The Sekong River in Viet Nam, Lao PDR and Cambodia

An Information Sourcebook for Dialogue on River Flow Management

Peter-John Meynell

BRIDGE: Building River Dialogue and Governance

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Table of contents

1 Introduction

This sourcebook has been produced as a contribution to the BRIDGE project. The purpose of the paper is to provide a range of information which may be useful during dialogue to establish appropriate river flow regimes in the Sekong River in Viet Nam, Lao PDR and Cambodia when large hydropower projects are constructed and operated. The sourcebook is not a manual on carrying out environmental flow assessments, but is designed to provide baseline or background information to assist in the process.

1.1 Using this information source book

This sourcebook starts by putting the Sekong River into context as one of the most significant large tributaries of the Mekong, and the northernmost of the 3S Rivers – Sekong, Sesan and Sre Pok. The Sekong is then disaggregated into a total of 17 sub-basins, using the SWAT[1] boundaries developed for hydrological modelling around the key tributaries and catchments of the Sekong. An understanding of the various geomorphological characteristics of the Sekong River has been built up from a number of measurable GIS parameters and their distribution within these sub-basins. In the absence of systematic ecological measurements, these parameters serve to highlight the ecological differences and importance of the different sub-basins.

Some information on the basic hydrology of the Sekong has been provided based on data from one of the hydrological monitoring stations in Lao PDR where there are sufficiently long reference records.

The second part of the sourcebook is based upon a description of the Sekong River using analysis of its features as observed through Google Earth. The mainstem of the river has been described at one-kilometre intervals upstream from the confluence with the Sesan/Sre PokRivers in Cambodia, noting channel width, obvious features such as sandbanks, rapids and riffles, the presence of incoming tributaries, and presence of riverside towns and villages. The sinuosity of the river is also assessed over 10-kilometre lengths upstream of the confluence.

The purpose of collecting this information is to help to distinguish and classify the different reaches of the river, and their geomorphological and ecological features, so that the effects of changing flow regimes can be assessed. Some characteristic reaches of the Sekong and Se Kamman Rivers are suggested.

Other chapters include information on fish biodiversity. Basic information on the human populations and settlements along the river are included because in any consideration of managing changing flows and the impacts on local livelihoods, consultations with local users of the river are essential.

The final chapters consider the existing and proposed hydropower projects and status of irrigation projects. The changes in flow patterns resulting from increased regulation of the flows in the Sekong are discussed. An example of changes in the "Flow Health" indicators illustrates the potential impacts from a simulated change in the annual hydrograph at Attapeu.

1.2 Methodologies used

1.2.1 GIS analysis

The GIS analysis builds upon techniques developed for analysing the ecological significance of the 102 tributaries and catchments of the Mekong, prepared by the author for the Mekong River Commission (Meynell, 2012) as part of a series of studies on the significance of the tributaries of the Mekong synthesised by Vogel (2012). This analysis was carried out byMs Penroong Bamrungrach.

This technique consists of superimposing a series of geographic parameters over the SWAT catchments of the Sekong, and assessing the proportions of the area of each SWAT catchment

[1]SWAT = Soil and Water Assessment Tool for hydrological modelling

occupied, or the length of the different stream orders in each catchment. The key parameters that have been used include:

- Sub-basin area
- Stream order length
- Slope of the terrain
- Geology
- Soils
- Climate – mean annual rainfall and temperature
- Ecological zones
- Land use – agriculture, forest cover etc.
- Protected Areas and Key Biodiversity Areas

1.2.2 Databases

The following databases and maps have been accessed from the MRC and other organisations to carry out this assessment. The metadata is shown in Annex 1.

- MRCS (2000) Watershed Classification Project (WSCP)
- Mekong mainstream and tributary rivers and streams, with stream order, showing seven levels
- Digital Terrain Model (DTM) for the Lower Mekong Basin for altitudes of tributaries and for determining slopes of the tributaries between each node
- Lower Mekong Basin 1968 ATLAS: Geology
- Lower Mekong Basin 1968 ATLAS: Land Potential
- Soil Map of the Lower Mekong Basin
- Landcover of the Mekong Basin 1992/93 and 2003
- Wetlands of the Mekong Basin
- Forest Functions / Protected Areas of the Lower Mekong Basin for Protected Areas, Ramsar sites

1.2.3 Google Earth survey

A Google Earth survey has been carried out on both the Sekong and Se Kamman Rivers. The procedure has been to follow the river up from the confluence with the Sesan/Sre Pok Rivers and take observations of the character of the river every 1 km. This procedure works well with the increasing clarity of Google Earth images especially in the lower or middle reaches, but less well in the upland reaches of the river where the image may be distorted by the topography and the decreasing width of the river. Elevation information may also have variable accuracy.

The following parameters are observed through each one-kilometre stretch of the river:

- Latitude and longitude
- Elevation
- Width of the channel (where the channel is split, estimates of the width of the main branches are made)
- Character of the channel – plain with no distinguishing features, rocky, sandy
- Features observed – exposed rocks, sand banks and beaches, riffles, rapids, islands
- Tributaries on left and right banks
- Human settlements – villages and towns on left and right banks
- Other observations

For analysis, the one-kilometre stretches are aggregated into 10-kilometre reaches, and the results expressed in a matrix to illustrate the changing character of the river with distance from the confluence – lowland, middle and upland reaches, with typical transition zones.

This information is complemented by estimates of the sinuosity of the river – the numbers and lengths of bends, and the changing width of the river with elevation.

1.2.4 Flow Health modelling

Flow Health modelling uses the *Flow Health* software application to model changes in the hydrograph that may result from increasing regulation of the river due to construction of storage reservoirs for hydropower on the Sekong. This is used to illustrate the key changes that might occur and which will influence the character of the river e.g. at the reference sites suggested.

Flow Health is an open access application developed by Christopher Gippel et al of the International Water Centre in Brisbane[2]. It offers a simple method for consideration of flows and changes occurring due to regulation.

[2]Gippel, C.J., Marsh, N. and Grice, T. 2012. Flow Health - Software to assess the deviation of river flows from reference and to design a monthly environmental flow regime. Technical Manual and User Guide, Version 2.0. ACEDP Australia-China Environment Development Partnership, River Health and Environmental Flow in China. International WaterCentre, Brisbane, Fluvial Systems Pty Ltd, Stockton, and Yorb Pty Ltd, Brisbane, September.

2 The Sekong River in context

2.1 Mekong

The Sekong is one of the most significant tributaries of the Mekong.With a catchment area of 28,815 sq km, it is the fourth largest of the tributaries of the Mekong, excluding the Delta as shown in Table 2-1. The large tributaries are classified as those over 5,000 sq km. It can be seen that the 3S Rivers together cover a total of 78,645 sq km.

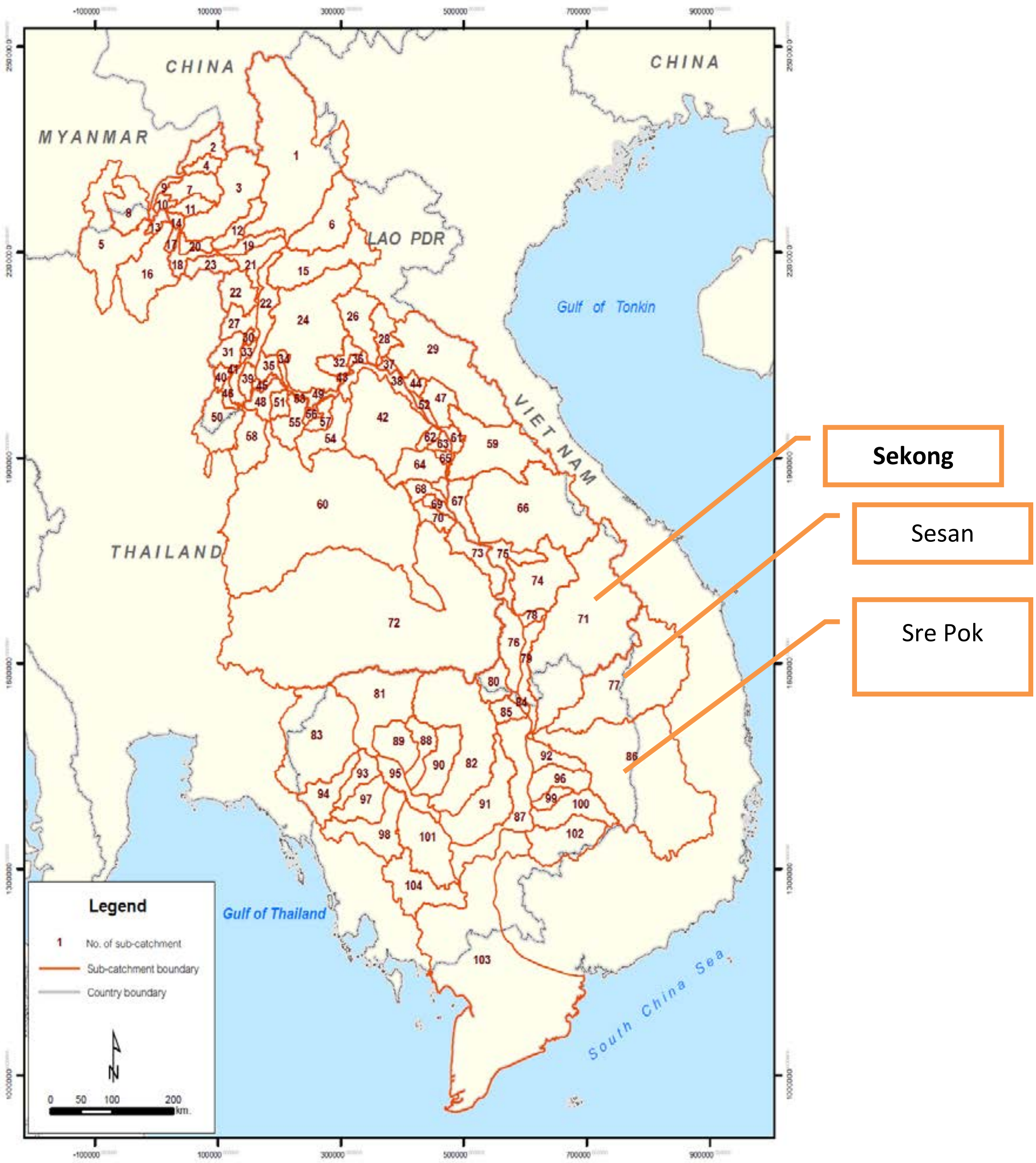
Table 2-1: Catchment areas and stream order lengths of the largest tributaries of the Mekong

Code No.	Tributary	Catchment area	Geological zone	Distance of confluence from the source	Length of all stream orders
		sq km		km	km
72	NAM MUN	70,574	KP	3,632	12,192
60	NAM CHI	49,133	KP	*3,632	9,303
103	DELTA	48,235	D	4,313	5,467
86	**SRE POK**	**30,942**	**KM**	***3,900**	**6,729**
71	**SE KONG**	**28,815**	**KM**	**3,901**	**4,932**
1	NAM OU	26,033	NH	2,443	5,740
66	SE BANG HIENG	19,958	AMR	3,496	5,114
77	**SE SAN**	**18,888**	**KM**	***3,900**	**2,785**
24	NAM NGUM	16,906	NH	3,039	3,365
82	ST. SEN	16,360	NTS	TS	3,182
83	ST.MONGKOL BOREY	14,966	NTS	TS	3,171
29	NAM CADINH	14,822	AMR	3,173	2,981
42	NAM SONGKHRAM	13,123	KP	3,265	2,759
5	NAM MAE KOK	10,701	NH	2,115	1,833
59	SE BANG FAI	10,407	AMR	3,364	1,583
81	ST.SRENG	9,986	NTS	TS	2,091
3	NAM THA	8,918	NH	2,203	1,029
87	SIEM BOK	8,851	NTS		2,258
91	ST.CHINIT	8,237	NTS	TS	1,748
15	NAM KHAN	7,490	NH	2,467	1,454
16	NAM MAE ING	7,267	NH	2,176	1,682
74	SE DONE	7,229	AMR	3,677	2,249
101	ST.BARIBO	7,154	CM	TS	2,192
6	NAM SUONG	6,578	NH	2,453	1,070
104	PREK THNOT	6,124	CM	4,285	1,740
98	ST.PURSAT	5,965	CM	TS	1,597
102	PREK CHHLONG	5,957	VU	4,077	1,713
GRAND TOTAL LARGE TRIBUTARIES		**479,616**			**91,962**
GRAND TOTAL FOR LMB		**624,654**			**120,333**

Code		
Northern highlands		NH
Annamite range		AMR
Loei Petchuan Fold Belt		LFB
Khorat Plateau		KP
Bolevan Plateau		BP
North Tonle Sap		NTS
Kontum Massif		KM
Cardamon mountains		CM
Tonle Sap		TS
Volcanic Uplands		VU
Delta		D

The Sekong arises in the Kontum Massif in the Central Highlands of Viet Nam, flows through Lao PDR and Cambodia and discharges into the Mekong near Stung Treng, some 3,900 km from the source of the Mekong. All of the different stream orders have a total of 4,932 km.

Figure 2-1: Catchments of the Lower Mekong Basin



2.2 3S Rivers

The 3S Rivers arise from volcanic geological formations in the Central Highlands of Viet Nam. The longest river, with the largest number of streams is the Sre Pok, followed by the Sekong and Sesan. All three rivers have a middle range of proportions of length at stream orders 1 and 2, and the Sesan stands out as having a higher proportion of stream length for stream orders 3 and 4. The Sre Pok, as a more complex river, has a higher proportion of length at stream orders 5 and 6. The Sekong is the steepest river, especially for 2nd order streams, followed by the Sre Pok and the Sesan. The Sekong has the highest proportions of its length arising over 1,500 masl, extending down to less than 100 masl. The Sesan and Sre Pok have similar elevation profiles.

Table 2-2: Physical characteristics of 3S Rivers

Code	Tributary	Catchment area	Total length and number of all stream orders		Stream orders length as % of total length			Average slope		Stream density	Elevation - % lengths of tributary over				
			Length	number	1 & 2	3 & 4	5 & 6	1st order streams	2nd order streams		<100 masl	100 masl	500 masl	1000 masl	1500 masl
		sq km	km	number	%	%	%	%	%	km/sq km	%	%	%	%	%
71	SE KONG	28,815	4,931.56	357	81.63	13.32	5.05	2.03	0.77	0.171	9.0	36.7	37.5	15.8	0.9
77	SE SAN	18,888	2,784.70	253	78.05	21.95		0.94	0.28	0.147	11.3	49.1	39.0	0.6	
86	SRE POK	30,942	6,729.10	626	76.63	17.37	6.01	0.99	0.39	0.217	4.0	67.5	28.3	0.2	

These three rivers pass through five different ecological zones[3](ecozones): High-elevation moist broadleaf forests(HEMBF), Mid-elevation moist broadleaf forests (MEMBF), Mid-elevation dry broadleaf forests (MEDBF), Low-elevation dry broadleaf forests (LEDBF) and a small amount of floodplain and wetland (FP). The distribution of these ecozones throughout the Lower Mekong Basin is shown in Figure 2-2 with an inset showing greater detail for the 3S Rivers.

Figure 2-3 shows a comparison of the ecological profiles of the stream orders of each of the three 3S Rivers. It can be seen that the Sekong has a more complex profile than the Sesan and Sre Pok. The Sekong has significant proportions of its lower stream orders flowing through three ecozones: HEMBF, MEDBF and LEDBF. Higher stream orders on the Sekong mostly flow through LEDBF.

By contrast the Sesan flows through predominantly MEDBF, with a smaller amount of HEDBF, especially at lower stream orders. The Sre Pok mainly flows through MEDBF also, with a smaller amount of LEDBF at higher stream orders.

[3] These ecological zones reflect the type of ecosystem that would naturally have been in the area before human land-use changes. They are based on factors such as soils, slope, elevation, rainfall.

Figure 2-2: Ecological zone classification for greater Mekong and for 3S Rivers (Inset)

