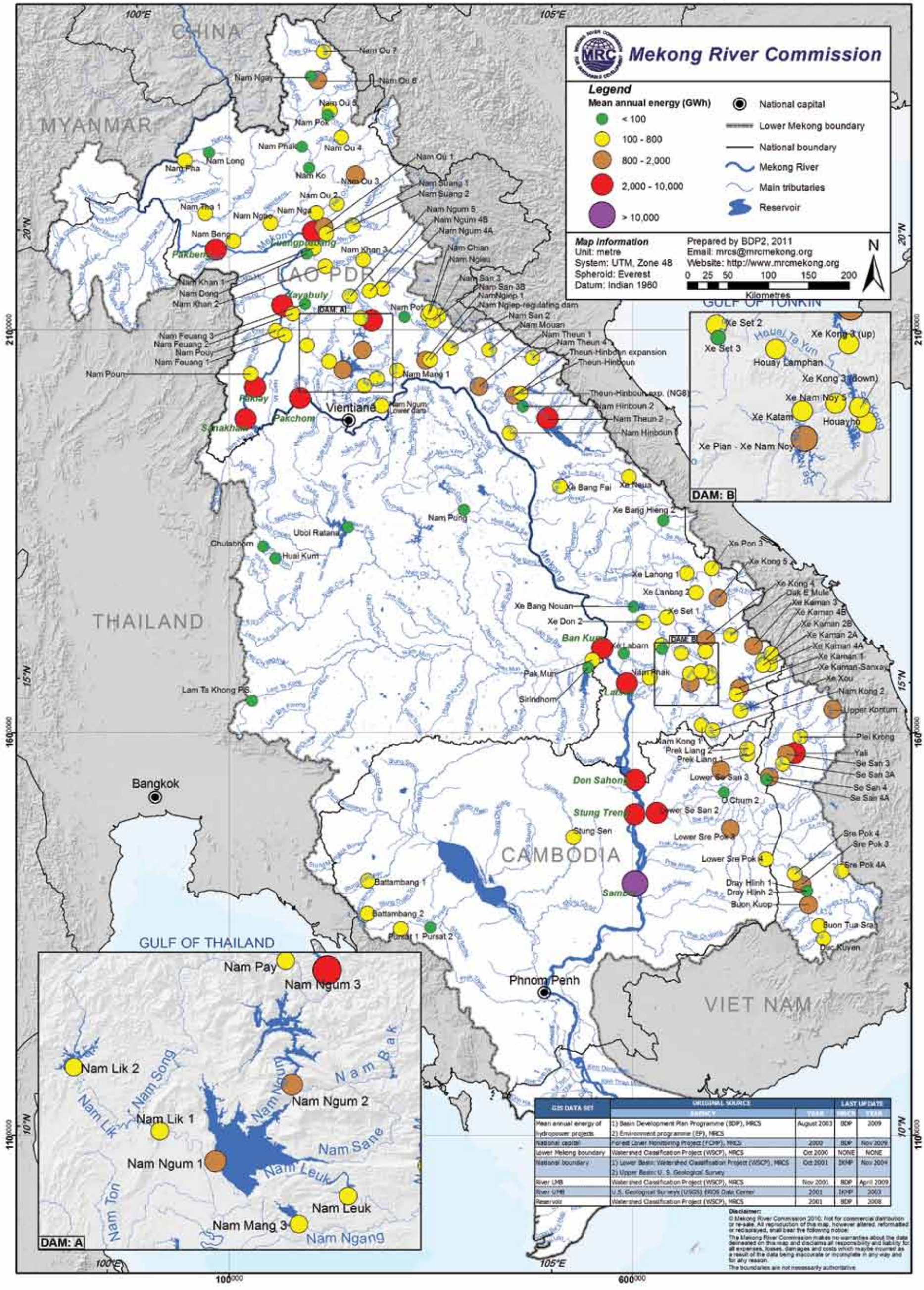
Mean annual energy of hydropower projects



GIS DATA SET	ORIGINAL SOURCE		LAST UP DATE	
	AGENCY	YEAR	MRCS	YEAR
Mean annual energy of hydropower projects	1) Basin Development Plan Programme (BDP), MRCS 2) Environment programme (EP), MRCS	August 2003	BDP	2009
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	BDP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Surveys (USGS) EROS Data Center	2001	BDP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

6.6 Mean Annual Energy of Hydropower Projects

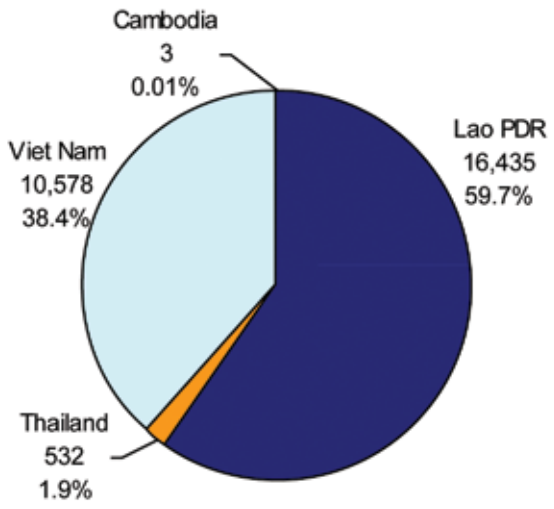
The mean annual energy output of a hydropower dam is a function of the installed capacity of the turbines (see previous map), the rated head and the volume of water passed through the turbines. Head is defined as the difference between the water elevation in the reservoir and the elevation of the turbines which are located towards the base of the dam wall. Head is a measure of the height of water fall at the dam and represents the potential energy of the water stored in the reservoir. Rated head refers to the head at the minimum operating water level. For the same design flow and therefore installed capacity, dams with a larger rated head will produce more energy.

The adjacent map illustrates the mean annual energy production of all existing and planned hydropower projects in the lower Mekong Basin and those under construction. Mean annual energy production is represented by the size and colour of circles. Sambor Dam will have the largest mean annual energy output of 14,870 gigawatts per hour (GWh). This large energy output is predominantly due to the dams position in the lower reaches of the Mekong River allowing a very large design flow through the turbines of more than 19,000 m^3/s. The rated head of the Sambor dam, like most of the planned mainstream dams is only moderate at 32.9m. An additional 11 planned dams would each produce between 2,000 and 10,000 GWh of energy annually. These include the other planned mainstream dams and the recently completed Nam Thuen 2 dam in Lao PDR.

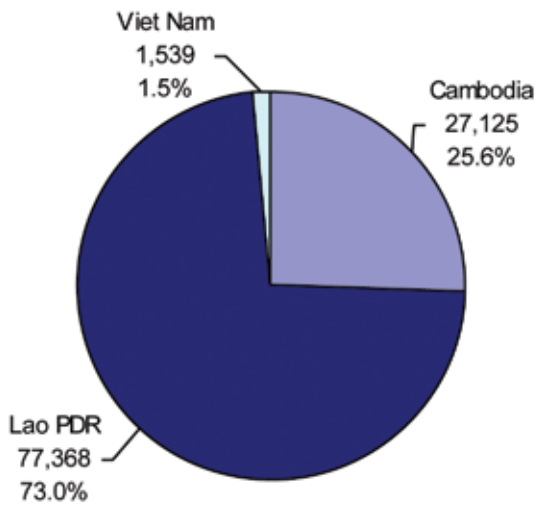
The pie graphs below illustrate the distribution of mean annual energy production from hydropower between the four lower Mekong countries for: a) existing projects and those under construction, b) planned projects and c) existing and planned projects combined. When the under construction projects are operational, Lao PDR will produce 60% of total hydropower energy production in the LMB (over 16,000 GWh). Viet Nam produces 38% (10,600 GWh), while Thailand 2% and Cambodia, with one existing, only 0.01%. Of the planned projects, 73% of the total planned additional energy production is in Lao PDR, which aims to increase production by 77,400 GWh; and 26% in Cambodia, which aims to produce 27,000 GWh from new projects. If all planned projects would be completed, Lao PDR would produce 70% of the Basin's energy (93,800 GWh), followed by Cambodia (20%), much of which would come from the Sambor Dam on the Mekong mainstream, Viet Nam 9% and Thailand 0.4%.