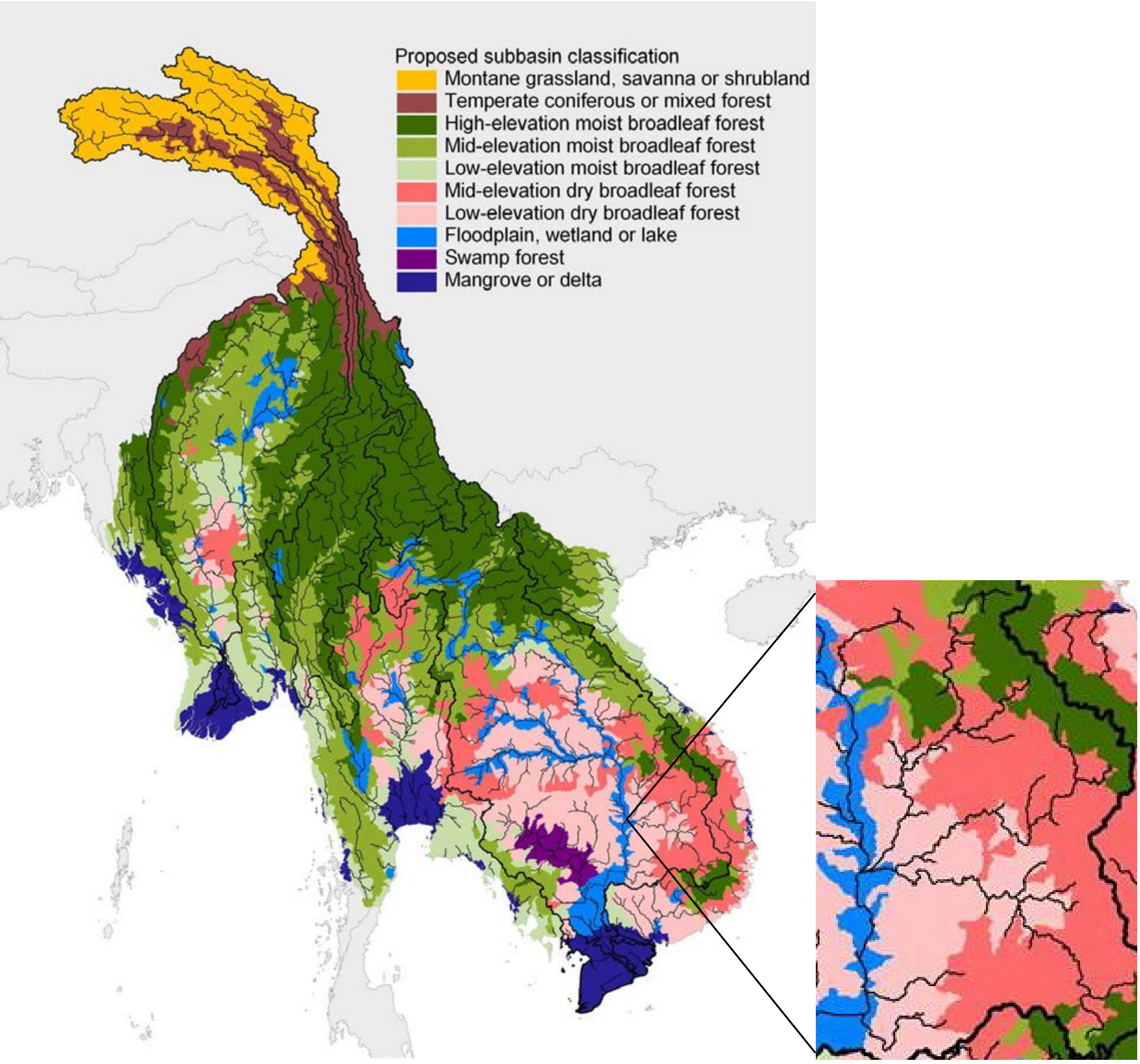
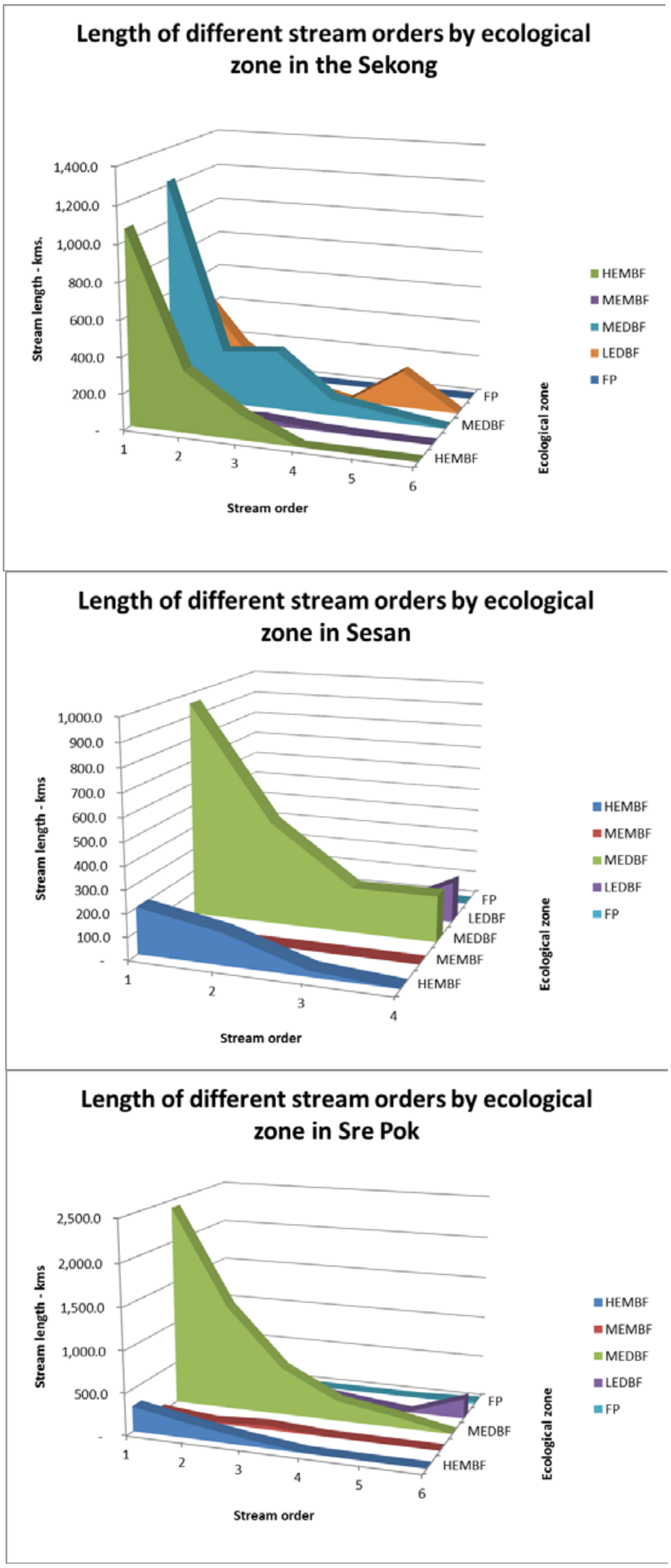


Figure 2-3: Stream order/Ecological profiles of the 3S Rivers



2.2.1 Ecological Diversity of 3S Rivers

The comparison of the different parameters in the MRC study on ecological significance of the tributaries was used to highlight the tributaries that had the highest parameters that might contribute to ecological diversity as shown below in Table 2-3. The rows for the 3S Rivers have been highlighted.

It can be seen that the Sekong is one of the tributaries, along with the other 3S Rivers, which have the highest values for a number of the parameters for ecological diversity among all of the tributaries of the Mekong. The Sekong, in particular, is one of the top 80th-percentile tributaries for greatest slope diversity, highest elevation of source and greatest elevation range. It is among the top tributaries with the highest ecological diversity index and highest forested areas in the catchment. It also scores highly in fish species diversity and in biodiversity interest, in terms of high proportion of its catchment lying in recognised national Protected Areas and Key Biodiversity Areas.

Table 2-3: Comparison of parameters contributing ecological diversity among large tributaries of the Mekong

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical Parameters**	Stream density	Greatest slope	Highest elevation of source	Greatest elevation range	**Ecological character**	Ecological diversity index	Highest forested areas in catchment	Greatest % of natural wetlands	**Biodiversity and Fish**	Fish species diversity	Migratory fish species %	Biodiversity interest (PAs and KBAs)
			sq km	km														
1	NAM OU	3	26,033	5,740	NH													
3	NAM THA	3	8,918	1,029	NH													
5	NAM MAE KOK	3	10,701	1,833	NH													
6	NAM SUONG	3	6,578	1,070	NH													
15	NAM KHAN	3	7,490	1,454	NH													
16	NAM MAE ING	3	7,267	1,682	NH													
24	NAM NGUM	3	16,906	3,365	NH													
29	NAM CADINH	3	14,822	2,981	AMR													
42	NAM SONGKHRAM	3	13,123	2,759	KP													
59	SE BANG FAI	3	10,407	1,583	AMR													
60	NAM CHI	3	49,133	9,303	KP													
66	SE BANG HIENG	3	19,958	5,114	AMR													
71	SEKONG	3	28,815	4,932	KM													
72	NAM MUN	3	70,574	12,192	KP													
74	SE DONE	3	7,229	2,249	AMR													
77	SESAN	3	18,888	2,785	KM													
81	ST.SRENG	3	9,986	2,091	NTS													
82	ST. SEN	3	16,360	3,182	NTS													
83	ST.MONGKOL BOREY	3	14,966	3,171	NTS													
86	SRE POK	3	30,942	6,729	KM													
87	SIEM BOK	3	8,851	2,258	NTS													
91	ST.CHINIT	3	8,237	1,748	NTS													
98	ST.PURSAT	3	5,965	1,597	CM													
101	ST.BARIBO	3	7,154	2,192	CM													
102	PREK CHHLONG	3	5,957	1,713	VU													
103	DELTA	3	48,235	5,467	D													
104	PREK THNOT	3	6,124	1,740	CM													

2.2.2 Ecological Uniqueness

A similar exercise comparing the tributaries of the Mekong for those parameters contributing to ecological uniqueness, some of which overlap with the diversity comparison, is shown in Table 2-4. As before, the Sekong and the other 3S Rivers feature quite prominently for significance of ecological uniqueness. The Sekong comes in the top 80thpercentile for greatest slope and highest elevation of source, i.e. would lead to unique habitats at high elevations and high slopes. It is also scores highly due to the presence of important wetlands, fish species diversity, the high numbers of endangered fish species, and the biodiversity interest, all of which reflect uniqueness.

Table 2-4: Comparison of parameters contributing ecological uniqueness among tributaries of the Mekong

Code	Tributary	Size category	Catchment area	Stream length	Geological zone	**Physical parameters**	Stream density	Greatest slope	Highest elevation of source	Limited elevation range	**Geological character**	Greatest proportion of limestone	**Ecological character**	Restricted ecological zone	Greatest % of natural wetlands	Presence of important wetlands	**Biodiversity and Fish**	Fish species diversity	Endemic species %	Endangered fish species numbers	Endangered species	Biodiversity interest (PAs and KBAs)
			sq km	km																		
1	NAM OU	3	26,033	5,740	NH																	
3	NAM THA	3	8,918	1,029	NH																	
5	NAM MAE KOK	3	10,701	1,833	NH																	
6	NAM SUONG	3	6,578	1,070	NH																	
15	NAM KHAN	3	7,490	1,454	NH																	
16	NAM MAE ING	3	7,267	1,682	NH																	
24	NAM NGUM	3	16,906	3,365	NH																	
29	NAM CADINH	3	14,822	2,981	AMR																	
42	NAM SONGKHRAM	3	13,123	2,759	KP																	
59	SE BANG FAI	3	10,407	1,583	AMR																	
60	NAM CHI	3	49,133	9,303	KP																	
66	SE BANG HIENG	3	19,958	5,114	AMR																	
71	SEKONG	3	28,815	4,932	KM																	
72	NAM MUN	3	70,574	12,192	KP																	
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86	SRE POK	3	30,942	6,729	KM																	
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102	PREK CHHLONG	3	5,957	1,713	VU																	
103	DELTA	3	48,235	5,467	D																	
104	PREK THNOT	3	6,124	1,740	CM																	

3 Characteristics of the Sekong River

A total of 33 SWAT sub-catchments for the Sekong River have been delineated by the MRC hydrological analysis, as shown in Figure 3-1. These have been consolidated into 17 sub-basins that make up the Sekong mainstem and important tributaries, as shown in Table 3-1, with mainstem sections highlighted.

Figure 3-1: SWAT sub-catchment boundaries for the Sekong River Basin

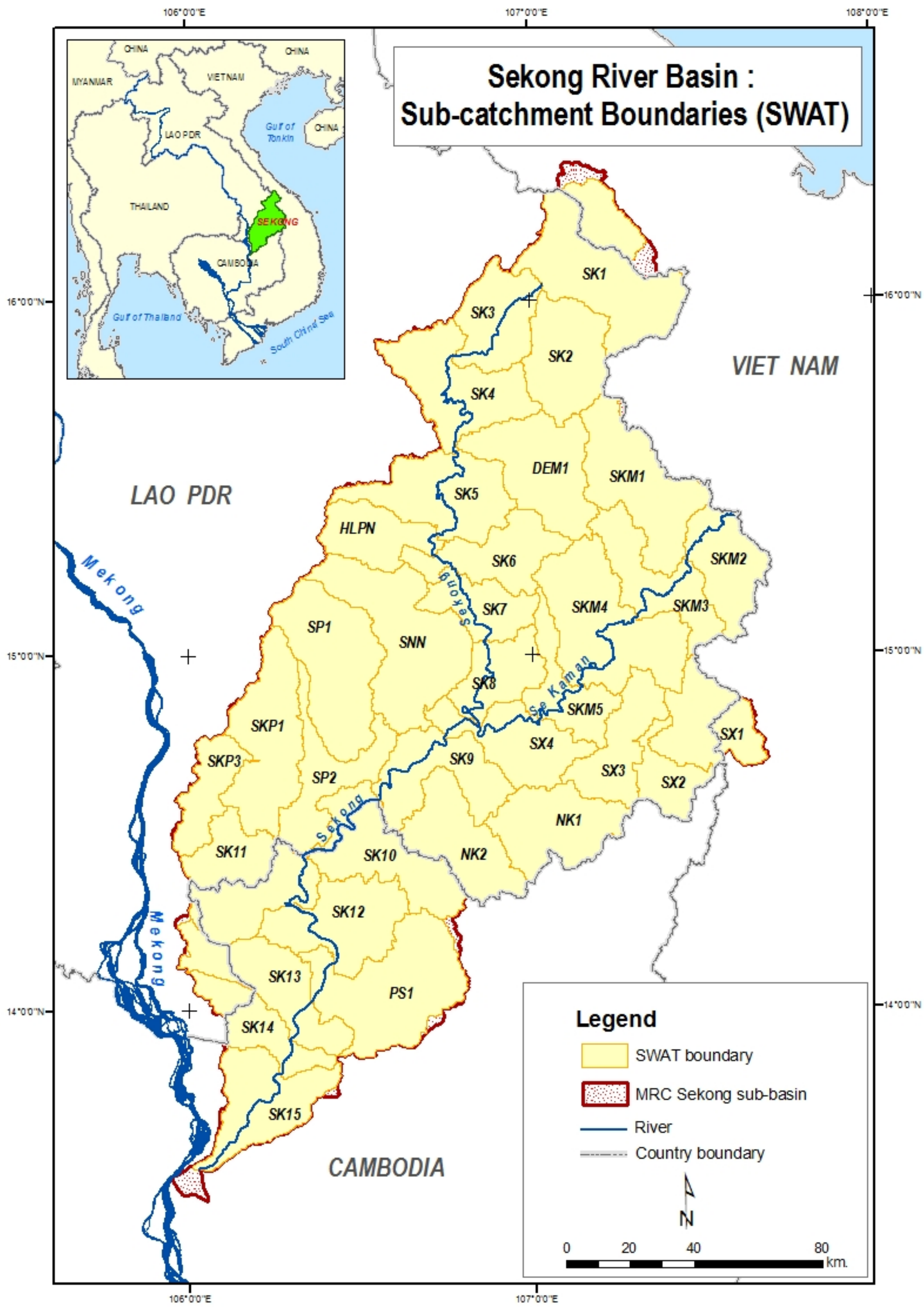
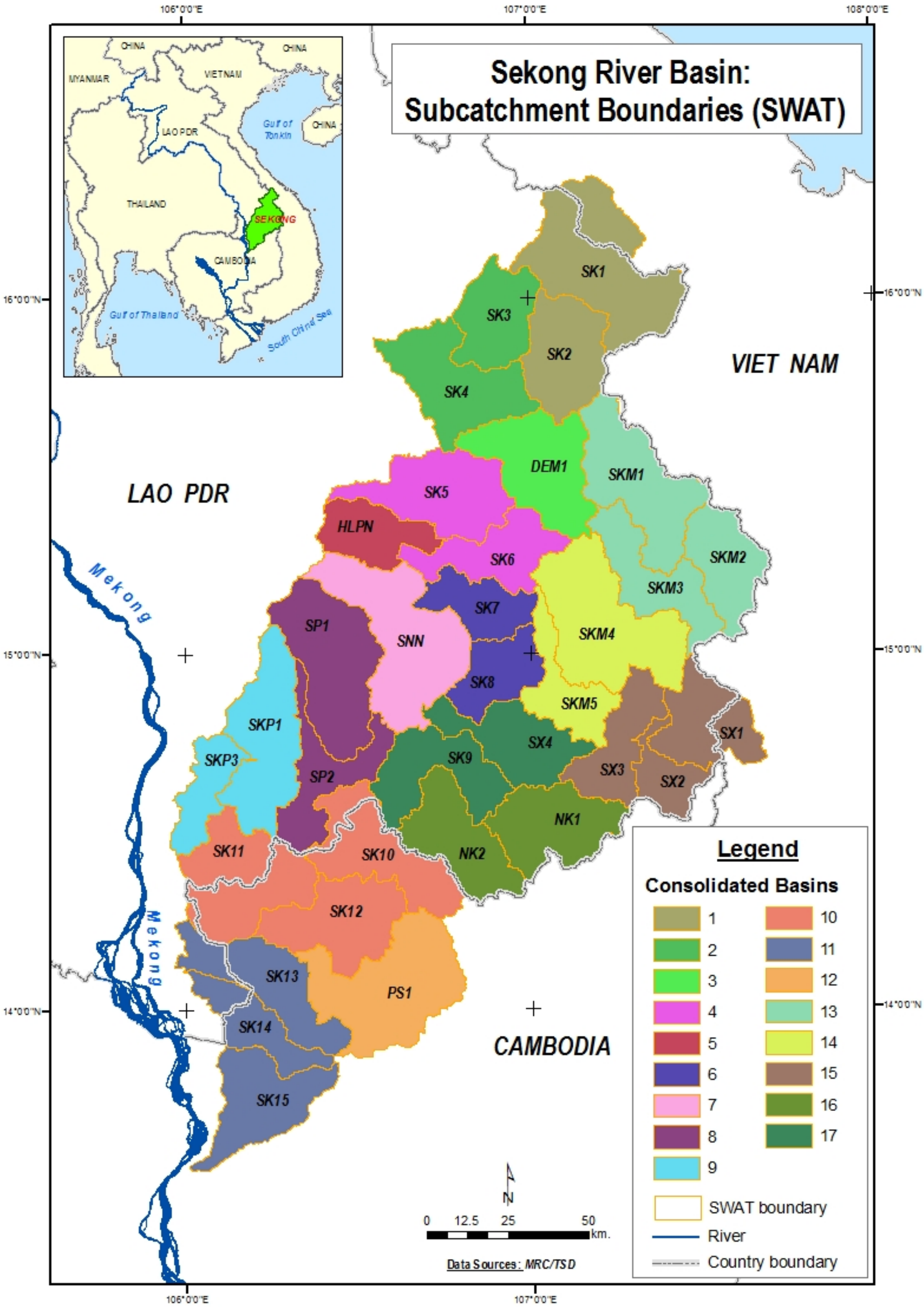


Table 3-1: Consolidated sub-basins for the Sekong River

Consol. code	Name of consolidated basins	SWAT sub-catchments	Comment
1	Sekong headwaters	SK1+SK2	Includes catchment in Viet Nam and Lao PDR down to the confluence of several headwater tributaries
2	Sekong in Kaleum	SK3+SK4	Beginning of the Sekong mainstem
3	Dak e Meule	DEM1	Tributary on left bank
4	Sekong above Sekong town	SK5+SK6	Sekong mainstem
5	Houay Lamphan Ngai	HPLN	Tributary on right bank
6	Sekong above Attapeu	SK7+SK8	Sekong mainstem
7	Se Nam Noy	SNN	Tributary on right bank originating on Bolevan Plateau
8	Se Pian	SP1+SP2	Tributary on right bank originating on Bolevan Plateau
9	Se Khampho	SKP1+SKP2+SKP3	Tributary on right bank originating on Bolevan Plateau
10	Sekong upper, Cambodia	SK10+SK11+SK12	Sekong mainstem
11	Sekong lower, Cambodia	SK13+SK14+SK15	Sekong mainstem
12	Prek Samang	PS1	Tributary on left bank entirely within Cambodia
13	Upper Se Kamman	SKM1 + SKM2 + SKM3	Headwaters of major tributary of Sekong
14	Lower Se Kamman	SKM4 + SKM5	Major tributary of Sekong with confluence at Attapeu
15	Se Xou	SX1 + SX2 + SX3	Tributary of the Se Kamman entering on left bank above Attapeu
16	Nam Kong	NK1 + NK2	Second major tributary of the Sekong entering on left bank downstream of the confluence of Sekong and Se Kamman at Attapeu
17	Sekong/Se Kamman confluence	SX4 +SK9	Sekong mainstem from above Attapeu down to confluence with Nam Kong

Figure 3-2: Map of consolidated sub-basins in the Sekong River



3.1 Structure and stream order

Table 3-2 shows the catchment areas for the consolidated sub-basins. This shows that the Sekong has a total of 28,414 km^2 with 541 km^2 lying in Viet Nam, 22,455 km^2 in Lao PDR and 5,417 km^2 in Cambodia[4]. The additional parts of the basin recorded by the MRC are shown in grey on Figure 2-1 and occur in the headwaters in Viet Nam, and in the Prek Samang catchment and after the confluence with the Sesan and Sre Pok rivers in Cambodia. The consolidated basins are shown in Figure 3-2.

Table 3-2: Consolidated sub-basin areas for the Sekong River by country

Code	Name of consolidated basins	Vietnam	Lao PDR	Cambodia	Total
		sq.km			
	Sekong mainstem				
1	Sekong headwaters	324.6	1,975.3		**2,299.8**
2	Sekong in Kaleum		1,647.4		**1,647.4**
4	Sekong above Sekong town		1,616.1		**1,616.1**
6	Sekong above Attapeu		1,018.5		**1,018.5**
17	Sekong/Se Kamman confluence		1,513.0	1.2	**1,514.2**
10	Sekong upper, Cambodia		664.6	2,255.3	**2,919.9**
11	Sekong lower, Cambodia		343.2	1,831.6	**2,174.8**
	Tributaries				
3	Dak e Meule		977.9		**977.9**
5	Houay Lamphan Ngai		540.5		**540.5**
7	Se Nam Noy		1,345.4		**1,345.4**
8	Se Pian		1,848.1	3.8	**1,851.9**
9	Se Khampho		1,491.9	0.0	**1,491.9**
13	Upper Se Kamman	tr	2,439.1		**2,439.1**
14	Lower Se Kamman		1,906.4		**1,906.4**
15	Se Xou	216.8	1,508.3	tr	**1,725.1**
16	Nam Kong		1,619.6	7.4	**1,627.0**
12	Prek Samang			1,318.0	**1,318.0**
	Totals	**541.4**	**22,455.0**	**5,417.3**	**28,413.8**

The lengths of the Strahler stream orders have been estimated in each sub-basin as shown in Table 3-3. Stream order 1 has by far the greatest lengths (3,089 km) throughout the basin, as one would expect from small streams, followed by 907 km for stream order 2, and 557 km for stream order 3.

The total length for the Sekong mainstem from the headwaters to the confluence with the Sesan and Sre Pok is estimated at 515.8 km, with 184 km of stream order 3; 98 km of stream order 4; 233 km of stream order 5; and 1 km of stream order 6.

The stream density – the lengths of all the combined stream orders divided by the sub-basin area is shown in Table 3-4. The small sub-basin 5, Houay Lamphan Ngai stands out as having the highest stream density with 0.355 km/sq km, followed by sub-basin 17, the Sekong Se Kamman confluence with 0.262 km/sq km and sub-basin 11, Lower Sekong in Cambodia with 0.227 km/sq km.

[4]Note that the MRC figures for the Sekong River Basin are slightly larger than the SWAT basin areas at 28,815 km2.

Table 3-3: Strahler stream order length for the Sekong mainstem (highlighted) and tributaries

Consol. code	Name of consolidated basins	Stream order - Length of stream order reaches in km						Total length
		1	2	3	4	5	6	
	SEKONG MAINSTEM							
1	Sekong headwaters	218.2	94.2	38.9				351.3
2	Sekong in Kaleum	91.8	33.9	98.0				223.6
4	Sekong above Sekong town	161.2	47.4	47.2	7.0			262.8
6	Sekong above Attapeu	45.4	37.6		77.1			160.1
17	Sekong/Se Kamman confluen	211.4	53.9	63.6	13.7	54.4		397.0
10	Sekong upper, Cambodia	324.8	50.2	20.9		102.7		498.5
11	Sekong lower, Cambodia	324.9	92.2			75.9	0.9	493.9
	TOTAL FOR MAINSTEM			**184.1**	**97.7**	**233.1**	**0.9**	**515.8**
	TRIBUTARIES							
3	Dak e Meule	118.2	30.7					148.9
5	Houay Lamphan Ngai	120.5	20.3	48.2	0.3			189.3
7	Se Nam Noy	129.7	10.8					140.5
8	Se Pian	222.3	56.0	85.3		1.2		364.8
9	Se Khampho	199.1	42.7					241.8
13	Upper Se Kamman	255.9	106.7	41.3				403.9
14	Lower Se Kamman	228.0	13.4	80.3				321.7
15	Se Xou	149.3	51.1	33.9				234.3
16	Nam Kong	158.0	105.2					263.1
12	Prek Samang	130.7	60.8			14.5		206.0
	TOTAL FOR SEKONG	**3,089.3**	**907.1**	**557.7**	**98.0**	**248.7**	**0.9**	**4,901.8**

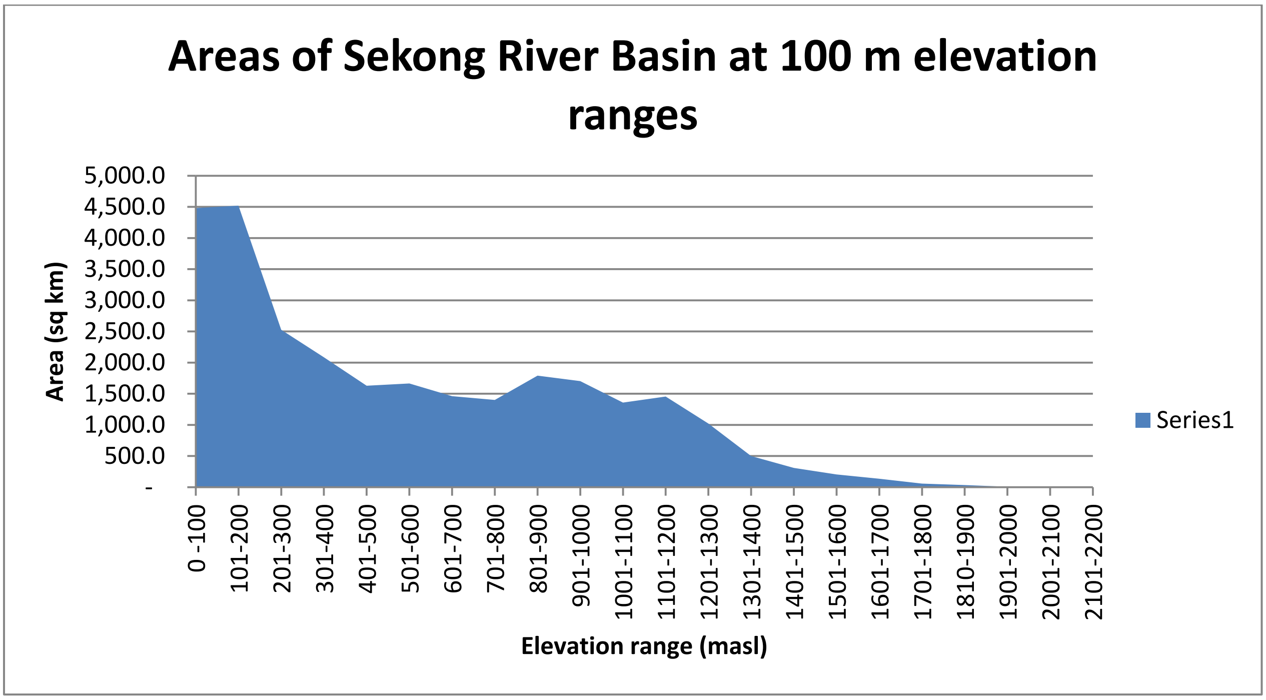
Table 3-4: Stream density of the sub-basins in the Sekong

Consol. code	Name of consolidated basins	Total area	Stream length	Stream density
		sq km	km	km/sq km
1	Sekong headwaters	2,300	351	0.153
2	Sekong in Kaleum	1,647	224	0.136
4	Sekong above Sekong town	1,616	263	0.163
6	Sekong above Attapeu	1,019	160	0.157
17	Sekong/Se Kamman confluence	1,514	397	0.262
10	Sekong upper, Cambodia	2,920	499	0.171
11	Sekong lower, Cambodia	2,175	494	0.227
	Total for mainstem	**13,191**	**2,387**	**0.181**
3	Dak e Meule	978	149	0.152
5	Houay Lamphan Ngai	540	189	0.350
7	Se Nam Noy	1,725	234	0.136
8	Se Pian	1,852	365	0.197
9	Se Khampho	1,492	242	0.162
13	Upper Se Kamman	2,439	404	0.166
14	Lower Se Kamman	1,906	322	0.169
15	Se Xou	1,725	234	0.136
16	Nam Kong	1,627	263	0.162
12	Prek Samang	1,318	206	0.156
	TOTAL SEKONG BASIN	**28,414**	**4,902**	**0.173**

3.2 Elevation

The highest parts of the Sekong catchment reach 2,200 metres above sea level (masl) as shown inTable 3-6. This is expressed graphically in Figure 3-3. The greatest proportion of the river catchment lies between 0-200 masl with a total of about 9,000 sq km. Between 200 and 300 masl there are about 2,500 sq km, then between about 400 and 1,200 masl, there are more or less equal areas in each 100 m range of about 1,500 sq km.

Figure 3-3: Areas of the Sekong catchment at different elevations



When the elevations of the different sub-basins are considered, the Sekong and Se Kamman headwaters both arise in areas above 2,100 masl, and show a clear fall in elevation downstream, while of the tributaries that arise on the Bolevan Plateau, the Houay Lamphan Gnai arises from about 1,800 masl, the Se Nam Noy about 1,700 masl, Se Pian at about 1,400 masl and the Se Kampho at about 1,300 masl. The Se Xou also arises at quite a high elevation of 1,700 masl while the Nam Kong and Prek Samang arise at 1,500 masl and 900 masl, respectively.

Table 3-5 and Figure 3-4 aggregate the areas into four ecologically significant elevation ranges – low elevation (0 – 200 masl), medium elevation (200 – 700 masl), high elevation (700 – 1,500 masl) and montane (>1,500 masl). Overall the Sekong River basin has a very even spread of about 33% of its area in the low, medium and high elevations, with only 1.6% of the basin area at montane elevations. Of the mainstem reaches, only the Sekong headwaters and Sekong in Kaleum have any montane reaches, and the Sekong headwaters have no low elevation reaches. The Lower Sekong in Cambodia has virtually all its catchment at low elevations. The other reaches show an increasing proportion of areas at medium to low elevation with passage downstream.

Of the tributaries, only Dak-e-Meule, Houay Lamphan Ngai and Upper Se Kamman have relatively small areas in the montane elevations, and these with the Se Nam Noy have virtually no areas at low elevations. Se Nam Noy stands out because virtually all of its area is within the high-elevation range, followed by Dak-e-Meule and Upper Se Kamman. Houay Lamphan Ngai has slightly over 50% of its area at high elevation.

Nam Kong and Xe Xou tributaries have the highest proportion of their areas in medium elevation (about 70%), followed by Se Khampho, Houay Lamphan Gnai and Lower Se Kamman (45 – 35%). Prek Samang stands out because over 74% of its catchment area is at low elevation.

Table 3-5: % of catchment area of Sekong at four different elevations

Consol. code	Name of consolidated basins	Low elevation		Medium elevation		High elevation		Montane		Total
		<200 masl		200 - 700		700-1500 masl		>1500 masl		
		sq km	%	sq km	%	sq km	%	sq km	%	sq km
	SEKONG MAINSTEM									
1	Sekong headwaters	-	0.0	425.7	18.7	1,609.4	70.8	236.8	10.4	2,271.9
2	Sekong in Kaleum	6.7	0.4	908.6	55.2	688.6	41.8	43.4	2.6	1,647.1
4	Sekong above Sekong town	307.8	19.0	1,053.3	65.2	255.0	15.8	-	0.0	1,616.0
6	Sekong above Attapeu	599.5	58.9	329.4	32.3	89.5	8.8	-	0.0	1,018.5
17	Sekong/Se Kamman confluence	1,023.4	67.6	397.8	26.3	93.0	6.1	-	0.0	1,514.2
10	Sekong upper, Cambodia	1,833.2	63.3	1,022.0	35.3	42.4	1.5	-	0.0	2,897.6
11	Sekong lower, Cambodia	2,165.9	**99.6**	8.8	0.4	-	0.0	-	0.0	2,174.6
	TRIBUTARIES									
3	Dak e Meule	0.3	0.0	180.3	18.4	774.8	79.2	22.4	2.3	977.9
5	Houay Lamphan Ngai	57.6	10.7	193.0	35.7	284.2	52.6	5.6	1.0	540.4
7	Se Nam Noy	-	0.0	31.5	2.3	1,311.2	**97.5**	2.7	0.2	1,345.4
8	Se Pian	652.3	35.2	447.5	24.2	752.1	40.6	-	0.0	1,851.8
9	Se Khampho	688.1	46.1	681.4	45.7	122.1	8.2	-	0.0	1,491.6
13	Upper Se Kamman	1.4	0.1	298.3	12.2	2,009.7	82.4	129.9	5.3	2,439.2
14	Lower Se Kamman	429.8	22.5	670.1	35.2	803.5	42.1	3.0	0.2	1,906.4
15	Se Xou	187.2	10.9	1,237.5	71.7	298.4	17.3	2.0	0.1	1,725.1
16	Nam Kong	70.2	4.3	1,146.5	70.5	410.2	25.2	-	0.0	1,626.9
12	Prek Samang	978.5	74.2	339.2	25.7	0.2	0.0	-	0.0	1,318.0
	TOTAL FOR SEKONG	**9,001.9**	**31.7**	**9,370.8**	**33.0**	**9,544.2**	**33.7**	**445.7**	**1.6**	**28,362.5**

Note: highlighted cells indicate significant proportions of catchment at these elevations (i.e. over 50%)

Figure 3-4: % of catchment area of Sekong at different elevations

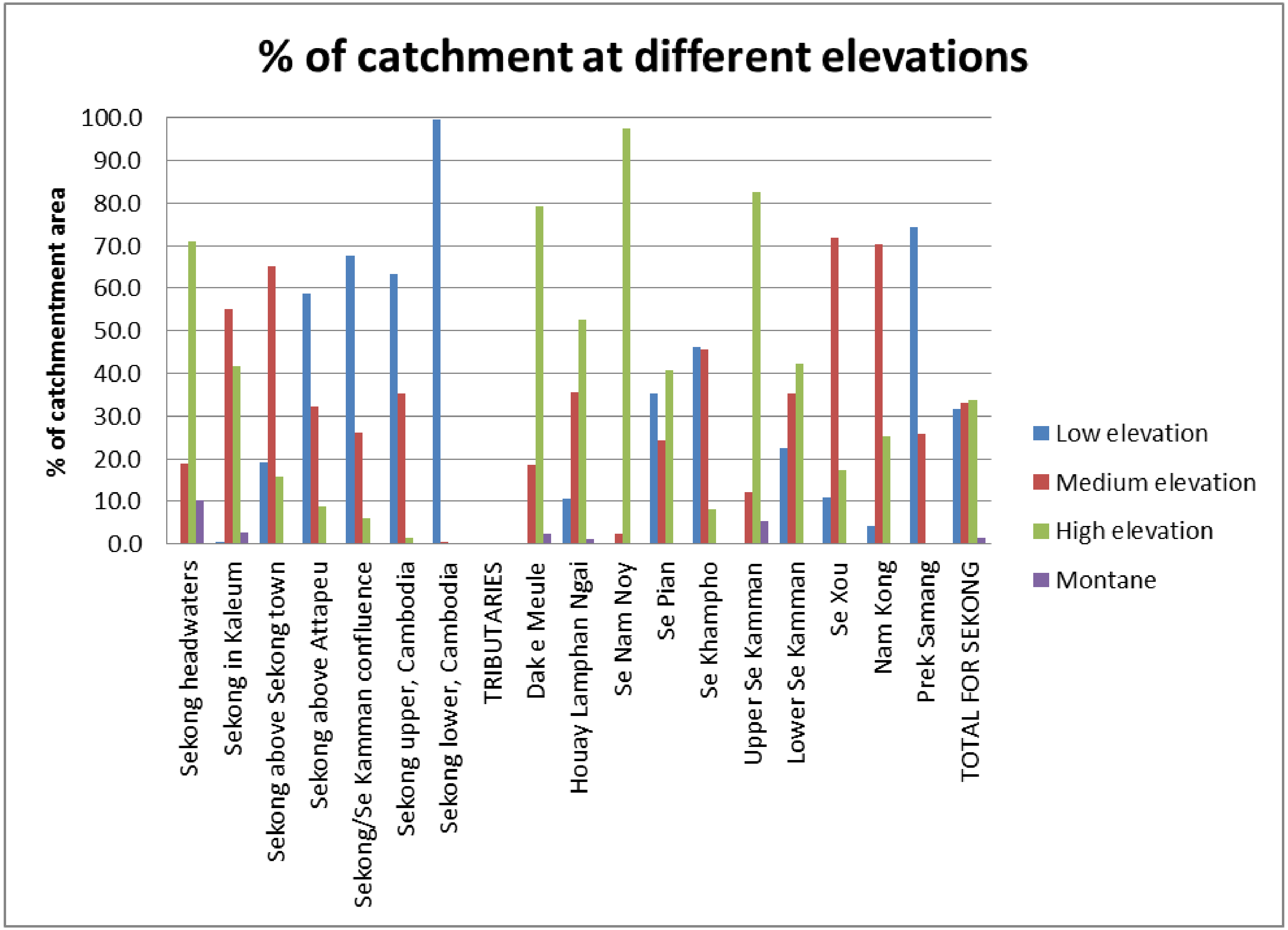
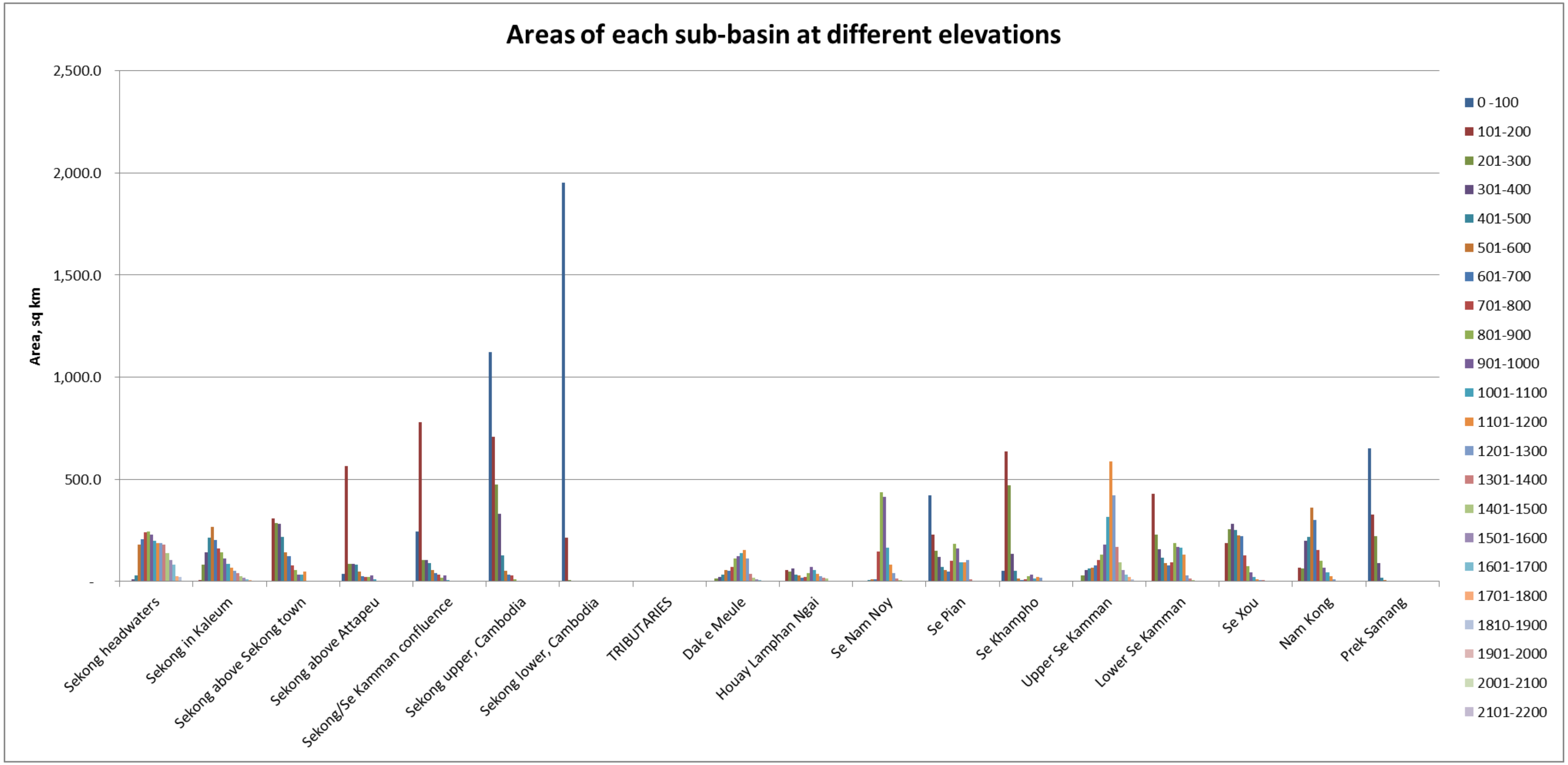