It is noted that electricity demand of the region is much higher than hydropower development in the Lower Mekong Basin can provide. For example, the annual energy potential of all the planned hydropower projects in the Lower Mekong Basin (ie the projects that are not yet under operation or under construction) will probably be less than 15% of the combined electricity demand of Viet Nam and Thailand in 2020.

A) Existing projects and those under construction



B) Planned projects



C) Existing and planned projects combined

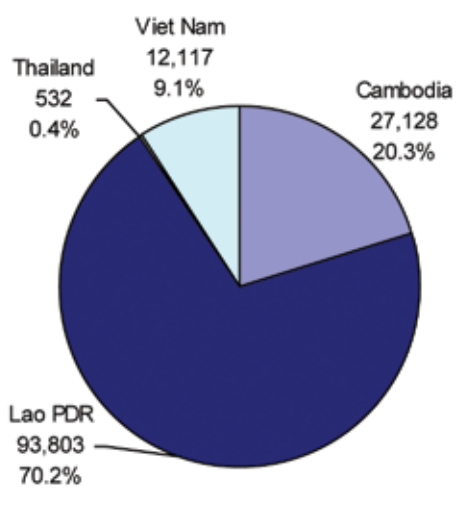


Figure 18 Pie graphs showing the distribution of mean annual energy production from hydropower between the four lower Mekong countries for: a) existing projects and those under construction, b) planned projects and c) existing and planned projects combined

REFERENCES AND FURTHER READING

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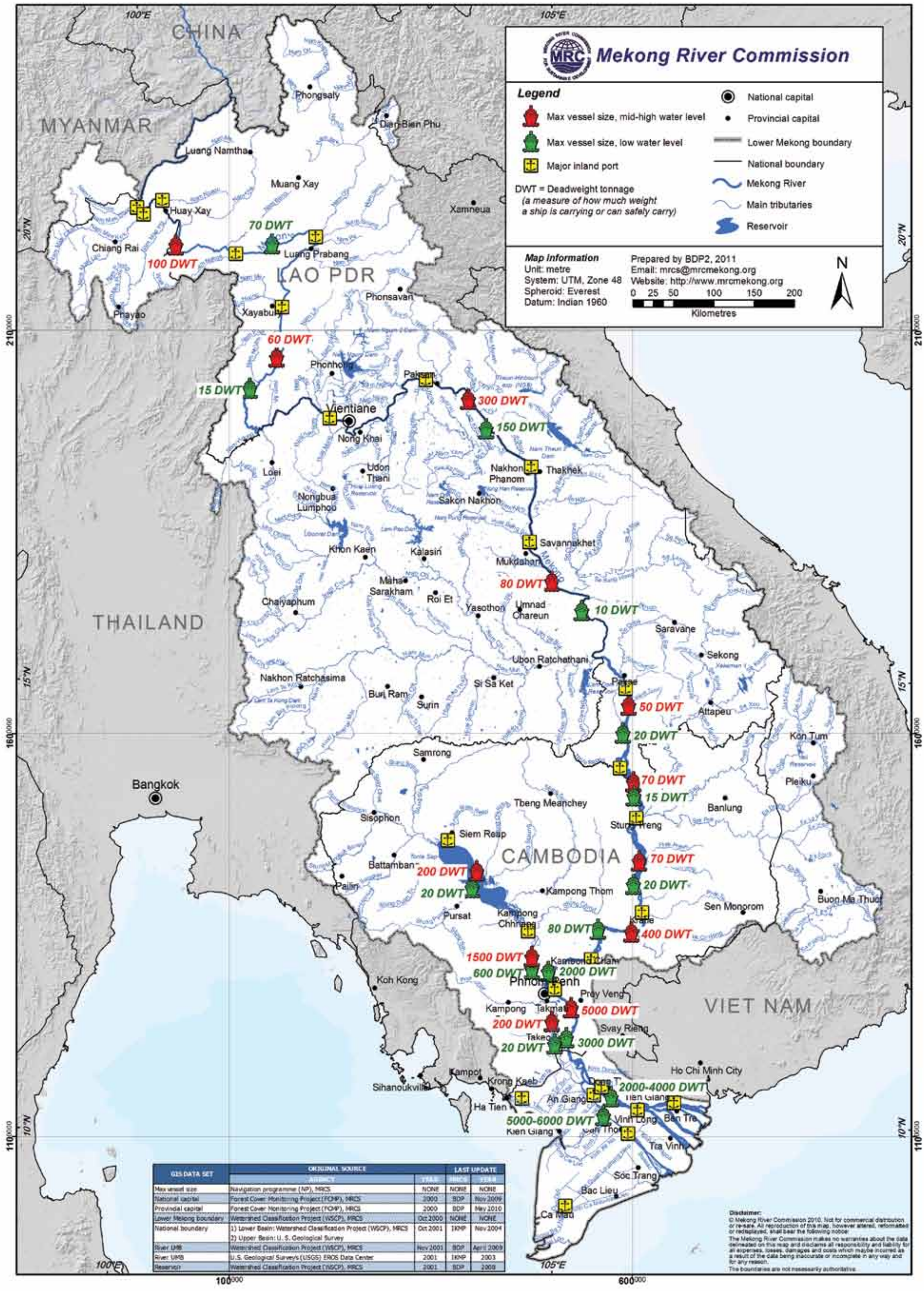
Navigation



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Max vessel size	Navigation programme (NP), MRCS	NONE	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River UMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2009

6.7 Navigation

The Mekong River is being increasingly utilised for waterborne trade and tourism. While traditional forms of trade in small boats linking local communities has occurred for thousands of years and continues today, the river is also becoming an important international trade route. Each year, about 300,000 tonnes of goods are shipped via the Mekong for part of the transit chain between Kunming in China and Bangkok (MRC 2010d). The navigation capacity of the Mekong River is highly variable as depicted in this map of deadweight tonnage (DWT), the maximum weight a ship can safely carry, in various river reaches. The location of all ports on the Mekong mainstream and the Tonle Sap River are also shown.

Much of the lower Mekong River is cut into bedrock and flows through steep and narrow valleys. The influence of bedrock is intermittent but extends downstream to within 20 km of Kratie in Cambodia, placing a major constraint on the navigation potential of the River. Rapids, narrow channels, strong currents and tight bends limit the size and weight of vessels able to safely navigate bedrock reaches.

Navigation is further limited by the prolonged dry season, when water levels drop to as low as 2-5 m along the thalweg (line of deepest flow along a river) of alluvial reaches and 5-10m in bedrock reaches. In bedrock reaches, flow is often limited to a narrow inner channel cut into the much wider 'outer' channel that carries the wet season flow. The narrow channel width poses safety risks for two ships passing each other. Furthermore, outcrops of bedrock in the riverbed become exposed at low flows creating additional hazards for ships. Partially submerged rocks also pose great hazards. In alluvial reaches, deposition of large sand bars towards the end of the wet season pose draft restrictions as water levels continue to drop through the dry season, especially in the alluvial reach between Vientiane to Savannakhet where low water DWT is only 150 T compared with 2000-3000 T in alluvial reaches downstream of Kampong Cham in Cambodia. The navigation capacity of various river reaches is summarised below and based on the work of the Navigation Programme of the MRC.