Table 3-6: Areas of the catchment at different elevations

Consol. code	Name of consolidated basins	0 -100	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300	1301-1400	1401-1500	1501-1600	1601-1700	1701-1800	1810-1900	1901-2000	2001-2100	2101-2200	Total
		Area at each elevation (sq km)																						
	SEKONG MAINSTEM																							
1	Sekong headwaters	-	-	-	9.5	30.0	178.9	207.3	239.4	246.0	228.1	200.1	188.6	188.3	180.2	138.7	105.6	80.7	24.7	21.2	3.3	1.1	0.2	**2,271.9**
2	Sekong in Kaleum	-	6.7	82.6	143.9	214.1	266.3	201.6	163.0	141.6	111.1	86.3	65.7	53.6	40.3	27.0	19.7	12.5	7.1	2.9	1.1	0.1		**1,647.1**
4	Sekong above Sekong town	0.1	307.7	286.4	281.9	217.0	142.9	125.1	80.1	54.6	33.7	33.3	49.2	3.8	0.4	0.0								**1,616.0**
6	Sekong above Attapeu	36.2	563.4	87.4	85.6	82.2	47.6	26.6	22.3	22.4	29.1	11.1	3.4	1.2	0.2									**1,018.5**
17	Sekong/Se Kamman confluence	243.1	780.2	104.3	104.9	91.9	57.1	39.6	33.3	20.4	28.9	6.7	2.9	0.7										**1,514.2**
10	Sekong upper, Cambodia	1,124.6	708.6	473.6	330.2	128.8	54.3	35.2	29.9	12.4														**2,897.6**
11	Sekong lower, Cambodia	1,951.0	214.8	6.9	1.4	0.5																		**2,174.6**
	TRIBUTARIES																							
3	Dak e Meule	-	0.3	13.7	20.9	34.6	57.0	54.2	73.1	111.5	124.7	140.9	154.0	113.2	38.9	18.4	10.7	7.1	4.1	0.4	0.1			**977.9**
5	Houay Lamphan Ngai	0.0	57.6	49.8	63.0	31.9	28.9	19.4	21.1	40.3	72.2	56.8	36.7	24.4	19.6	13.1	4.5	1.1	0.0					**540.4**
7	Se Nam Noy	-	-	0.8	3.3	7.0	9.2	11.2	146.0	436.8	413.3	167.0	84.1	39.7	16.5	7.8	2.6	0.1						**1,345.4**
8	Se Pian	420.9	231.4	150.7	121.3	69.5	57.3	48.7	102.4	183.3	163.3	93.4	93.7	105.5	10.5									**1,851.8**
9	Se Khampho	51.5	636.5	469.9	134.6	52.1	16.4	8.4	9.4	25.3	35.3	13.2	20.7	18.2										**1,491.6**
13	Upper Se Kamman	-	1.4	31.7	56.8	62.6	66.8	80.5	105.6	132.3	182.3	315.5	587.2	422.3	170.2	94.2	57.8	34.2	22.6	10.5	3.4	1.1	0.3	**2,439.2**
14	Lower Se Kamman	1.1	428.7	228.2	156.6	118.2	89.7	77.4	95.1	186.3	170.5	166.0	131.6	30.8	15.4	7.8	2.8	0.2						**1,906.4**
15	Se Xou	-	187.2	255.9	282.1	250.4	225.3	223.8	126.5	76.6	43.5	22.3	12.1	8.4	5.9	3.0	1.6	0.4						**1,725.1**
16	Nam Kong	3.2	67.1	62.4	200.9	219.5	361.9	301.8	153.8	101.6	67.6	46.4	25.9	11.9	2.7	0.2								**1,626.9**
12	Prek Samang	650.2	328.3	223.5	89.1	19.2	6.4	1.0	0.2	0.0														**1,318.0**
	TOTAL FOR SEKONG	**4,482.0**	**4,519.9**	**2,527.7**	**2,085.8**	**1,629.5**	**1,665.8**	**1,462.0**	**1,401.2**	**1,791.4**	**1,703.6**	**1,358.9**	**1,455.9**	**1,022.1**	**500.8**	**310.2**	**205.3**	**136.3**	**58.5**	**35.0**	**7.8**	**2.3**	**0.5**	**28,362.5**

Figure 3-5: Areas of different sub-basins at different elevations



3.3 Slope

Slope is an important parameter determining the character of a river, because this determines the rate of flow of water in the river, and hence its stream power. The slope of the overall terrain of each sub-basin has been taken as a surrogate for the actual slope of the river bed. In general, river or stream beds would have a much lower slope, because the river has cut down into the terrain, creating the channel and river valley. Figure 3-6 and Table 3-8 show the proportion of different slope classes of the catchment areas. The Sekong Basin as a whole has about 29% of its catchment at very low slope (0-2%), but then about 21% at a very steep slope (30.1-60%) and 19% at steep slope (15.1–30%).

When the Sekong mainstem is considered, it can be seen that only the Sekong headwaters and the Sekong in Kaleum district have significant proportions of the area in the extreme slope class (>60%) and very steep slopes. Farther down the Sekong mainstem, there are increasing proportions of the catchment at the very low slopes (0-2%), with over 90% of the catchment of the "Sekong lower, Cambodia" being at very low slope.

Of the tributaries, the Se Khampho, Se Pian and Prek Samang all have high proportions at very low slope. All the others have about 25–30% of the catchment at high slope (15.1–30%), and Dak-e-Meule, Upper and Lower Se Kamman and Se Xou, have between 30–40% at very high slope. These tributaries also have the highest proportions of catchments at extreme slope – usually between 5–10% of the area.

Figure 3-6: % of areas of sub-basins at different slope classes

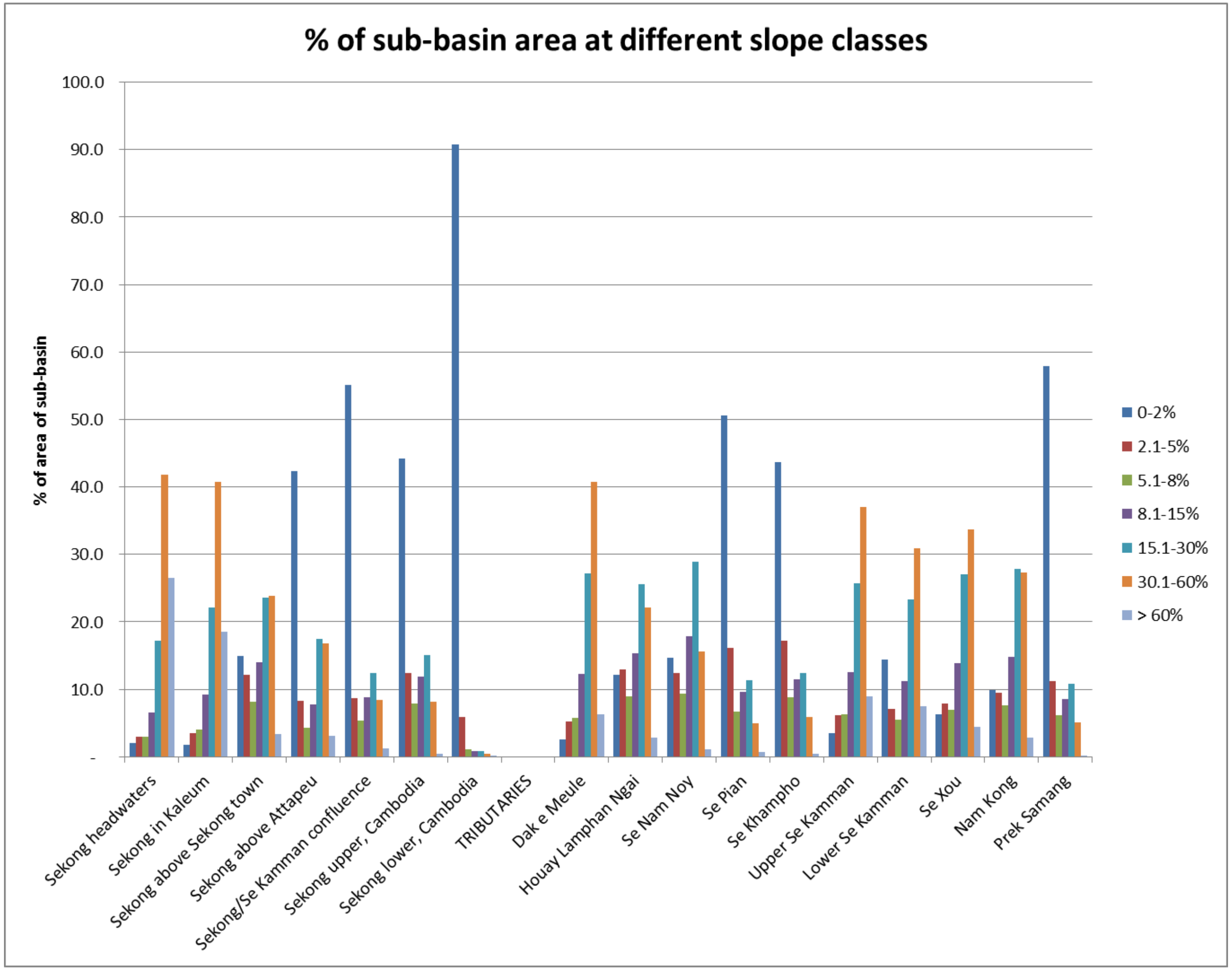


Table 3-7: Areas of different catchments by slope class with i) % of total slope class and ii) % of sub-basin

Consol. code	Name of consolidated basins	0-2% sq km	% of sub-basin	2.1-5% sq km	% of sub-basin	5.1-8% sq km	% of sub-basin	8.1-15% sq km	% of sub-basin	15.1-30% sq km	% of sub-basin	30.1-60% sq km	% of sub-basin	> 60% sq km	% of sub-basin	Total sq km
	SEKONG MAINSTEM															
1	Sekong headwaters	46.14	2.0	67.80	2.9	69.17	3.0	149.61	6.5	395.34	17.2	962.33	41.8	609.41	26.5	**2,299.8**
2	Sekong in Kaleum	29.42	1.8	57.67	3.5	65.47	4.0	151.89	9.2	365.12	22.2	672.26	40.8	305.30	18.5	**1,647.1**
4	Sekong above Sekong town	241.00	14.9	196.12	12.1	132.51	8.2	225.45	14.0	380.63	23.6	385.72	23.9	54.61	3.4	**1,616.0**
6	Sekong above Attapeu	430.90	42.3	84.35	8.3	43.36	4.3	78.91	7.7	178.28	17.5	171.40	16.8	31.30	3.1	**1,018.5**
17	Sekong/Se Kamman confluence	834.85	55.1	131.83	8.7	81.09	5.4	132.71	8.8	187.72	12.4	126.81	8.4	19.19	1.3	**1,514.2**
10	Sekong upper, Cambodia	1289.69	44.2	364.26	12.5	231.26	7.9	346.18	11.9	439.46	15.1	237.05	8.1	11.88	0.4	**2,919.8**
11	Sekong lower, Cambodia	1975.20	90.8	127.76	5.9	23.41	1.1	17.79	0.8	19.52	0.9	10.50	0.5	0.49	0.0	**2,174.6**
	TRIBUTARIES															
3	Dak e Meule	24.67	2.5	50.73	5.2	56.22	5.7	119.71	12.2	265.68	27.2	398.70	40.8	62.17	6.4	**977.9**
5	Houay Lamphan Ngai	65.86	12.2	70.23	13.0	48.42	9.0	82.68	15.3	138.38	25.6	119.74	22.2	15.12	2.8	**540.4**
7	Se Nam Noy	197.27	14.7	167.48	12.4	125.01	9.3	241.30	17.9	389.60	29.0	209.39	15.6	15.31	1.1	**1,345.4**
8	Se Pian	936.37	50.6	298.08	16.1	124.88	6.7	177.41	9.6	209.10	11.3	91.93	5.0	14.06	0.8	**1,851.8**
9	Se Khampho	650.81	43.6	257.25	17.2	131.57	8.8	171.66	11.5	184.98	12.4	88.43	5.9	6.89	0.5	**1,491.6**
13	Upper Se Kamman	84.39	3.5	151.18	6.2	152.23	6.2	305.43	12.5	626.66	25.7	901.66	37.0	217.65	8.9	**2,439.2**
14	Lower Se Kamman	274.37	14.4	135.47	7.1	105.65	5.5	214.09	11.2	445.94	23.4	588.22	30.9	142.65	7.5	**1,906.4**
15	Se Xou	108.50	6.3	135.64	7.9	119.08	6.9	238.32	13.8	466.63	27.0	581.27	33.7	75.68	4.4	**1,725.1**
16	Nam Kong	160.16	9.8	154.84	9.5	125.00	7.7	241.65	14.9	453.97	27.9	444.75	27.3	46.55	2.9	**1,626.9**
12	Prek Samang	763.94	58.0	147.45	11.2	80.93	6.1	112.75	8.6	143.09	10.9	67.76	5.1	2.05	0.2	**1,318.0**
	TOTAL FOR SEKONG	**8,113.5**	**28.6**	**2,598.1**	**9.1**	**1,715.3**	**6.0**	**3,007.5**	**10.6**	**5,290.1**	**18.6**	**6,057.9**	**21.3**	**1,630.3**	**5.7**	**28,412.6**

Consol. code	Name of consolidated basins	0-2% sq km	% of total slope class	2.1-5% sq km	% of total slope class	5.1-8% sq km	% of total slope class	8.1-15% sq km	% of total slope class	15.1-30% sq km	% of total slope class	30.1-60% sq km	% of total slope class	> 60% sq km	% of total slope class	Total sq km
	SEKONG MAINSTEM															
1	Sekong headwaters	46.14	0.6	67.80	2.6	69.17	4.0	149.61	5.0	395.34	7.5	962.33	15.9	609.41	37.4	**2,299.8**
2	Sekong in Kaleum	29.42	0.4	57.67	2.2	65.47	3.8	151.89	5.1	365.12	6.9	672.26	11.1	305.30	18.7	**1,647.1**
4	Sekong above Sekong town	241.00	3.0	196.12	7.5	132.51	7.7	225.45	7.5	380.63	7.2	385.72	6.4	54.61	3.3	**1,616.0**
6	Sekong above Attapeu	430.90	5.3	84.35	3.2	43.36	2.5	78.91	2.6	178.28	3.4	171.40	2.8	31.30	1.9	**1,018.5**
17	Sekong/Se Kamman confluence	834.85	10.3	131.83	5.1	81.09	4.7	132.71	4.4	187.72	3.5	126.81	2.1	19.19	1.2	**1,514.2**
10	Sekong upper, Cambodia	1289.69	15.9	364.26	14.0	231.26	13.5	346.18	11.5	439.46	8.3	237.05	3.9	11.88	0.7	**2,919.8**
11	Sekong lower, Cambodia	1975.20	24.3	127.76	4.9	23.41	1.4	17.79	0.6	19.52	0.4	10.50	0.2	0.49	0.0	**2,174.6**
	TRIBUTARIES															
3	Dak e Meule	24.67	0.3	50.73	2.0	56.22	3.3	119.71	4.0	265.68	5.0	398.70	6.6	62.17	3.8	**977.9**
5	Houay Lamphan Ngai	65.86	0.8	70.23	2.7	48.42	2.8	82.68	2.7	138.38	2.6	119.74	2.0	15.12	0.9	**540.4**
7	Se Nam Noy	197.27	2.4	167.48	6.4	125.01	7.3	241.30	8.0	389.60	7.4	209.39	3.5	15.31	0.9	**1,345.4**
8	Se Pian	936.37	11.5	298.08	11.5	124.88	7.3	177.41	5.9	209.10	4.0	91.93	1.5	14.06	0.9	**1,851.8**
9	Se Khampho	650.81	8.0	257.25	9.9	131.57	7.7	171.66	5.7	184.98	3.5	88.43	1.5	6.89	0.4	**1,491.6**
13	Upper Se Kamman	84.39	1.0	151.18	5.8	152.23	8.9	305.43	10.2	626.66	11.8	901.66	14.9	217.65	13.4	**2,439.2**
14	Lower Se Kamman	274.37	3.4	135.47	5.2	105.65	6.2	214.09	7.1	445.94	8.4	588.22	9.7	142.65	8.8	**1,906.4**
15	Se Xou	108.50	1.3	135.64	5.2	119.08	6.9	238.32	7.9	466.63	8.8	581.27	9.6	75.68	4.6	**1,725.1**
16	Nam Kong	160.16	2.0	154.84	6.0	125.00	7.3	241.65	8.0	453.97	8.6	444.75	7.3	46.55	2.9	**1,626.9**
12	Prek Samang	763.94	9.4	147.45	5.7	80.93	4.7	112.75	3.7	143.09	2.7	67.76	1.1	2.05	0.1	**1,318.0**
	TOTAL FOR SEKONG	**8,113.5**		**2,598.1**		**1,715.3**		**3,007.5**		**5,290.1**		**6,057.9**		**1,630.3**		**28,412.6**

Note: Highlighted cells show significant proportions of the area at these slope classes

3.4 Geology

The geology of the Sekong basin is shown in Figure 3-7. An analysis of the main features in Table 3-9 shows that over 56% of the area consists of formations with conglomerates, sandstone and gravel; 22% of the area consists of formations containing limestone, 13% basalt and 8% granite. When this is considered in greater detail, the top 10 formations are highlighted in Table 3-10, reflecting this distribution.