Golden Triangle to Luang Prabang (362 km)
Year-round navigation is possible but hampered by rocky passages and strong currents. Maximum capacity is 70 T at low water levels and 100 T at mid-high water levels. Channel width and depth are highly variable but the channel is generally deeper than the next reach.

Luang Prabang to Vientiane (425 km)
This is one of the most difficult reaches for navigation due to strong structural controls on the River with extensive bedrock exposed in the bed and banks. Navigation capacity is limited to 60 T at mid-high water levels. During the dry season only small boats (max 15 T) and skilled pilots can negotiate the swift currents combined with sharp bends and frequent bedrock obstructions in the narrow and winding inner bedrock channel of this reach.

Vientiane to Savannahkhet (459 km)
Navigation is possible year-round in this wide alluvial reach but restricted to 150 T during low water conditions and 300 T during mid-high water levels. During the low water season, draft restrictions must be observed due to shallow sand bars and occasional rocky outcrops.

Savannakhet to the Lao PDR-Cambodian border (419 km)
South of Savannakhet numerous rapids (see Map 5.5) extending along 60 km of the river in the vicinity of Khemmarat restrict navigation to mid and high water levels and a maximum DWT of 80 T. The Mekong River is a narrow and winding, bedrock channel as it crosses a mountain range: Phu Phan Uplift (see Map 3.1) and the edge of the Khorat Plateau.

Lao PDR-Cambodian border to Kratie (168 km)
Although a number of rapids make navigation difficult, 400 concrete beacons have been installed since 1910 to mark the navigation channel. During high water levels, vessels of up to 50-70 T can pass while dry season navigation is restricted to vessels of only 15-20 T. The Khone Falls, a 10m high waterfall located near the Lao PDR – Cambodian border creates an absolute barrier to navigation.

Kratie to Phnom Penh (213 km)
Downstream of Kratie, there is an abrupt change to an alluvial channel without bedrock control. Navigation capacity between Kratie and Kampong Cham increases to 400 T at mid-high water levels, and 80 T at low water levels. Deposition of sandy sediment on the riverbed during the dry season limits the available draft for vessels. Navigation capacity increases with distance downstream to the delta and is due to steady increase in thalweg depth associated with downstream fining of bank sediments which increases bank strength and forms a narrower and deeper channel. There is no difficulty for 4m draft maritime ships, equivalent to about 2000 DWT to reach Kampong Cham from the sea year round provided that proper navigation systems and river maintenance are ensured.

Phnom Penh to the sea
Phnom Penh can be reached by maritime vessels up to 4,000-5,000 DWT. The proximity to the sea means that the difference between wet and dry season water levels is much smaller than upstream river reaches and this DWT can be maintained throughout the year. The Bassac River distributary between Phnom Penh and the the Vam Nao Pass (a short channel linking the Mekong and Bassac dsitributaries in Viet Nam) has a low DWT capacity of 400 T. However, downstream of the Vam Nao Pass, the Bassac River has the larger capacity of up to 5000 T.

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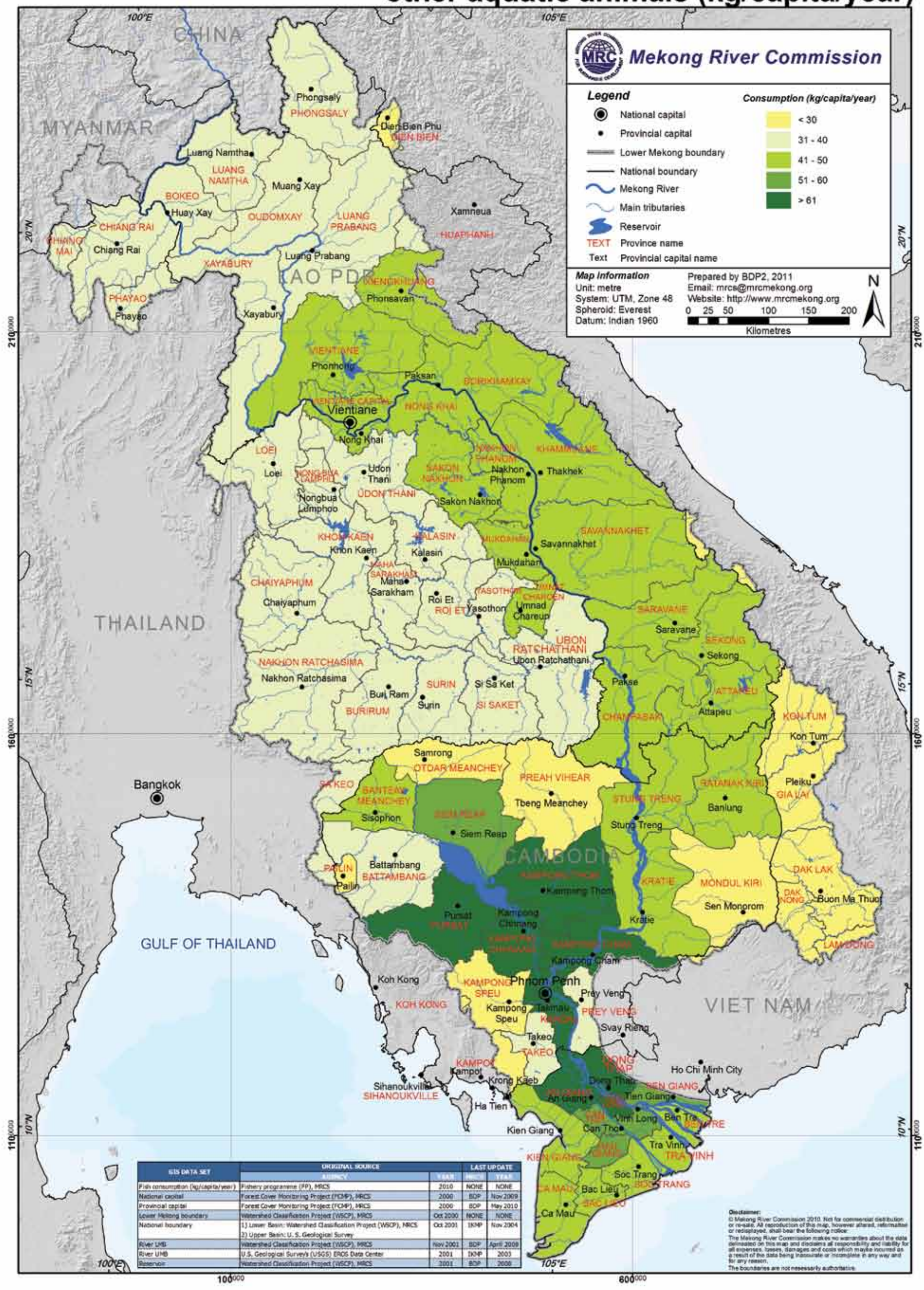
- Starr, P. (2004) *The People's Highway: Past, Present and Future transport on the Mekong river system*. Mekong Development Series No. 3. Mekong River Commission, Phnom Phen. p 44.

Consumption of inland fish and other aquatic animals (kg/capita/year)



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Fish consumption (kg/capita/year)	Fishery programme (FP), MRCS	2010	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2009

6.8 Consumption of Inland Fish and Other Aquatic Animals (kg/capita/year)

In the LMB, almost all people regularly eat fish and 'other aquatic animals' (OAAs). The term 'OAA' includes all freshwater animals other than fish, including both vertebrates (aquatic mammals, frogs, reptiles – including snakes, and water birds) and invertebrates (snails, crabs, shrimp and water insects). Fish and OAAs provide a major source of protein and essential elements and vitamins for people of the LMB. Basin wide, average per capita consumption of inland fish and OAAs is about 45 kg per year as 'fresh whole animal equivalent weights' (FWAE) or 34kg per year as actual flesh consumed. Country averages range from 41-51 kg/capita (Figure 19). The adjacent map shows the distribution of per capita consumption of inland fish and OAAs by Province in 2000. Overall, Cambodia and Viet Nam have above average per capita consumption, while consumption is below average in Lao PDR and Thailand.

Provincial estimates are based on a synthesis of the results of 20 field surveys conducted at various locations in the LMB between 1988 and 2002 (Hortle 2007). Data were typically obtained through interviews where people were asked to recall their weekly household consumption of fish and OAAs. Two studies directly monitored household consumption. Overall, measured data was available for 26 out the total 87 Provinces in the LMB. For Provinces where per capita consumption data were not available, Hortle (2007) derived estimates using per capita consumption data from nearby Provinces with similar ecology and socio-economic structure.

People residing in central Cambodia, particularly the Provinces surrounding the lower Tonle Sap Lake and the upper delta in Viet Nam consume the most fish and OAAs (> 61 kg/capita/year). The highest consumption is 112 kg/capita/year in Kampong Chhnang Province, located at the confluence of the Tonle Sap Lake and Tonle Sap River. Thee Provinces surrounding the Tonle Sap Lake and in the upper delta are the most productive part of LMB for inland fisheries. This is the result of large areas of these Provinces being inundated each year by either floodwaters or rainfall held in rice paddies, providing ideal spawning habitat for fish and an abundance of food for fish and other aquatic animals.

Per capita consumption is moderate (41-60 kg/ year) in central and southern Lao PDR and the lower delta in Viet Nam; and slightly lower in northern Lao PDR and most of northeast Thailand (31-40 kg/year). Although much of Lao PDR is mountainous, there are numerous rivers and streams and most people have access to rice paddies where many OAAs and smaller fish are caught. In the central and southern Provinces of Lao PDR, the lower part of tributary catchments tend to have larger floodplains and more numerous wetlands along river corridors than in the northern Provinces, and hence more productive fisheries. The Siphandon area in Champasak Province is a particularly productive fishing ground owing to the numerous channels characterized by deep pools and rapids and seasonally flooded forests which together provide diverse habitats and food for fish and OAAs (Baird and Flaherty 2004; Baird and Flaherty 2005)

The lower than average per capita consumption in Lao PDR may be due, in part, to larger average household size (see Map 2.6), and in particular due to a larger number of children per household who eat less or because larger households can acquire less food per capita (Hortle 2007). In the lower delta in Viet Nam, the lower per capita consumption of inland fish and OAAs in the lower delta near the sea compared with the upper delta is due to greater consumption of marine fish in Provinces located closer to the sea (Hortle 2007). Provinces in the central highlands of Viet Nam and upland areas in Cambodia ate the least amount of fish and OAAs (21-30 kg/year) but were not directly surveyed. Hortle (2007) estimated that people in the central highlands consumed 50% of the average consumption in delta Provinces, and people in the highland areas of Cambodia consumed 50% of the average consumption in Svay Rieng Province, which had a similarly drier climate and the lowest consumption of the surveyed Provinces.

Figure 19 below describes the per capita consumption of inland fish (fresh and preserved), OAAs and marine fish by country. Preserved fish includes fermented, smoked, dried and salted fish as well as fish paste and fish sauce. People in Cambodia, Thailand and Viet Nam eat more fresh fish than preserved, while in Lao PDR, near equal amounts of fresh and preserved fish are consumed. Per capita consumption of OAAs is similar in each country, 5.4 - 9.2 kg/year, which constitutes between 17% and 21% of total per capita consumption of all inland fish and OAAs.

Figure 20 shows the proportions of all types of fish, OAAs and other (non-aquatic) animal products (beef, poultry, pork, eggs and wildlife) consumed by people in each country in the LMB (Hortle 2007). Clearly, inland fish and OAAs together are the main source of protein in the diet of LMB people. The population of Cambodia is particularly reliant on inland fish and OAAs which make up 85% of total per capital consumption of animal products.

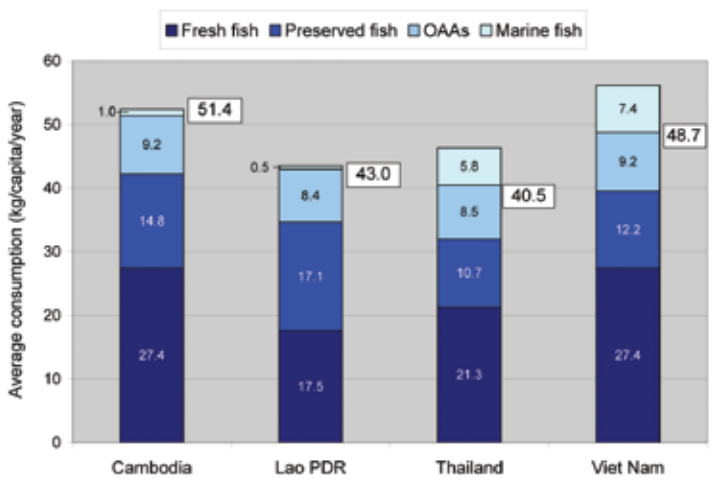


Figure 19 Average per capita consumption of inland fresh and preserved fish, other aquatic animals (OAAs) and marine fish by country, reported as 'fresh whole animal equivalent weights' (FWAE). The average per capital consumption of inland fish (fresh and preserved) plus OAAs but excluding marine fish is indicated by numbers in the white boxes (Hortle 2007).