Figure 3-7: Geological map of the Sekong RiverBasin

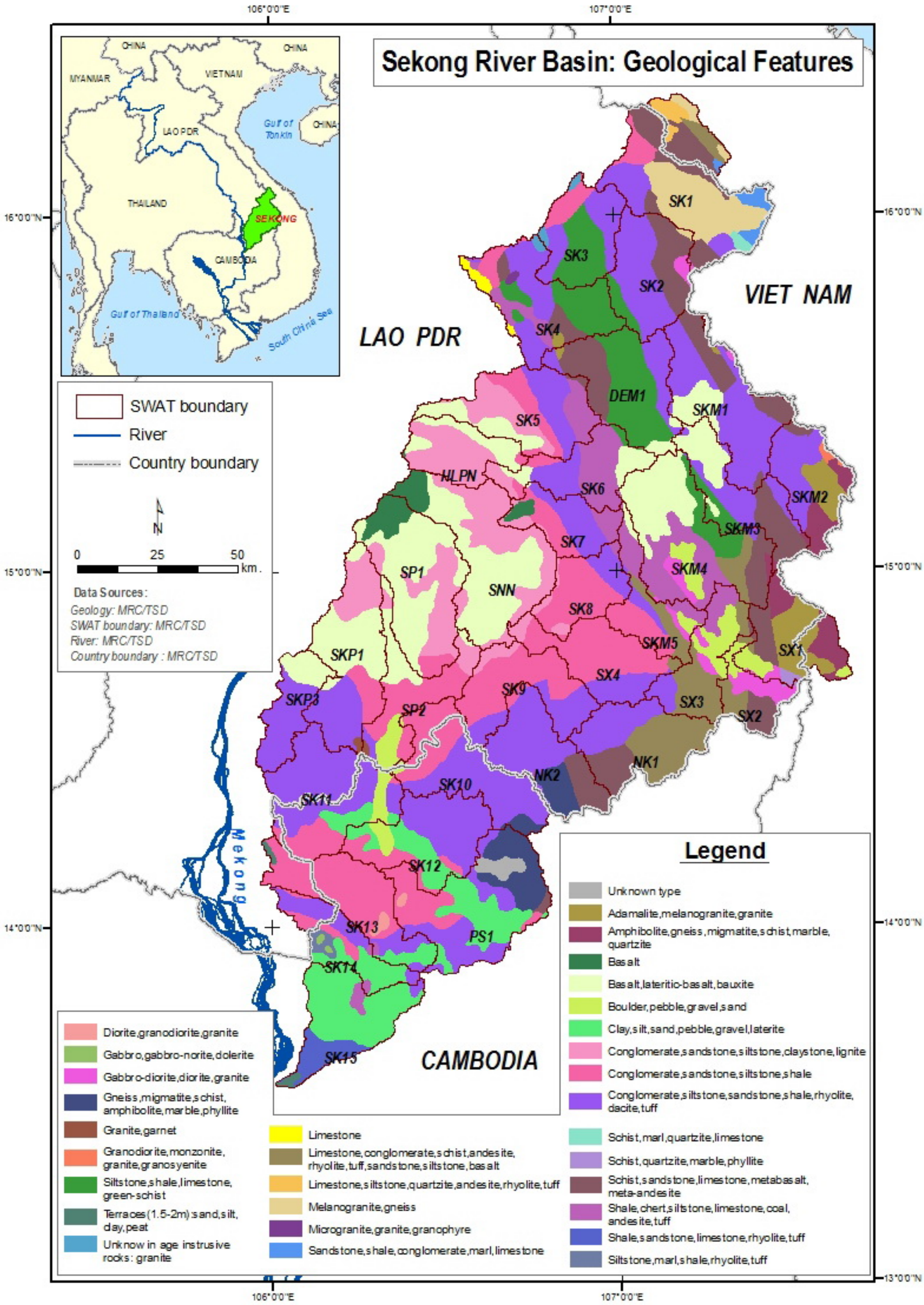


Table 3-8: Overall Geology of the Sekong Basin

	sq km	%
Granite	2,319.0	8.2
Basalt	3,684.7	13.0
Limestone containing	6,333.7	22.3
Conglomerates, sand, gravel	15,964.1	56.2
Other	112.3	0.4
Total area	**28,413.8**	

Table 3-9: Geological formations throughout the Sekong Basin

Geological formation	Total for Sekong		
	Sq km	%	Rank
Adamalite,melanogranite,granite	452.6	1.59	
Amphibolite,gneiss,migmatite,schist,marble,quartzite	381.1	1.34	
Basalt	282.2	0.99	
Basalt,lateritic-basalt,bauxite	3,402.6	11.98	3
Boulder,pebble,gravel,sand	602.5	2.12	10
Clay,silt,sand,pebble,gravel,laterite	1,475.1	5.19	6
Conglomerate,sandstone,siltstone,claystone,lignite	1,982.7	6.98	5
Conglomerate,sandstone,siltstone,shale	**4,278.0**	**15.06**	2
Conglomerate,siltstone,sandstone,shale,rhyolite,dacite,tuff	**7,625.7**	**26.84**	1
Diorite,granodiorite,granite	35.0	0.12	
Gabbro,gabbro-norite,dolerite	10.6	0.04	
Gabbro-diorite,diorite,granite	292.3	1.03	
Gneiss,migmatite,schist,amphibolite,marble,phyllite	461.1	1.62	
Granite,garnet	24.4	0.09	
Granodiorite,monzonite,granite,granosyenite	21.2	0.07	
Limestone	52.5	0.18	
Limestone,conglomerate,schist,andesite,rhyolite,tuff,sandstone,siltstone,basalt	1,040.6	3.66	9
Limestone,siltstone,quartzite,andesite,rhyolite,tuff	81.1	0.29	
Melanogranite,gneiss	554.2	1.95	
Microgranite,granite,granophyre	11.4	0.04	
Sandstone,shale,conglomerate,marl,limestone	93.2	0.33	
Schist,marl,quartzite,limestone	27.9	0.10	
Schist,quartzite,marble,phyllite	31.1	0.11	
Schist,sandstone,limestone,metabasalt,meta-andesite	2,171.9	7.64	4
Shale,chert,siltstone,limestone,coal,andesite,tuff	1,227.0	4.32	8
Shale,sandstone,limestone,rhyolite,tuff	170.2	0.60	
Siltstone,marl,shale,rhyolite,tuff	50.4	0.18	
Siltstone,shale,limestone,green-schist	1,419.0	4.99	7
Terraces(1.5-2m):sand,silt,clay,peat	34.7	0.12	
Unknow in age instrusive rocks: granite	43.9	0.15	
Unkown	77.5	0.27	
Total by sub-catchment	**28,413.8**		

Table 3-10 and Table 3-11 show the distribution of these geological formations among the Sekong mainstem and the tributaries. It is clear that the two main conglomerate formations predominate throughout the length of the mainstem (*Conglomerate, siltstone, sandstone, shale, rhyolite, dacite, tuff*; and *Conglomerate, sandstone, siltstone, shale).* In the Sekong headwaters, *Melanogranite, gneiss;* and *Schist, sandstone, limestone, metabasalt, meta-andesite* contribute 24% and 27%, respectively. In the Sekong in Kaleum District, *Siltstone, shale, limestone, green-schist* contributes 35%, compared to a slightly smaller proportion of conglomerates.

There is an interesting coal-bearing formation (*Shale, chert, siltstone, limestone, coal, andesite, tuff*) in Sekong in Kaleum, Sekong above Sekong town and Sekong above Attapeu. In the Sekong above

Sekong town sub-basin this formation makes up 25% of the area. There are recognised deposits of coal in this area which may be commercially exploitable, even adjacent to the river channel.

In the reach of Sekong above Sekong town there are significant formations of *Basalt, lateritic-basalt, bauxite* making up 18% of the area, the greatest proportion of basalt formations in the Sekong mainstem.

The two reaches of the Sekong in Cambodia, Sekong upper and lower, Cambodia show increasing proportions of *Clay, silt, sand, pebble, gravel, laterite* reflecting the deposition of these finer sediments in the Sekong floodplain.

In the tributaries, *Basalt* and *Basalt, lateritic-basalt, bauxite* formations predominate in the tributaries originating from the Bolevan Plateau, namely Houay Lamphan Ngai, Se Nam Noi, Se Pian, Se Khampho with 33%, 60%, 50% and 38%, respectively. In these tributaries the balance of the formations are made up of *Conglomerate, sandstone, siltstone, claystone, lignite;* and *Conglomerate, sandstone, siltstone, shale.*

Dak-e-Meule is an interesting tributary because 75% of the area consists of limestone-bearing rocks, principally *Siltstone, shale, limestone, green-schist* (50%) and *Schist, sandstone, limestone, metabasalt, meta-andesite* (24%) and the rest *Conglomerate, siltstone, sandstone, shale, rhyolite, dacite, tuff* (20%) and *Basalt, lateritic-basalt, bauxite (5%).*

Se Kamman and Se Xou appear to be similar geologically with higher proportions of granites, but the Se Kamman upper and lower sections both contain high proportions of *Basalt, lateritic-basalt, bauxite* (15% and 25%, respectively) while the Se Xou has none of this formation. The Upper Se Kamman has a high proportion of *Conglomerate, siltstone, sandstone, shale, rhyolite, dacite, tuff* (48%) whilst the lower Se Kamman and the Se Xou have much lower proportions (3% and 4%, respectively). The Lower Se Kamman and Se Xou both have significant proportions of limestone-containing rock formations with *Limestone, conglomerate, schist, andesite, rhyolite, tuff, sandstone, siltstone, basalt;* and *Schist, sandstone, limestone, metabasalt, meta-andesite;* and *Siltstone, shale, limestone, green-schist* making up 53% and 40% of the area, respectively. Upper Se Kamman has 24% of these formations.

The Nam Kong is made up principally of *Conglomerate, siltstone, sandstone, shale, rhyolite, dacite, tuff* (47%); *Limestone, conglomerate, schist, andesite, rhyolite, tuff, sandstone, siltstone, basalt* (24%); and *Schist, sandstone, limestone, metabasalt, meta-andesite* (19%).

The Prek Samang catchement is principally made up of the two main conglomerate formations (46%) and *Boulder, pebble, gravel and sand* (25%); plus *Gneiss, migmatite, schist, amphibolite, marble, phyllite* (21%).

Table 3-10: Distribution of geological formations within the Sekong mainstem

Geological formation	Sekong headwaters		Sekong in Kaleum		Sekong above Sekong town		Sekong above Attapeu		Sekong/Se Kamman confluence		Sekong upper, Cambodia		Sekong lower, Cambodia	
	1		2		4		6		17		10		11	
	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%
Adamalite,melanogranite,granite			14.84	0.90		-		-		-		-		-
Amphibolite,gneiss,migmatite,schist,marble,quartzite				-		-		-		-		-		-
Basalt				-		-	39.26	3.85		-		-		-
Basalt,lateritic-basalt,bauxite				-	295.57	18.29	2.17	0.21	0.37	0.02		-		-
Boulder,pebble,gravel,sand				-		-		-		-	138.17	4.73		-
Clay,silt,sand,pebble,gravel,laterite				-		-		-		-	309.29	10.59	832.18	38.26
Conglomerate,sandstone,siltstone,claystone,lignite				-	286.64	17.74	93.05	9.14	95.82	6.33		-		-
Conglomerate,sandstone,siltstone,shale	92.69	4.03	168.03	10.20	215.50	13.33	480.43	47.17	986.44	65.15	671.02	22.98	692.11	31.82
Conglomerate,siltstone,sandstone,shale,rhyolite,dacite,tuff	648.50	28.20	570.46	34.63	375.23	23.22	324.12	31.82	416.71	27.52	1,753.90	60.07	304.20	13.99
Diorite,granodiorite,granite				-		-		-		-		-	24.32	1.12
Gabbro,gabbro-norite,dolerite				-		-		-		-		-	10.62	0.49
Gabbro-diorite,diorite,granite	35.25	1.53		-		-		-		-		-		-
Gneiss,migmatite,schist,amphibolite,marble,phyllite				-		-		-		-	45.17	1.55		-
Granite,garnet				-		-		-		-	1.60	0.05		-
Granodiorite,monzonite,granite,granosyenite				-		-		-		-		-		-
Limestone			52.52	3.19		-		-		-		-		-
Limestone,conglomerate,schist,andesite,rhyolite,tuff,sandstone,siltstone,basalt	61.79	2.69		-		-	0.24	0.02	14.85	0.98		-		-
Limestone,siltstone,quartzite,andesite,rhyolite,tuff	78.23	3.40	2.83	0.17		-		-		-		-		-
Melanogranite,gneiss	554.22	24.10		-		-		-		-		-		-
Microgranite,granite,granophyre			11.45	0.70		-		-		-		-		-
Sandstone,shale,conglomerate,marl,limestone	93.18	4.05		-		-		-		-		-		-
Schist,marl,quartzite,limestone	27.86	1.21		-		-		-		-		-		-
Schist,quartzite,marble,phyllite				-		-		-		-		-		-
Schist,sandstone,limestone,metabasalt,meta-andesite	633.67	27.55	97.32	5.91	14.26	0.88		-		-		-		-
Shale,chert,siltstone,limestone,coal,andesite,tuff			100.43	6.10	411.64	25.47	79.23	7.78		-		-	56.28	2.59
Shale,sandstone,limestone,rhyolite,tuff				-		-		-		-		-	170.23	7.83
Siltstone,marl,shale,rhyolite,tuff				-		-		-		-		-	50.43	2.32
Siltstone,shale,limestone,green-schist	74.45	3.24	585.57	35.55	17.26	1.07		-		-		-		-
Terraces(1.5-2m):sand,silt,clay,peat				-		-		-		-	0.25	0.01	34.46	1.58
Unknow in age instrusive rocks: granite			43.94	2.67		-		-		-		-		-
Unkown				-		-		-		-	0.48	0.02		-
Total by sub-catchment	**2,299.8**		**1,647.4**		**1,616.1**		**1,018.5**		**1,514.2**		**2,919.9**		**2,174.8**	

Table 3-11: Distribution of geological formations within the Sekong tributaries

Geological formation	Dak e Meule		Houay Lamphan Ngai		Se Nam Noy		Se Pian		Se Khampho		Upper Se Kamman		Lower Se Kamman		Se Xou		Nam Kong		Prek Samang	
	3		5		7		8		9		13		14		15		16		12	
	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%	sq km	%
Adamalite,melanogranite,granite	7.97	0.82		-		-		-		-	148.78	6.10		-	281.03	16.29		-		-
Amphibolite,gneiss,migmatite,schist,marble,quartzite		-		-		-		-		-	157.49	6.46	16.46	0.86	207.17	12.01		-		-
Basalt		-	3.25	0.60	102.90	7.65	136.76	7.38		-		-		-		-		-		-
Basalt,lateritic-basalt,bauxite	45.19	4.62	177.24	32.79	712.80	52.98	783.00	42.28	560.77	37.59	358.33	14.69	467.13	24.50		-		-		-
Boulder,pebble,gravel,sand		-		-		-	91.97	4.97		-		-	113.94	5.98	258.47	14.98		-		-
Clay,silt,sand,pebble,gravel,laterite		-		-		-		-		-		-		-		-		-	333.67	25.32
Conglomerate,sandstone,siltstone,claystone,lignite		-	348.69	64.51	529.36	39.35	421.52	22.76	207.63	13.92		-		-		-		-		-
Conglomerate,sandstone,siltstone,shale		-	11.31	2.09	0.33	0.02	378.14	20.42	114.93	7.70		-	182.77	9.59		-	25.95	1.60	258.38	19.60
Conglomerate,siltstone,sandstone,shale,rhyolite,dacite,tuff	191.72	19.61		-		-	28.01	1.51	598.23	40.10	1,166.52	47.83	63.08	3.31	77.59	4.50	765.17	47.03	342.25	25.97
Diorite,granodiorite,granite		-		-		-		-		-		-		-		-		-	10.63	0.81
Gabbro,gabbro-norite,dolerite		-		-		-		-		-		-		-		-		-		-
Gabbro-diorite,diorite,granite		-		-		-		-		-	6.13	0.25	76.30	4.00	174.59	10.12		-		-
Gneiss,migmatite,schist,amphibolite,marble,phyllite		-		-		-		-		-		-		-		-	138.82	8.53	277.06	21.02
Granite,garnet		-		-		-	12.49	0.67	10.33	0.69		-		-		-		-		-
Granodiorite,monzonite,granite,granosyenite		-		-		-		-		-	21.18	0.87		-		-		-		-
Limestone		-		-		-		-		-		-		-		-		-		-
Limestone,conglomerate,schist,andesite,rhyolite,tuff,sandstone,siltstone,basalt		-		-		-		-		-		-	213.86	11.22	368.05	21.34	381.77	23.47		-
Limestone,siltstone,quartzite,andesite,rhyolite,tuff		-		-		-		-		-		-		-		-		-		-
Melanogranite,gneiss		-		-		-		-		-		-		-		-		-		-
Microgranite,granite,granophyre		-		-		-		-		-		-		-		-		-		-
Sandstone,shale,conglomerate,marl,limestone		-		-		-		-		-		-		-		-		-		-
Schist,marl,quartzite,limestone		-		-		-		-		-		-		-		-		-		-
Schist,quartzite,marble,phyllite		-		-		-		-		-		-		-	31.13	1.80		-		-
Schist,sandstone,limestone,metabasalt,meta-andesite	233.48	23.88		-		-		-		-	492.46	20.19	133.17	6.99	233.34	13.53	315.23	19.38	18.93	1.44
Shale,chert,siltstone,limestone,coal,andesite,tuff	6.79	0.69		-		-		-		-		-	478.96	25.12	93.71	5.43		-		-
Shale,sandstone,limestone,rhyolite,tuff		-		-		-		-		-		-		-		-		-		-
Siltstone,marl,shale,rhyolite,tuff		-		-		-		-		-		-		-		-		-		-
Siltstone,shale,limestone,green-schist	492.72	50.39		-		-		-		-	88.25	3.62	160.71	8.43		-		-		-
Terraces(1.5-2m):sand,silt,clay,peat		-		-		-		-		-		-		-		-		-		-
Unknow in age instrusive rocks: granite		-		-		-		-		-		-		-		-		-		-
Unkown		-		-		-		-		-		-		-		-		-	77.06	5.85
Total by sub-catchment	**977.9**		**540.5**		**1,345.4**		**1,851.9**		**1,491.9**		**2,439.1**		**1,906.4**		**1,725.1**		**1,626.9**		**1,318.0**	

3.5 Soils

The soil map of the Sekong Basin is shown in Figure 3-8. This shows a predominance of Acrisols throughout the basin. The analysis of the soil types is shown inTable 3-12. Acrisols cover 69% of the basin, followed by Cambisols with 15%, with Leptosols, Gleysols and Luvisols making up about 4% – 6% each. Ferralsols make up about 1.6% of the basin.