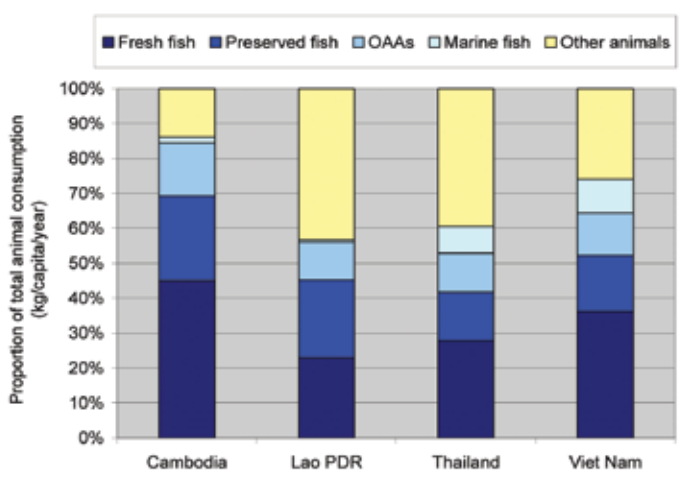
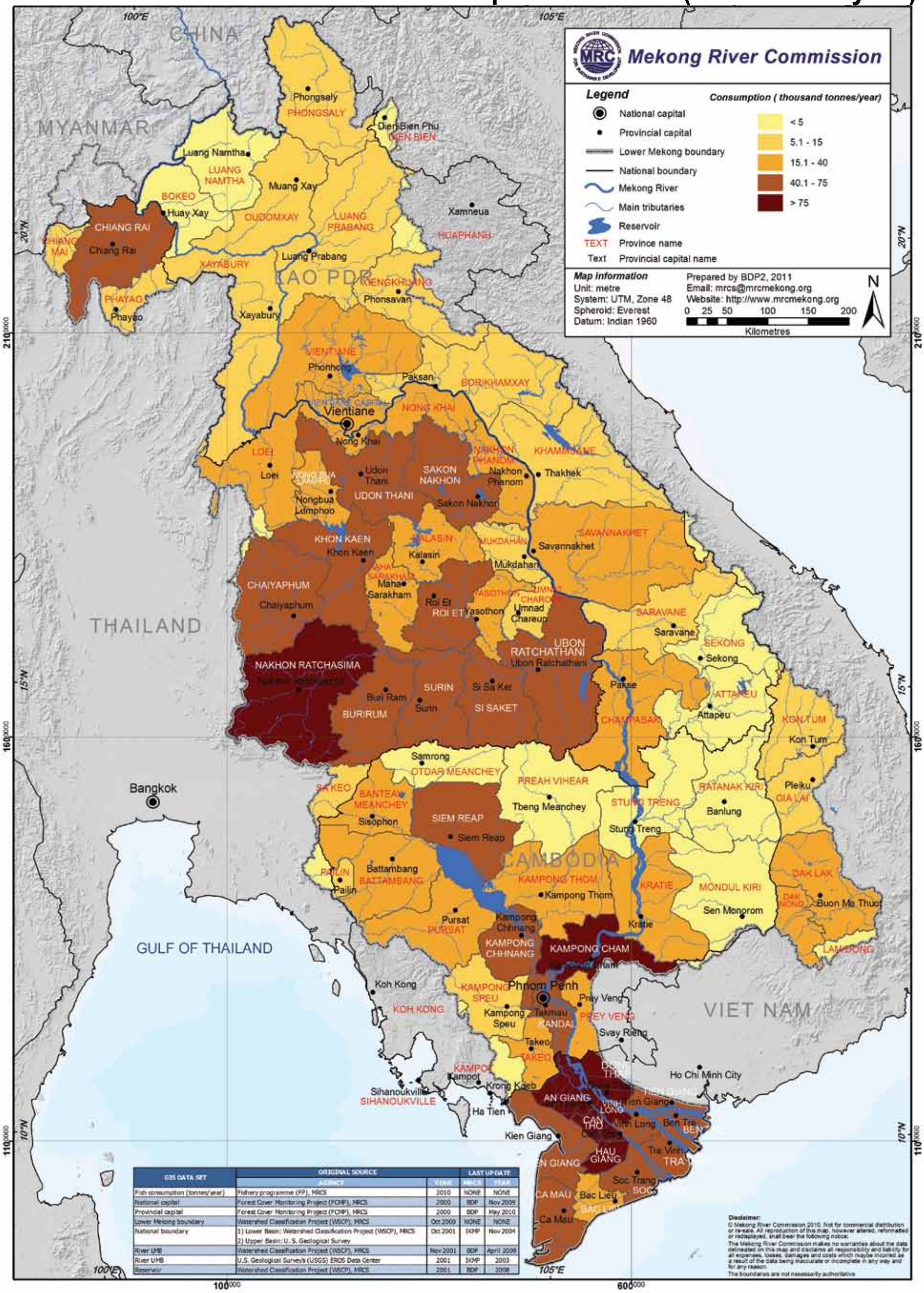


Figure 20 Average per capita consumption of inland fresh and preserved fish, other aquatic animals (OAAs), marine fish and other (non-aquatic) animal products as a proportion of total per capita consumption of animal products. Non-aquatic animal products include beef, poultry, pork, eggs & wildlife. (Hortle 2007)

Consumption of inland fish and other aquatic animals ('000 tonnes/year)



GIS DATA SET	ORIGINAL SOURCE		LAST UP DATE	
	AGENCY	YEAR	MRCS	YEAR
Fish consumption (tonnes/year)	Fishery programme (FP), MRCS	2010	NONE	NONE
National capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	Nov 2009
Provincial capital	Forest Cover Monitoring Project (FCMP), MRCS	2000	BDP	May 2010
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008

Consumption of Inland Fish and Other Aquatic Animals ('000 tonnes/year)

6.9

Throughout the LMB, approximately 2.1 million tonnes of inland fish and 0.5 million tonnes of OAAs (other aquatic animals) are eaten by people each year (Hortle 2007). Actual consumption (that is flesh eaten) is about 1.9 million tonnes. Thailand and Viet Nam consume 33% and 36% of the LMB total; Cambodia consumes 25% and Lao PDR consumes the least at 8% (Figure 21). The relatively low consumption in Lao PDR is due to moderate per capita consumption (previous map) and a low population.

This map shows the spatial distribution of total consumption of inland fish and OAAs (as tonnes/year) in the LMB by Province in the year 2000. In other words, it shows the total amount (as a weight) consumed in each Province in each year and is distinct from per capita consumption, which described the amount consumed by each person.

Provincial consumption estimates are based on a synthesis of the results of 20 field surveys conducted at various locations in the LMB between 1988 and 2002 (Hortle 2007) as described for the previous map on per capita consumption. Total provincial consumption was calculated by Hortle (2007) by multiplying the estimated per capita consumption in a Province by the population of that Province in the year 2000.

The spatial patterns in this map are different to the previous map on per capita consumption because the data in this map reflect the product of per capita consumption and population. Provinces in northeast Thailand, the delta in Viet Nam and the Tonle Sap and Mekong River corridors in southern Cambodia have the highest total consumption (>40,000 tonnes/year). These high consumption rates are due to moderate to high per capita consumption and large provincial populations (see population map 2.1).

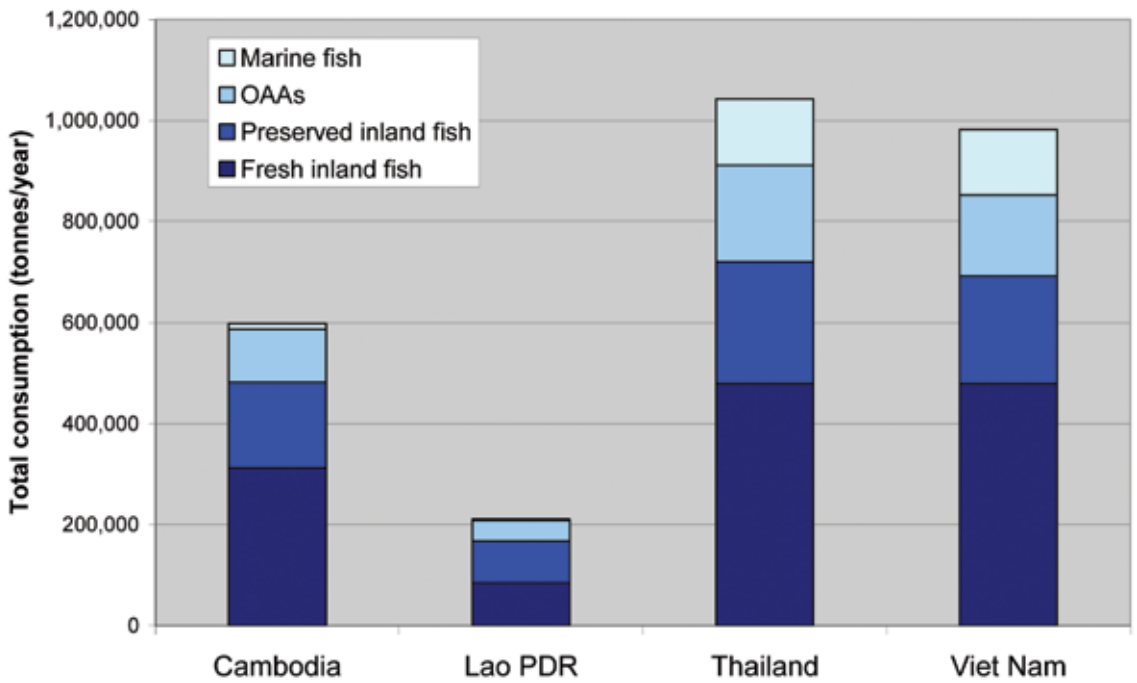


Figure 21 Total consumption of inland fish (fresh and fermented), other freshwater aquatic animals (OAAs) and marine fish by country. Total consumption is reported as tonnes of 'fresh whole animal equivalent weights' (FWAE) per year. Source: (Hortle 2007)

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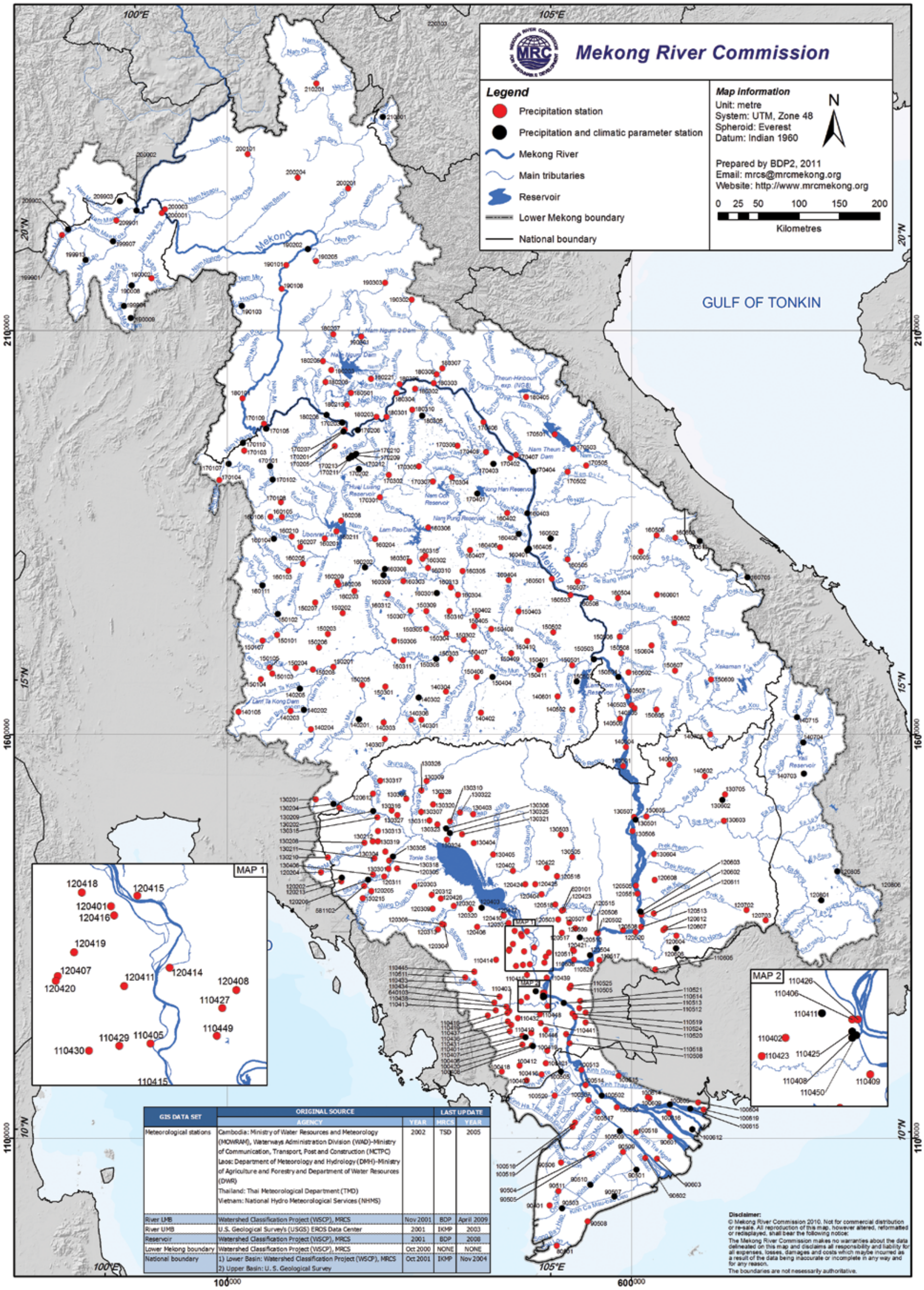
7 Monitoring Stations

7.1 Meteorological Stations

7.2 Hydrological Stations

7.3 Water Quality Stations

Meteorological stations



GIS DATA SET	ORIGINAL SOURCE		LAST UPDATE	
	AGENCY	YEAR	MRCS	YEAR
Meteorological stations	Cambodia: Ministry of Water Resources and Meteorology (MOWRAM), Waterways Administration Division (WAD)-Ministry of Communication, Transport, Post and Construction (MCTPC) Laos: Department of Meteorology and Hydrology (DMH)-Ministry of Agriculture and Forestry and Department of Water Resources (DWR) Thailand: Thai Meteorological Department (TMD) Vietnam: National Hydro Meteorological Services (NHMS)	2002	TSD	2005
River UMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004

7.1 Meteorological Stations

This map shows the location of 480 precipitation (rainfall) monitoring stations throughout the lower Mekong Basin, as well as 115 stations where some or all other standard meteorological parameters are also measured including air temperature, evaporation, wind speed and direction, solar radiation and air pressure. Monitoring stations are operated by the four riparian countries who periodically share the data with the Mekong River Commission. All historical data from the stations marked on this map is available on the Master Catalogue of the MRC Portal (see references below). Historical rainfall data from this network of stations was used to create the rainfall distribution map (Map 4.2).

Some rainfall gauges in the LMB are automatic tipping bucket style gauges which can transmit data by satellite and hence can be operated remotely. However, most sites rely on manual daily readings by trained residents from nearby villages or district government staff. Local villagers are often also engaged to maintain the rainfall monitoring stations. Complete meteorological stations, where other climatic parameters are also measured, are typically operated and maintained at the provincial level by a designated team of trained meteorologists.

Rainfall records go back to the 1920s at some locations with the earliest records from 1913 at Takeo in southern Cambodia (station code 100408). Most rainfall monitoring stations in northeast Thailand, Laos and Cambodia began operation between the late 1960s to early 80s and continue to this day. Records from Lao PDR and Cambodia tend to be more discontinuous than Thailand due to wars in those countries. Data collection in the Mekong Delta in Viet Nam began more recently: the year 2000 for the majority of stations, although the larger cities have longer historical records dating to the 1920s.