Table 3-13 provides the distribution of these six main soil types in the Sekong mainstem and the tributaries. In the Sekong mainstem, *Acrisols* make up virtually 100% in the upper reaches, falling to about 60% between Sekong town and the Sekong upper, Cambodia, and down to 40% in Sekong lower, Cambodia. *Cambisols* make up about 30% in Sekong above Sekong town, and 14% above Attapeu, increasing to 26% in the reach around the Sekong/Se Kamman confluence. In the Sekong lower Cambodia, *Cambisols* reach 10%. *Ferralsols* are found in small proportions in the headwaters, and more significantly from above Sekong town and Attapeu.

Gleysols are wetland soilsand can be seen clearly on the map following the river channel and are predominant in the two reaches in Cambodia, with Sekong upper, Cambodia having 20% and Sekong lower, Cambodia having 30.5%.*Leptosols* are found in relatively small proportions of the catchments of the middle reaches of the Sekong mainstem, only reaching 10% of the coverage in Sekong upper, Cambodia. *Luvisols*are only found in significant proportions in the reach around the confluence between the Sekong and the Se Kamman where they achieve 27% of the coverage. As can be seen from the map, the Luvisols are concentrated in the lower reaches of the Se Kamman around Attapeu in association with an area of Cambisols.

When considering the tributaries, the catchments of the Dak-e-Meule, Upper Se Kamman and Prek Samang have over 90% of Acrisol soils, with some proportions of Cambisols (4%) in Dak-e-Meule, and of Gleysols (7%) in the Prek Samang. Of the four tributaries arising on the Bolevan Plateau, Houay Lamphan Gnai stands out as having a much lower Acrisol coverage (19%) compared to Se Nam Noi, Se Pian and Se Khampho which all have about 67% Acrisols. Houay Lamphan Gnai has 28% Cambisol and 50% Leptosol – the highest of any of the tributaries with this soil type. Se Nam Noi has 24% Cambisol and 20% Leptosol. Se Pian has 24% Cambisol, 8.5% Gleysol, and 3.5% Leptosol. Se Khampho has only 10% Cambisol and 23% Leptosol.

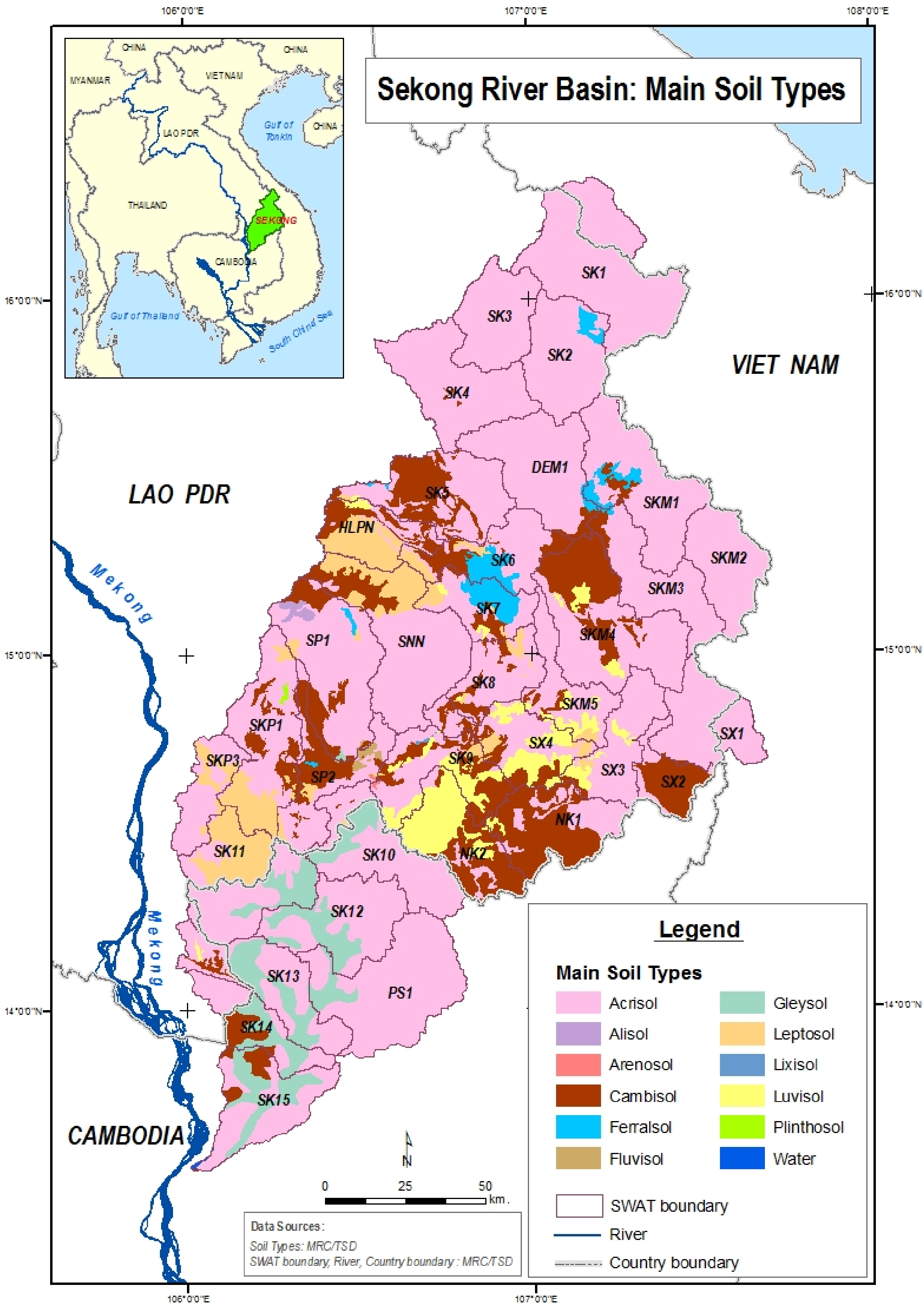
Upper Se Kamman has high Acrisols with small proportions of Cambisols and Ferralsols (about 4% each). Lower Se Kamman and Se Xou show slightly lower Acrisols (65%–80%), with higher proportions of Cambisols. Lower Se Kamman has 27% Cambisol and 7% Luvisol. Se Xou has 16% Cambisol and 4% Luvisol.

By contrast, Nam Kong has only 21% Acrisol, 55% Cambisol and 24% Luvisol, indicating its very different soil characteristics compared to the other tributaries.

Table 3-12: Distribution of soil types in the Sekong Basin

Soil type	sq km	% of catchment	Rank
Acrisol	18,689.85	68.98	1
Alisol	43.04	0.16	
Arenosol	6.95	0.03	
Cambisol	3,987.51	14.72	2
Ferralsol	442.37	1.63	
Fluvisol	35.77	0.13	
Gleysol	1,246.72	4.60	4
Leptosol	1,556.68	5.75	3
Lixisol	5.40	0.02	
Luvisol	1,065.52	3.93	5
Plinthosol	9.37	0.03	
Water	6.65	0.02	
Totals	**27,095.8**		

Figure 3-8: Soil map of the Sekong Basin



Soil types found in the Sekong Basin

- **Acrisol** is a clay-rich soil type is associated with humid, tropical climates, such as those found in Brazil, which often supports forested areas. It is one of the 30 major soil groups of the World Reference Base for Soil Resources. The low fertility of Acrisol and toxic amounts of aluminium pose limitations to its agricultural use, favouring in many places its use for silviculture, low intensity pasture and protected areas. Crops that can be successfully cultivated if the climate allows include tea, rubber tree, oil palm, coffee and sugar cane.

- **Cambisol** is a soil with a beginning of soil formation. The horizon differentiation is weak. This is evident from weak, mostly brownish discolouration and/or structure formation in the soil profile. Cambisols are developed in medium and fine-textured materials derived from a wide range of rocks, mostly in alluvial, colluvial and aeolian deposits. Most of these soils make good agricultural land and are intensively used. Cambisols in temperate climates are among the most productive soils on earth.

- The main processes of soil formation of **Ferralsols** are weathering, humification and pedoturbation due to animals. These processes produce the characteristic soil profile. They are defined as soils containing at all depths no more than 10% weatherable minerals, and low cation exchange capacity. Ferralsols are always a red or yellowish color, due to the high concentration of iron(III) and aluminium oxides and hydroxides. In addition they also contain quartz and kaolin, plus small amounts of other clay minerals and organic matter.

- **Gleysol** is a wetland soil (hydric soil) that, unless drained, is saturated with groundwater for long enough periods to develop a characteristic gleyic colour pattern. This pattern is essentially made up of reddish, brownish or yellowish colours at surfaces of soil particles (peds) and/or in the upper soil horizons mixed with greyish/blueish colours inside the peds and/or deeper in the soil. Gleysols occur on a wide range of unconsolidated materials, mainly fluvial, marine and lacustrine sediments of Pleistocene or Holocene age, with basic to acidic mineralogy. They are found in depression areas and low landscape positions with shallow groundwater. Wetness is the main limitation of virgin Gleysols; these are covered with natural swamp vegetation and lie idle or are used for extensive grazing. Artificially drained Gleysols are used for arable cropping, dairy farming and horticulture. Gleysols in the tropics and subtropics are widely planted to rice.

- **Luvisols** are technically characterized by a surface accumulation of humus overlying an extensively leached layer that is nearly devoid of clay and iron-bearing minerals. Below the latter lies a layer of mixed clay accumulation that has high levels of available nutrient ions comprising calcium, magnesium, sodium, or potassium. Luvisols are often associated with Cambisols. The mixed mineralogy, high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, from grains to orchards to vineyards.

- **Leptosol** is a very shallow soil over hard rock or highly calcareous material or a deeper soil that is extremely gravelly and/or stony. Leptosols can be found on hard rocks or where erosion has kept pace with soil formation or removed the top of the soil. Leptosols are unattractive soils for rainfed agriculture because of their inability to hold water, but may sometimes have potential for tree crops or extensive grazing. Leptosols are best kept under forest.

Table 3-13: Distribution of the six predominant soil types in the Sekong Basin i) by % of basin and ii) by % of catchment

Code	Name of consolidated basins	Acrisol		Cambisol		Ferralsol		Gleysol		Leptosol		Luvisol		Totals
		sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km
1	Sekong headwaters	2,247.42	12.02		-	52.42	11.85		-		-		-	2,299.84
2	Sekong in Kaleum	1,641.63	8.78	5.76	0.14		-		-		-		-	1,647.40
4	Sekong above Sekong town	921.81	4.93	491.34	12.32	126.63	28.63		-	72.91	4.68	3.41	9.55	1,616.10
6	Sekong above Attapeu	627.83	3.36	140.42	3.52	144.58	32.68		-	86.60	5.56	19.06	53.29	1,018.50
17	Sekong/Se Kamman confluence	616.51	3.30	400.83	10.05		-	0.28	0.02	74.83	4.81	412.08	1,152.18	1,514.19
10	Sekong upper, Cambodia	1,984.51	10.62	2.65	0.07		-	574.07	46.05	356.58	22.91	2.07	5.78	2,919.88
11	Sekong lower, Cambodia	1,273.51	6.81	223.72	5.61		-	663.89	53.25		-	7.07	19.76	2,174.84
	Tributaries													
3	Dak e Meule	921.92	4.93	41.90	1.05	14.05	3.18		-		-		-	977.87
5	Houay Lamphan Ngai	104.43	0.56	149.63	3.75		-		-	268.58	17.25	17.85	49.90	540.49
7	Se Nam Noy	911.08	4.87	166.74	4.18		-		-	267.56	17.19		-	1,345.38
8	Se Pian	1,239.75	6.63	440.40	11.04	16.81	3.80	8.49	0.68	64.95	4.17		-	1,851.89
9	Se Khampho	1,002.73	5.37	144.73	3.63		-		-	335.05	21.52		-	1,491.89
13	Upper Se Kamman	2,256.09	12.07	95.17	2.39	87.87	19.86		-		-		-	2,439.14
14	Lower Se Kamman	1,241.65	6.64	506.54	12.70		-		-	19.16	1.23	139.02	388.71	1,906.38
15	Se Xou	1,364.77	7.30	280.47	7.03		-		-	10.44	0.67	69.40	194.05	1,725.09
16	Nam Kong	334.19	1.79	897.21	22.50		-		-		-	395.55	1,105.94	1,626.95
12	Prek Samang	1,222.80	6.54		-		-	95.18	7.63		-		-	1,317.98
	Totals	**18,689.85**		**3,987.51**		**442.37**		**1,246.72**		**1,556.68**		**1,065.52**		**27,095.82**

Code	Name of consolidated basins	Acrisol		Cambisol		Ferralsol		Gleysol		Leptosol		Luvisol		Totals
		sq km	% of catchment	sq km	% of catchment	sq km	% of catchment	sq km	% of catchment	sq km	% of catchment	sq km	% of catchment	sq km
1	Sekong headwaters	2,247.42	97.72		-	52.42	2.28		-		-		-	2,299.8
2	Sekong in Kaleum	1,641.63	99.65	5.76	0.35		-		-		-		-	1,647.4
4	Sekong above Sekong town	921.81	57.04	491.34	30.40	126.63	7.84		-	72.91	4.51	3.41	0.21	1,616.1
6	Sekong above Attapeu	627.83	61.64	140.42	13.79	144.58	14.20		-	86.60	8.50	19.06	1.87	1,018.5
17	Sekong/Se Kamman confluence	616.51	40.72	400.83	26.47		-	0.28	0.02	74.83	4.94	412.08	27.21	1,514.2
10	Sekong upper, Cambodia	1,984.51	67.97	2.65	0.09		-	574.07	19.66	356.58	12.21	2.07	0.07	2,919.9
11	Sekong lower, Cambodia	1,273.51	58.56	223.72	10.29		-	663.89	30.53		-	7.07	0.32	2,174.8
	Tributaries													
3	Dak e Meule	921.92	94.28	41.90	4.28	14.05	1.44		-		-		-	977.9
5	Houay Lamphan Ngai	104.43	19.32	149.63	27.68		-		-	268.58	49.69	17.85	3.30	540.5
7	Se Nam Noy	911.08	67.72	166.74	12.39		-		-	267.56	19.89		-	1,345.4
8	Se Pian	1,239.75	66.95	440.40	23.78	16.81	0.91	8.49	0.46	64.95	3.51		-	1,851.9
9	Se Khampho	1,002.73	67.21	144.73	9.70		-		-	335.05	22.46		-	1,491.9
13	Upper Se Kamman	2,256.09	92.50	95.17	3.90	87.87	3.60		-		-		-	2,439.1
14	Lower Se Kamman	1,241.65	65.13	506.54	26.57		-		-	19.16	1.01	139.02	7.29	1,906.4
15	Se Xou	1,364.77	79.11	280.47	16.26		-		-	10.44	0.61	69.40	4.02	1,725.1
16	Nam Kong	334.19	20.54	897.21	55.15		-		-		-	395.55	24.31	1,626.9
12	Prek Samang	1,222.80	92.78		-		-	95.18	7.22		-		-	1,318.0
	Totals	**18,689.85**	**68.98**	**3,987.51**	**14.72**	**442.37**	**1.63**	**1,246.72**	**4.60**	**1,556.68**	**5.75**	**1,065.52**	**3.93**	**27,095.8**

3.6 Climate

3.6.1 Rainfall

The mean annual rainfall of the Sekong Basin ranges between 1,400–2,900 mm/yr as shown in Table 3-14. Nearly 60% of the basin falls into the range of 1,700–1,900 mm/yr, with 23% falling in the range of 2,300–2,700 mm/yr.

The distribution of these ranges by sub-basin is shown in Figure 3-9. Thus the highest rainfall (>2,700 mm/yr) occurs in the Sekong headwaters and in the Sekong in Kaleum district. There is a broad band of rainfall between 2,300–2,700 mm/yr which more or less follows the Sekong River valley down to Attapeu. This also includes the Se Nam Noi catchment.

Just downstream of Attapeu there is a moderate band of rainfall at 1,900–2,300 mm/yr, and then the rest of the basin has 1,700-1,900 mm/yr, apart from two drier sub-basins, one in the north, one just above the Cambodian border and the third in the Sekong lower, Cambodia. These experience 1,400–1,700 mm/yr.