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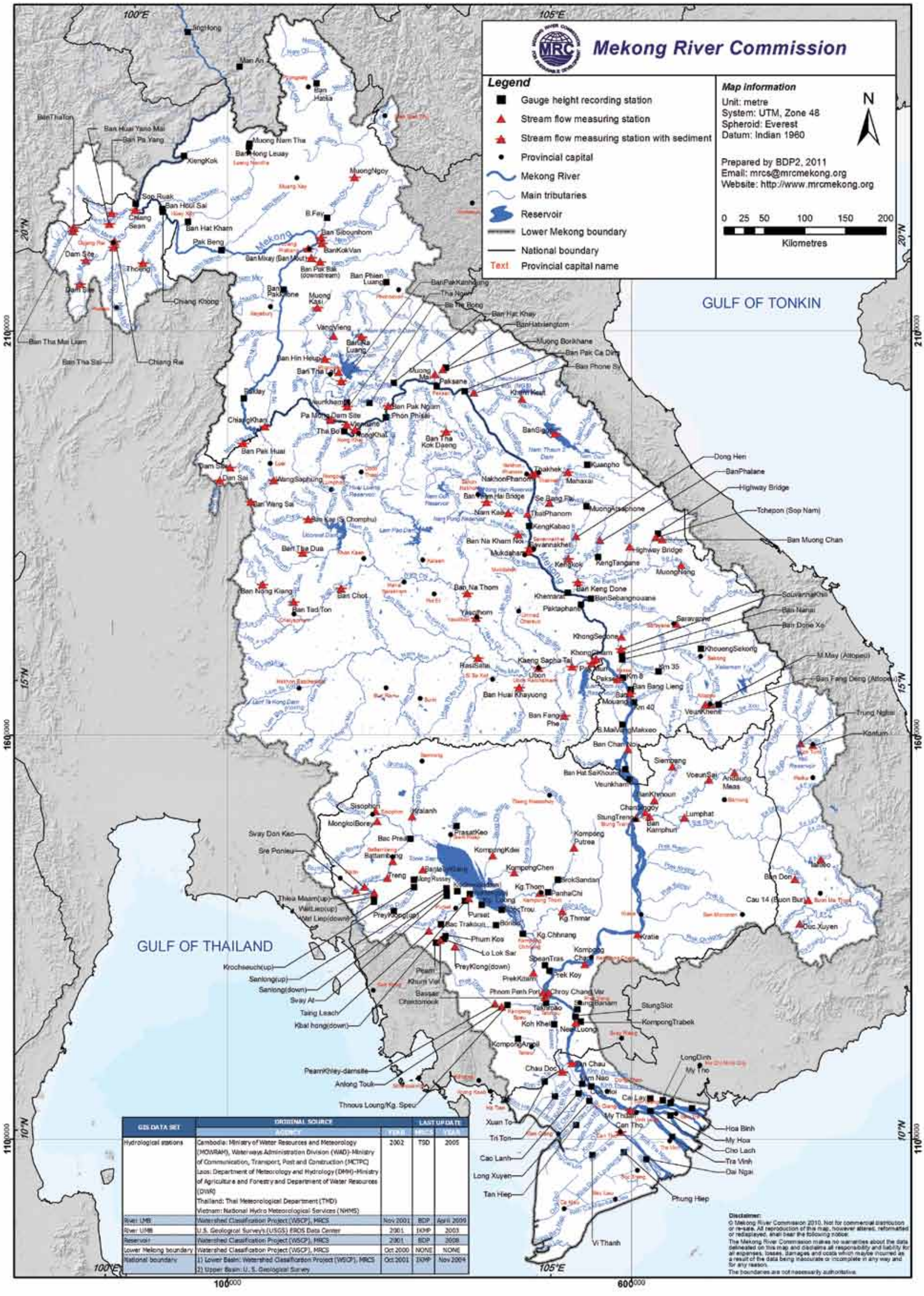
Hydrological stations



GIS DATA SET	ORIGINAL SOURCE		LAST UP DATE	
	AGENCY	YEAR	MRCS	YEAR
Hydrological stations	Cambodia: Ministry of Water Resources and Meteorology (MOWRAM), Waterways Administration Division (WAD)-Ministry of Communication, Transport, Post and Construction (MCTPC) Laos: Department of Meteorology and Hydrology (DMH)-Ministry of Agriculture and Forestry and Department of Water Resources (DWR) Thailand: Thai Meteorological Department (TMD) Vietnam: National Hydro Meteorological Services (NHMS)	2002	TSD	2005
River LMB	Watershed Classification Project (WSCP), MRCS	Nov 2001	BDP	April 2009
River UMB	U.S. Geological Survey's (USGS) EROS Data Center	2001	IKMP	2003
Reservoir	Watershed Classification Project (WSCP), MRCS	2001	BDP	2008
Lower Mekong boundary	Watershed Classification Project (WSCP), MRCS	Oct 2000	NONE	NONE
National boundary	1) Lower Basin: Watershed Classification Project (WSCP), MRCS 2) Upper Basin: U. S. Geological Survey	Oct 2001	IKMP	Nov 2004

7.2 Hydrological Stations

This map shows the location of stations on rivers where gauge height (water level), stream flow (discharge) and sediment (suspended sediment concentration) have been monitored on a regular or periodic basis since 1913, the year when water level measurements began in Vientiane. Some stations have only a few years of data while others have been in operation for longer periods. Not all marked stations are currently under operation. All hydrological stations are operated and managed by relevant provincial or national government agencies of the four riparian countries. Data are periodically transferred to the MRC and are available on the MRC Portal Master Catalogue (see references below). The MRC publish daily water level data at key mainstream stations on the MRC website www.mrcmekong.org.

On the Mekong River mainstream, water levels and stream flow is currently monitored on a regular and ongoing basis at 13 stations, with an additional 3 operational stations on the Bassac River and one station on the Tonle Sap River. Table 19 below describes the history, current monitoring frequency and measurement method at these stations. Similar information for tributary stations can be obtained from the Master Catalogue.

At gauge height stations, water levels are typically measured daily or twice a day with the exception of tidally-influenced sites in the Delta where hourly readings are taken. At stream flow monitoring stations, both water levels and discharge are measured. Discharge is measured periodically from a boat (1-4 times per month continuously or over a particular monitoring period, for example 1-2 years). At most mainstream and tributary stations, discharge is typically measured using water velocity meters and some form of depth measurement device, either a manual sounding line or an echo-sounder. On the Mekong mainstream, water velocity is measured at 2-3 points vertically in the water column at 20-30 verticals across the river. Acoustic Doppler Current Profilers (ADCP), which measure discharge automatically by driving a boat slowly across the river, are used at one station (Nong Khai) in Thailand, all mainstream stations in Cambodia and at most stations in the Mekong Delta in Viet Nam since 2008. The aim of discharge measurements is to obtain a rating curve for the station. A rating curve is the relationship between water level and discharge from which daily discharge can be 'estimated' from daily water level measurements. This relationship is dependant on the area of the river cross-section and, since river morphology at a station will change through time, discharge rating curves need to be updated every 1-10 years, depending on how quickly the river morphology changes.