Table 3-14: Mean Annual rainfall distribution over Sekong basin

Mean annual rainfall	Area	
mm/yr	sq km	%
1,400 - 1,700	2,681.22	9.4
1,701 - 1,900	16,341.61	57.5
1,900 - 2,300	777.35	2.7
2,300 - 2,700	6,452.46	22.7
2,700 - 2,900	2,161.76	7.6
Total	**28,414.40**	

Table 3-15: Mean annual temperature distribution over Sekong Basin

Mean Annual Temperature range	Area	
deg C	sq km	%
21 - 22	15,801.06	55.6
22.1 - 24	777.00	2.7
24.1 - 25	-	0.0
25.1 - 26	-	0.0
26.1 - 27	2,243.08	7.9
27.1 - 28	9,593.26	33.8
Total area	**28,414.40**	

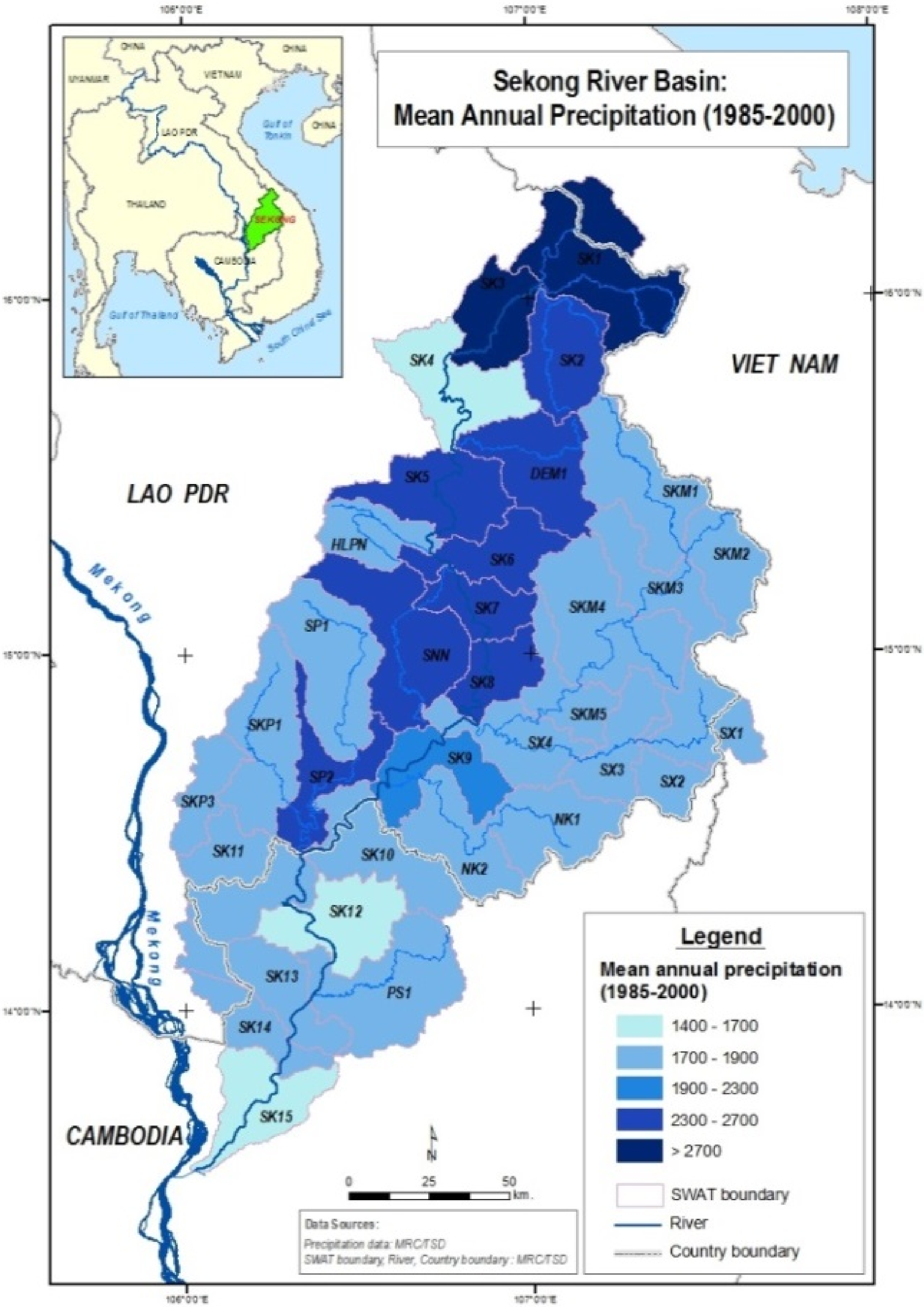


Figure 3-9: Rainfall map of the Sekong Basin, showing mean annual rainfall per sub-basin

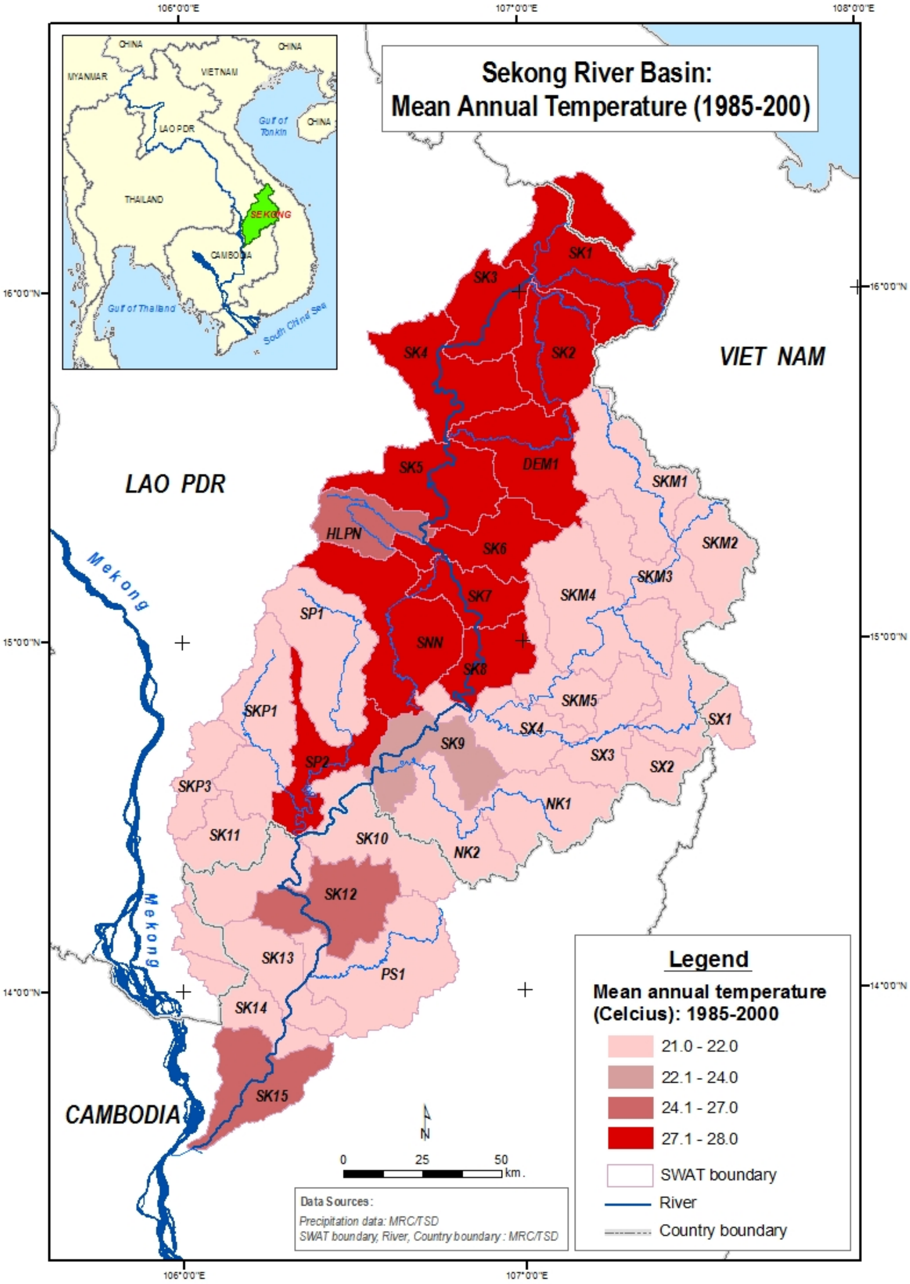
3.6.2 Temperature

The mean annual temperature of the Sekong basin lies in the range of 21–28° C. Most of the basin (56%) experiences the 21-22 ° C range, but there is about 33% of the area that experiences much higher temperatures, as shown inTable 3-15.

Figure 3-10 shows the map of mean annual temperatures. The sub-basins that experience the higher temperature ranges are from the headwaters down to the confluence with the Se Kamman – a very similar pattern to the rainfall distribution. There are three areas that experience mid-range temperatures (26–27 ° C), and these more or less correspond to the areas of lowest rainfall.

The Se Kamman catchment and most of the Bolevan Plateau catchments (apart from Se Pian) experience the lowest range of temperatures (21-22° C)

Figure 3-10: Temperature map of the Sekong Basin, showing mean annual temperature by sub-basin



3.7 Ecological zones

The ecological zones or ecozones of the Lower Mekong Basin (LMB) have been defined through an earlier study by World Wide Fund for Nature (WWF). These identify eight major ecozones through which the tributaries flow, which are shown inFigure 2-2. The zones include:

- High-elevation moist broadleaf forest (HEMBF)
- Mid-elevation moist broadleaf forest (MEMBF)
- Mid-elevation dry broadleaf forest (MEDBF)
- Low-elevation moist broadleaf forest (LEMBF)
- Low-elevation dry broadleaf forest (LEDBF)
- Floodplain, wetland or lake (FP)
- Swamp forest (SF)
- Mangrove or delta (MD)

It must be remembered that these zones do not indicate the actual forest coverage, or the quality of the forest in these areas, but indicate the type of vegetation that would naturally grow there depending upon the latitude, elevation, soils and climate. This will also determine the type of aquatic ecology of the tributaries.

This data set was kindly provided by WWF Greater Mekong. The data set was developed in 2005 as part of an aquatic ecosystem classification that combined elevation, vegetation, and wetness (water-wetland-floodplain or mangrove). This analytical method used four elevation levels, two dry or wet levels, and one floodplain level to determine the eight ecozones used. The analysis also included the Chinese Upper Mekong.

Within the Sekong Basin, five of the ecozones have been identified: HEMBF, MEMBF, MEDBF, LEDBF and FP. The distribution of these ecozones is shown inFigure 3-11 with areas and percentages of the sub-basins shown in Table 3-16.

The distribution broadly follows the elevation patterns, with HEMBF predominating in the subcatchments lying in the headwaters of both Sekong and Se Kamman, and another large zone in the northern and western parts of the Bolevan Plateau. These areas give way to MEMBF and MEDBF, largely following the rainfall patterns. LEDBF covers the lower part of the Sekong, below the junction with the Nam Kong and down into Cambodia. The lower lying parts of the Se Khampho are also included in this ecozone.

Table 3-17 shows that in the Sekong Basin as a whole, about 33% of the basin lies in HEMBF, 6% in MEMBF, 40% in MEDBF, 21% in LEDBF, and only 0.1% of FP.

When considering the Sekong mainstem, it is clear that the Sekong headwaters lie almost entirely in the HEMBF (25% of this zone in the basin as a whole). There is then a marked change towards MEMBF with the catchment areas of Sekong in Kaleum and above Sekong town containing 35%–40% of this zone of the whole basin. Sekong in Kaleum has an almost equal divide between three ecozones (HEMBF, MEMBF and MEDBF), and above Sekong town is more or less equally split between MEMBF and MEDBF. The Sekong above Attapeu is almost entirely in the MEDBF zone. Below the Se Kamman confluence the river passes through mostly MEDBF (87% of the sub-basin) and then into LEDBF zone (13%). Further down in the Sekongupper, Cambodia the river passes through 37% MEDBF and then 63% of LEDBF. In the Sekong lower, Cambodia the river is almost entirely LEDBF, with a very small section of FP.

Of the tributaries, Dak e Meule lies 75% in HEMBF and 25% in MEDBF. Of the four tributaries that arise on the Bolevan Plateau, Houay Lamphan Gnai is very similar with 73% in HEMBF and 25% in MEDBF, whilst Se Nam Noi has 97% in the HEMBF zone. Se Pian has a much greater spread of ecozones with 41% in HEMBF, 20% in MEMBF, 26% in MEDBF, and 13% in LEDBF. However, Se

Pian is significant in that it has 22% of all the MEMBF in the Sekong Basin as a whole. Se Khampho is very different in that it has 66% in MEDBF and 34% in LEDBF. It also has a small proportion of the area classified as FP.

The Upper Se Kamman is similar to the Sekong headwaters in having a high proportion (90%) of the sub-basin lying in the HEMBF, and 10% in MEDBF. Upper Se Kamman has about 23% of all the HEMBF in the Sekong Basin as a whole. The Lower Se Kamman sub-basin has a more or less even split between HEMBF (47%) and MEDBF (53%). Se Xou and Nam Kong are both almost entirely lying in MEDBF, 99.7% and 95.7%, respectively.

Prek Samang in Cambodia contains a high proportion of LEDBF (74%) and 26% of MEDBF.

Table 3-18 complements this area focus of each sub-basin with the lengths of each stream order flowing in each ecozone. The most interesting aspect of this table is the length of the mainstem within each ecozone. This is shown in Table 3-16, with the largest proportion of the length of the mainstem lying in the MEDBF zone (44%), followed by LEDBF (36%), 12% of the length in HEMBF, and 8% in MEMBF.

Table 3-16: Stream order lengths of the Sekong mainstem in each ecozone

Ecozone	Stream order length - km					% of
	3	4	5	6	Total	length
High-elevation moist broadleaf fores	61.8				61.8	12.0
Mid-elevation moist broadleaf fores	30.3	9.3			39.6	7.7
Mid-elevation dry broadleaf forest	92.1	88.5	45.4		226.0	43.8
Low elevation dry broadleaf forest			187.4		187.4	36.3
Floodplain, wetland, lake			0.2	0.9	1.2	0.2
Total	**184.1**	**97.7**	**233.1**	**0.9**	**515.8**	

Figure 3-11: Map of ecological zones within the Sekong Basin

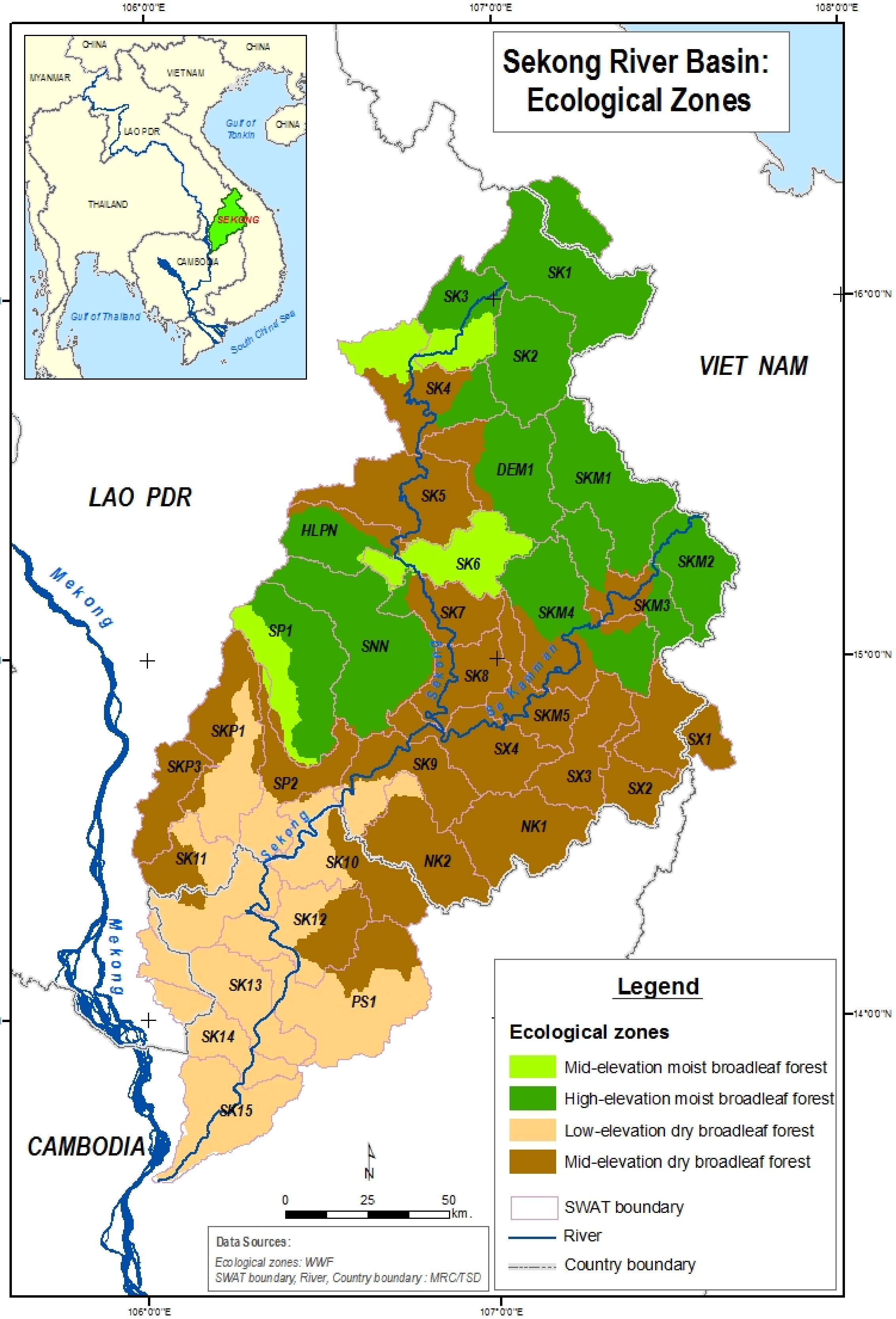


Table 3-17: Distribution of ecological zones i) throughout the Sekong basin and ii) in each sub-basin

Consol. code	Name of consolidated basins	High-elevation moist broadleaf forest		Mid-elevation moist broadleaf forest		Mid-elevation dry broadleaf forest		Low elevation dry broadeaf forest		Floodplain, wetland, lake		Total
		sq km	% in Sekong	sq km	% in Sekong	sq km	% in Sekong	sq km	% in Sekong	sq km	% in Sekong	sq km
	SEKONG MAINSTEM											
1	Sekong headwaters	2,291.8	24.7	8.0	0.5							2,299.84
2	Sekong in Kaleum	598.9	6.5	594.0	35.7	454.6	4.0					1,647.4
4	Sekong above Sekong town	14.3	0.2	662.0	39.8	939.8	8.2					1,616.1
6	Sekong above Attapeu	71.6	0.8	8.9	0.5	938.0	8.2					1,018.5
17	Sekong/Se Kamman confluence	0.9	0.0			1,318.3	11.5	195.0	3.3			1,514.2
10	Sekong upper, Cambodia					1,076.0	9.4	1,843.6	30.9	0.3	0.9	2,919.9
11	Sekong lower, Cambodia							2,148.7	36.0	26.1	90.2	2,174.8
	TRIBUTARIES											
3	Dak e Meule	731.2	7.9	3.2	0.2	243.5	2.1					977.9
5	Houay Lamphan Ngai	395.6	4.3	9.3	0.6	135.7	1.2					540.5
7	Se Nam Noy	1,301.7	14.0	3.2	0.2	40.6	0.4					1,345.4
8	Se Pian	762.7	8.2	372.3	22.4	475.2	4.1	241.7	4.0			1,851.9
9	Se Khampho		-	0.9	0.1	981.8	8.6	506.6	8.5	2.6	8.8	1,491.9
13	Upper Se Kamman	2,200.8	23.8		-	238.3	2.1		-			2,439.1
14	Lower Se Kamman	891.3	9.6	0.9	0.1	1,014.2	8.8		-			1,906.4
15	Se Xou	5.3	0.1			1,719.8	15.0		-			1,725.1
16	Nam Kong					1,557.8	13.6	69.2	1.2			1,626.9
12	Prek Samang					348.3	3.0	969.7	16.2			1,318.0
	TOTAL FOR SEKONG	**9,266.1**		**1,662.6**		**11,481.8**		**5,974.5**		**28.9**		**28,413.8**