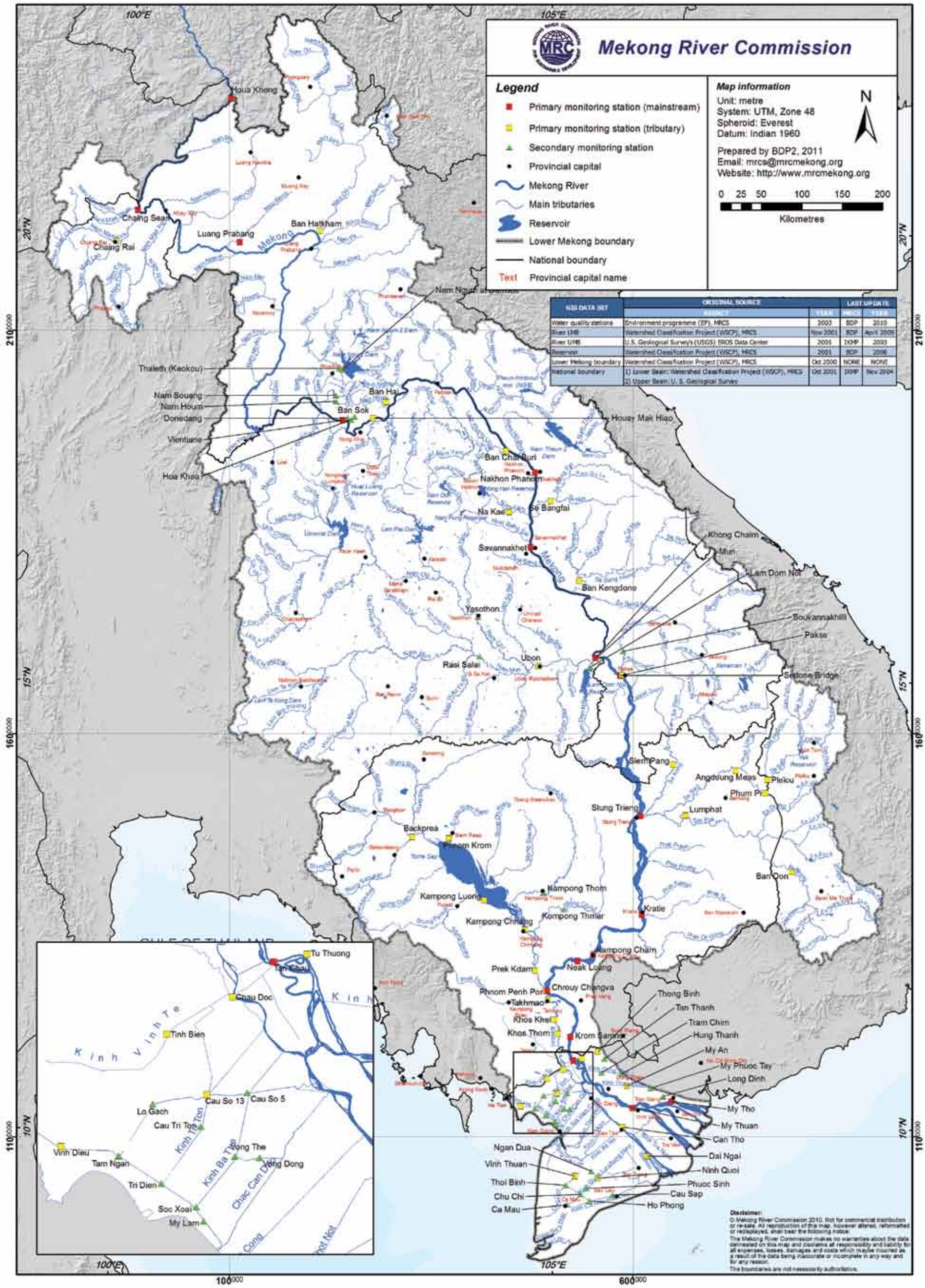
Suspended sediment sampling is used to determine the amount of sediment transported in suspension (clay, silt and some sand) by rivers. Suspended sediment typically constitutes about 90-95% of all sediment transported by rivers (Milliman and Meade 1983) and is used in many applications including estimating sediment trapping rates and hence the expected life of dams; estimating the transport of nutrients, which are absorbed into fine sediment; and monitoring the effect of various human activities on the river including land-use changes and dam construction (Kummu and Varis 2007; Walling 2008, 2009). Since river sediment is the building block of riverbanks, islands, the riverbed and coastal areas near the sea, changes to sediment loads can have significant impacts on the stability of these features as well as the delivery of nutrients, on which fisheries production depends, to floodplains and coastal areas. Suspended sediment monitoring has been sporadic at most mainstream and tributary stations in the LMB. Mekong mainstream stations in Thailand (along the Thai-Lao PDR border) have the longest and most continuous records since the 1970s/80s, while in Lao PDR there is good data from 1960-62 and less frequent data from periodic sampling periods during the 80s and 90s. The MRC currently hold no suspended sediment monitoring for Cambodia but sampling at some stations was conducted by various researchers in 1960-61 (Hazga 1961), 1962-63 (Carbonnel and Guiscafre 1965) and 2000-02 (Kummu et al. 2008). Regular suspended sediment sampling began in the Mekong Delta in Viet Nam in 2008.

Table 19 History and status of stream flow (discharge) and suspended sediment monitoring at stations on the Mekong River mainstream, and the Bassac and Tonle Sap rivers.

No	Station Name	Status
Thailand – Lao PDR (mainstream stations located on the border of the two countries)		
1	Chiang Saen - Ton Pheung	• Regular ongoing discharge measurements since 2005 (4 times per month in wet season, 1-2 times per month in dry season). • Prior to 2005, monitoring was sporadic or continuous at various monthly frequencies, depending on the station, since the 1960s to early 70s. • In recent years, discharge measurements at these border stations have been conducted by joint Thai-Lao teams. • Suspended sediment sampling on same day as discharge measurement
2	Chiang Khan - Sanakham	
3	Nong Khai - Thanaleng	
4	Nakhon Phanom - Thakhek	
5	Mukdahan - Savannakhet	
6	Kong Chiam	
Lao PDR		
1	Luang Prabang	• Currently water level monitoring only. Periodic discharge and suspended sediment monitoring since 1961 but none since 2004/05 for Luang Prabang, Vientiane and Pakse, or 1964 for Ban Chan Noi located just upstream of the Siphadon area.
2	Vientiane	
3	Pakse	
4	Ban Chan Noi	
Cambodia		
1	Stung Treng	• Daily water level monitoring since 1910 at Stung Treng, 1926 at Neak Luong and the 1960 at other stations. Periodic discharge measurements in the 1960s/70s and 90s. Since at least 2008, regular and ongoing discharge measurements have occurred 4 times per month in the wet season and 2 times per month in dry season. • Since the year 1999, discharge measurements have been carried out with an Acoustic Doppler Current Profile (ADCP). Prior to this, measurements were made by current meter. • No suspended sediment sampling
2	Kratie	
3	Kampong Cham	
4	Chaktumuk (Phnom Penh)	
5	Prek Dam *(Tonle Sap River)*	
6	Koh Khel *(Bassac River)*	
7	Neak Luong	
Viet Nam (all four stations in the delta are influenced by tides)		
1	Tan Chao	• Hourly water level measurements since the 1960s/70s and regular and ongoing discharge measurements since 2003. • Discharge measurement method and frequency is different to upstream stations due to the influence of tides, which is greatest in the dry season. The method involves hourly 'index' water velocity measurements at specific locations in the river cross-section as well as moving-boat discharge measurements done hourly over several 2-3 day periods in the dry season and every 2-3 days in the wet season. • Regular suspended sediment sampling has been conducted at the two upstream stations (Tan Chao and Chao Doc) since 2008.
2	Chao Doc (Bassac River)	
3	Vam Nao (Vam Nao River)	
4	My Thuan	
5	Can Tho (Bassac River)	

REFERENCES AND FURTHER READING (see 7.3 References and Further Reading section)

Water quality stations



7.3 Water Quality Stations

The Water Quality Monitoring Network (WQMN) of the lower Mekong Basin was established in 1985 and now includes regular monthly or two-monthly measurement of 11 water quality parameters at 48 permanent stations on the Mekong River mainstream and important transboundary tributaries (MRC 2008a). At the commencement of monitoring in 1985, 30 stations were sampled and since then the number of sampled stations has grown but varies from year to year depending on available logistical resources in each country.

This map shows the location of 116 stations that have been sampled for water quality as part of the WQMN for at least one year since 1985. Since 2004, the Network was divided into a Primary Network consisting of 55 stations having basin-wide and/or transboundary significance and a Secondary Network comprising the remaining stations having mainly local or national interest. The stations are monitored and analyses are performed by national laboratories un der the overall technical guidance of the MRC, which maintains a quality assurance programme. Until 2009, stations were sampled 12 times per year, usually on the 15th of each month, at a depth of 0.5 m in the middle of the cross-sectional profile (thalweg). The parameters measured are shown in Table 2.1 along with Map 4.5. Since 2010, most stations are sampled every two months.

A review of the WQMN data from 1985 to 2005 including major spatial and temporal trends can be found in MRC (2008a). The Environment Programme of the MRC now also publishes an Annual Report Card of Water Quality for the 48 key primary stations (MRC 2008d). Data from 2008 is illustrated in Map 4.5 of this Atlas.

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Basin Development Plan Programme

Planning Atlas of the Lower Mekong River Basin

2011

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