Consol. code	Name of consolidated basins	High-elevation moist broadleaf forest		Mid-elevation moist broadleaf forest		Mid-elevation dry broadleaf forest		Low elevation dry broadeaf forest		Floodplain, wetland, lake		Total
		sq km	% in sub-basin	sq km	% in sub-basin	sq km	% in sub-basin	sq km	% in sub-basin	sq km	% in sub-basin	sq km
	SEKONG MAINSTEM											
1	Sekong headwaters	2,291.8	99.7	8.0	0.3							2,299.84
2	Sekong in Kaleum	598.9	36.4	594.0	36.1	454.6	27.6					1,647.4
4	Sekong above Sekong town	14.3	0.9	662.0	41.0	939.8	58.2					1,616.1
6	Sekong above Attapeu	71.6	7.0	8.9	0.9	938.0	92.1					1,018.5
17	Sekong/Se Kamman confluence	0.9	0.1			1,318.3	87.1	195.0	12.9			1,514.2
10	Sekong upper, Cambodia					1,076.0	36.9	1,843.6	63.1	0.3	0.0	2,919.9
11	Sekong lower, Cambodia							2,148.7	98.8	26.1	1.2	2,174.8
	TRIBUTARIES											
3	Dak e Meule	731.2	74.8	3.2	0.3	243.5	24.9					977.9
5	Houay Lamphan Ngai	395.6	73.2	9.3	1.7	135.7	25.1					540.5
7	Se Nam Noy	1,301.7	96.8	3.2	0.2	40.6	3.0					1,345.4
8	Se Pian	762.7	41.2	372.3	20.1	475.2	25.7	241.7	13.0			1,851.9
9	Se Khampho			0.9	0.1	981.8	65.8	506.6	34.0	2.6	0.2	1,491.9
13	Upper Se Kamman	2,200.8	90.2			238.3	9.8					2,439.1
14	Lower Se Kamman	891.3	46.8	0.9	0.0	1,014.2	53.2					1,906.4
15	Se Xou	5.3	0.3			1,719.8	99.7					1,725.1
16	Nam Kong					1,557.8	95.7	69.2	4.3			1,626.9
12	Prek Samang					348.3	26.4	969.7	73.6			1,318.0
	TOTAL FOR SEKONG	**9,266.1**	**32.6**	**1,662.6**	**5.9**	**11,481.8**	**40.4**	**5,974.5**	**21.0**	**28.9**	**0.1**	**28,413.8**

Note: Sub-basins with significant proportions of each ecozone are highlighted

Table 3-18: Lengths of each stream order flowing through different ecological zones

Consol. code	Name of consolidated basins	High-elevation moist broadleaf forest			Mid-elevation moist broadleaf forest				Mid-elevation dry broadleaf					Low elevation dry broadeaf					Floodplain, wetland, lake						Totals
		Stream order - kms			Stream order - kms				Stream order - kms					Stream order - kms					Stream order - kms						
		1	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**6**	
	SEKONG MAINSTEM																								
1	Sekong headwaters	218.2	94.2	38.9																					351.3
2	Sekong in Kaleum	48.5	32.2	22.8	40.2		30.3		3.1	1.7	44.9														223.6
4	Sekong above Sekong town				65.9	8.1		6.9	95.3	39.3	47.2	0.1													262.8
6	Sekong above Attapeu		21.3			1.1		2.4	45.4	15.3		74.7													160.1
17	Sekong/Se Kamman confluence								211.4	34.0	63.6	13.7	44.5		19.9			9.9							397.0
10	Sekong upper, Cambodia								150.8	14.6			0.9	174.0	35.6	20.9		101.8							498.5
11	Sekong lower, Cambodia													322.3	92.2			75.7	2.6				0.2	0.9	493.9
	TOTAL FOR MAINSTEM	**266.6**	**147.7**	**61.8**	**106.1**	**9.2**	**30.3**	**9.3**	**506.0**	**104.8**	**155.7**	**88.5**	**45.4**	**496.3**	**147.7**	**20.9**	**-**	**187.4**	**2.6**	**-**	**-**	**-**	**0.2**	**0.9**	**2,387.3**
	TRIBUTARIES																								
3	Dak e Meule	118.2	1.4							29.4															148.9
5	Houay Lamphan Ngai	77.0	20.3	37.8			1.7	0.3	43.5		8.7														189.3
7	Se Nam Noy	129.7	10.8																						140.5
8	Se Pian	104.8	38.5	12.2	80.8	5.9			36.7		28.2				11.7	44.9		1.2							364.8
9	Se Khampho								162.6	16.8				36.5	25.9										241.8
13	Upper Se Kamman	254.7	106.7	9.1					1.2		32.2														403.9
14	Lower Se Kamman	116.1	13.4	12.1					111.9		68.2														321.7
15	Se Xou								149.3	51.1	33.9														234.3
16	Nam Kong								157.0	93.2				0.9	12.0										263.2
12	Prek Samang								50.0					80.7	60.8			14.5							206.0
	TOTAL FOR SEKONG	**1,067.1**	**338.8**	**133.0**	**186.9**	**15.1**	**32.0**	**9.6**	**1,218.3**	**295.2**	**326.9**	**88.5**	**45.4**	**614.4**	**258.0**	**65.8**	**-**	**203.0**	**2.6**	**-**	**-**	**-**	**0.2**	**0.9**	**4,901.8**

Note: Highlighted cells indicate mainstem sections

The ecozone diversity index is used to indicate the diversity of the ecological zones through which the river or stream flows. It is calculated as follows:

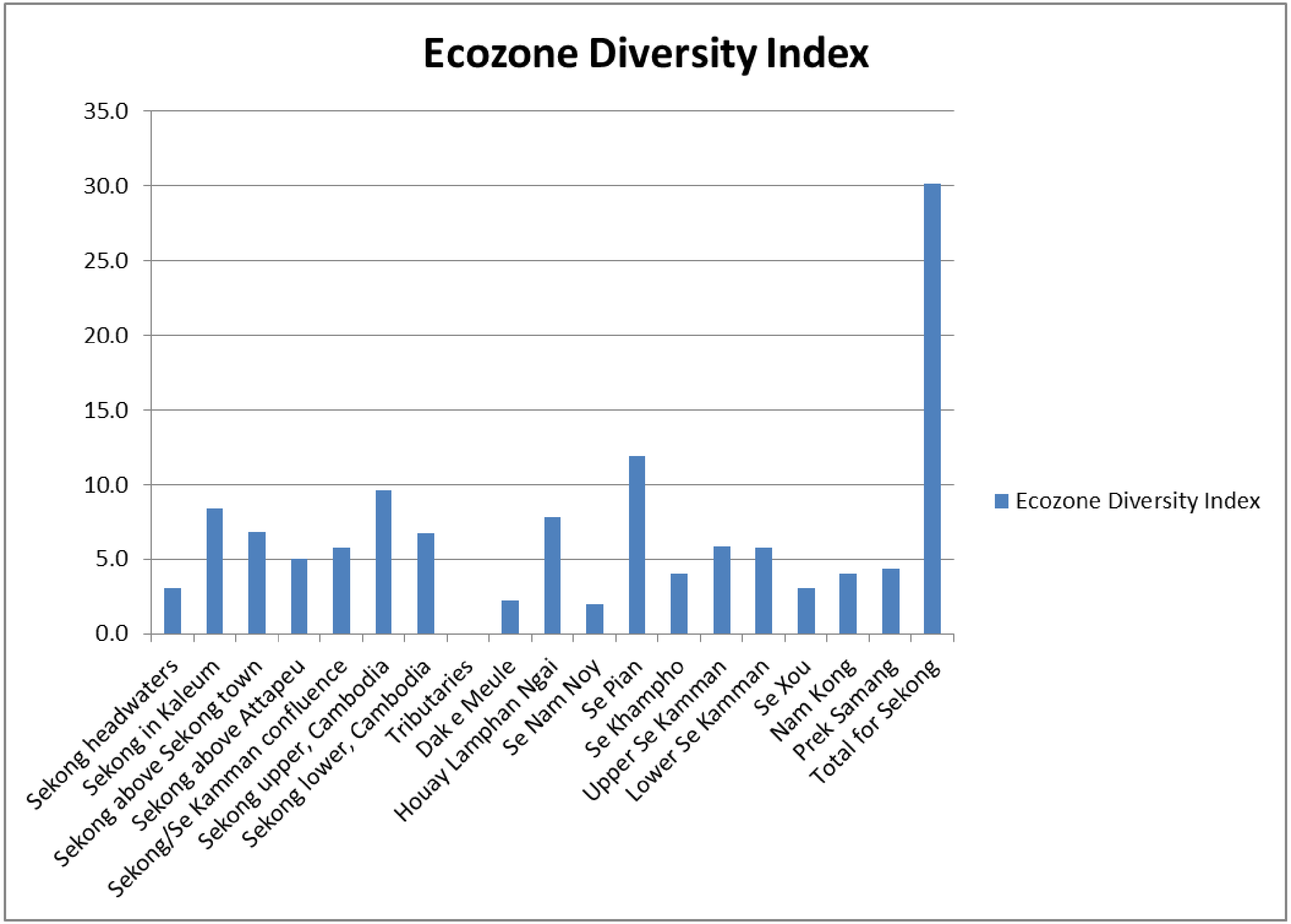
1. The total length of each stream order in the tributary is divided by the number of ecological zones in the sub-basin.
2. The results from step one of each stream order are summed, and divided by the number of stream orders found in that sub-basin.
3. The index of ecozone diversity is reached by dividing the total length of all the stream orders in the tributary by the result of step two. This is essentially a ratio of two lengths, with the higher numbers indicating a relatively higher diversity of ecozones.

The ecozone diversity indices for each sub-basin are shown in Table 3-19. This shows that the overall index for the Sekong basin as a whole is 3.82

Table 3-19: Ecozone diversity index by sub-basin

Code	Name of consolidated basins	Ecozone Diversity Index
	Sekong mainstem	
1	Sekong headwaters	3.0
2	Sekong in Kaleum	8.4
4	Sekong above Sekong town	6.8
6	Sekong above Attapeu	5.0
17	Sekong/Se Kamman confluence	5.8
10	Sekong upper, Cambodia	9.6
11	Sekong lower, Cambodia	6.7
	Tributaries	
3	Dak e Meule	2.2
5	Houay Lamphan Ngai	7.8
7	Se Nam Noy	2.0
8	Se Pian	11.9
9	Se Khampho	4.0
13	Upper Se Kamman	5.9
14	Lower Se Kamman	5.8
15	Se Xou	3.0
16	Nam Kong	4.0
12	Prek Samang	4.4
	Total for Sekong	**30.1**

Figure 3-12: Ecozone diversity index by sub-basin



3.8 Landuse and forest cover

The landuse map for the Sekong Basin is shown in Figure 3-13 and the analysis of the landcover and landuse types by sub-catchment within the Sekong Basin is shown in Table 3-20. Table 3-21 shows a similar analysis of the different proportions of these land use types within these sub-catchments.

The outstanding feature of this analysis is the very high proportion of forested areas in the Sekong catchment. However, comprehensive landuse datasets, comparable across all three countries are difficult to consolidate, and this version comes from 2003 datasets compiled by the MRC. The Sekong Basin has experienced significant changes in landuse over the past decade and much of the forest land has either been degraded or converted for agriculture and agroforestry plantations, especially in Lao PDR. There are extensive economic land concessions established on the right bank of the Sekong in Cambodia. As a result these figures need to be taken as indicative of the situation 10 years ago, rather than current land use.

Within the basin, land use features that stand out include the concentration of field crops on the eastern slopes of the Bolevan plateau that drain into the Sekong, the paddy land in the lowland areas of the Sekong near Attapeu, and the swidden areas to the east of the river in Cambodia. The agricultural areas in the headwaters of the Sekong in Viet Nam are also evident.

Figure 3-13: Land use map for Sekong Basin

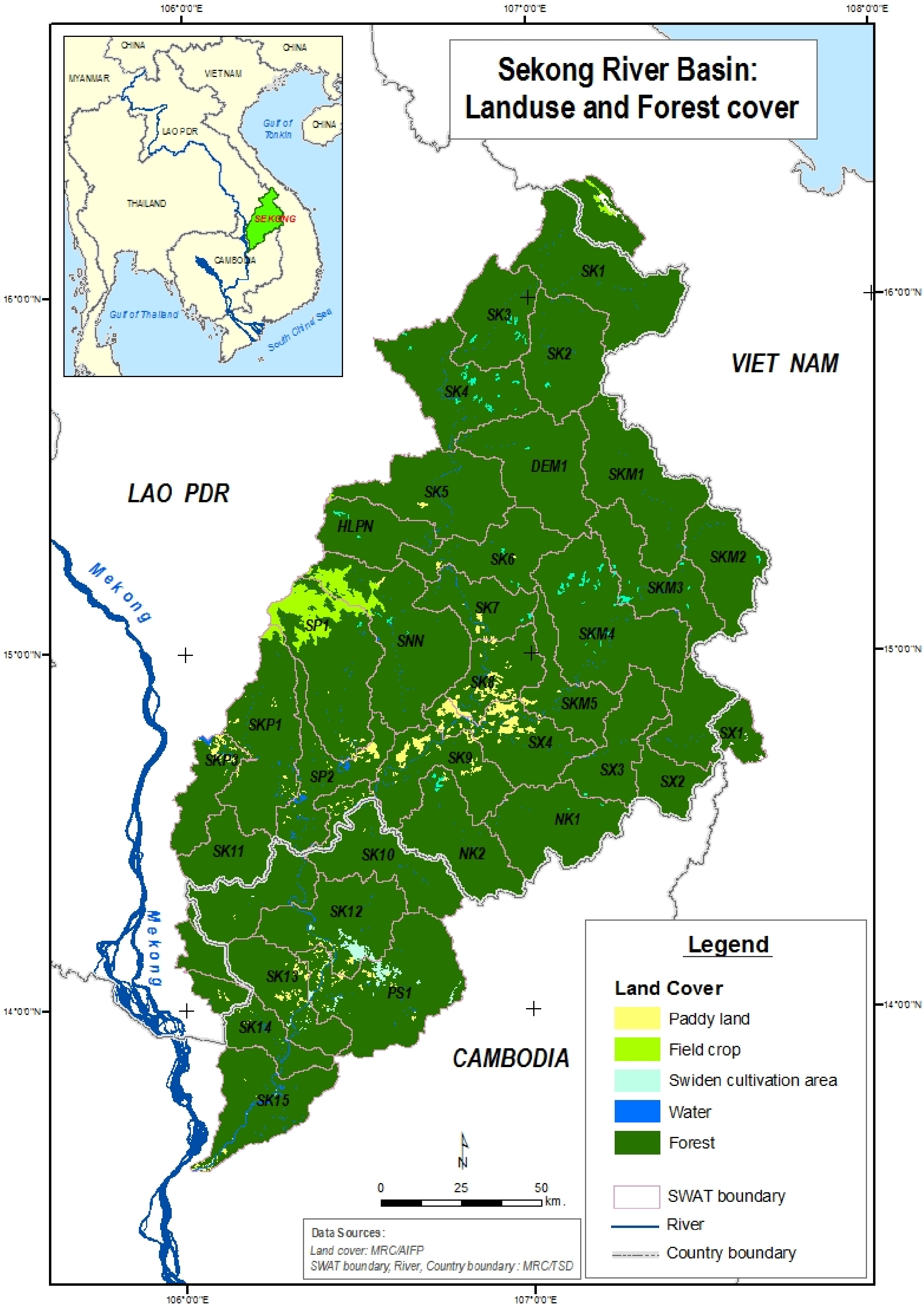


Table 3-20: Landcover/landuse types within the Sekong Basin

Code	Name of consolidated basins	Forest area		Paddy fields		Agricultural land		Field crop		Swidden		Swamp/ wetland		Water bodies		Riparian forest		Urban/ built up area		Other		Total
		sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	sq km	% of basin	
	Sekong mainstem																					
1	Sekong headwaters	2,232.1	8.2		-	12.0	100.0	15.2	3.8	1.7	1.0		-	6.5	3.9		-		-		-	2,267.4
2	Sekong in Kaleum	1,609.5	5.9		-		-		-	30.1	17.3		-	7.7	4.7		-		-		-	1,647.4
4	Sekong above Sekong town	1,593.2	5.9	6.9	1.8		-	3.4	0.9	2.5	1.4		-	9.3	5.6		-	0.7	19.1		-	1,616.1
6	Sekong above Attapeu	936.0	3.5	63.5	16.8		-		-	3.0	1.8		-	14.5	8.7		-	1.3	36.4	0.1	4.0	1,018.5
10	Sekong upper, Cambodia	2,799.5	10.3	18.8	5.0		-	1.6	0.4	38.8	22.3	0.6	1.4	31.5	19.0	0.7	0.8		-	2.0	59.4	2,893.6
11	Sekong lower, Cambodia	2,006.8	7.4	36.5	9.6		-	1.1	0.3	4.5	2.6	9.4	21.6	28.4	17.1	75.0	79.7		-	0.6	16.8	2,162.2
17	Sekong/Se Kamman confluenc	1,346.4	5.0	146.7	38.8		-		-		-		-	18.5	11.2		-	0.7	20.7	0.5	14.1	1,512.8
	Tributaries																					
3	Dak e Meule	975.7	3.6		-		-		-	1.0	0.6		-	1.1	0.7		-		-		-	977.9
5	Houay Lamphan Ngai	533.6	2.0		-		-	0.0	0.0	3.9	2.2		-	2.1	1.3		-	0.9	23.9		-	540.5
7	Se Nam Noy	1,219.5	4.5	2.6	0.7		-	115.0	29.1	2.9	1.7		-	5.4	3.2		-		-		-	1,345.4
8	Se Pian	1,552.1	5.7	32.0	8.5		-	236.4	59.9	1.1	0.6	19.8	45.4	9.6	5.8		-		-		-	1,851.0
9	Se Khampho	1,418.7	5.2	36.1	9.6		-	20.3	5.1	0.2	0.1	11.3	25.9	4.9	3.0		-		-		-	1,491.5
13	Upper Se Kamman	2,524.7	9.3	1.4	0.4		-	1.0	0.3	13.5	7.8		-	5.5	3.3		-		-		-	2,546.1
14	Lower Se Kamman	1,866.6	6.9	7.9	2.1		-		-	23.7	13.6		-	8.3	5.0		-		-		-	1,906.4
15	Se Xou	1,697.0	6.3		-		-		-	0.8	0.5		-	3.1	1.9		-		-		-	1,700.9
16	Nam Kong	1,590.1	5.9	2.1	0.6		-		-	7.3	4.2		-	3.1	1.9		-		-		-	1,602.5
12	Prek Samang	1,227.2	4.5	23.8	6.3		-	0.7	0.2	38.8	22.3	2.5	5.7	6.5	3.9	18.3	19.5		-	0.2	5.6	1,318.0
	Totals	**27,128.9**		**378.2**		**12.0**		**394.7**		**173.8**		**43.5**		**165.9**		**94.0**		**3.6**		**3.4**		**28,398.1**

Table 3-21: Landcover/landuse types by sub-basin

Code	Name of consolidated basins	Forest area		Paddy fields		Agricultural land		Field crop		Swidden		Swamp/ wetland		Water bodies		Riparian forest		Urban/ built up area		Other		Total
		sq km	% of subcatchmen	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	sq km	% of subcatchment	
	Sekong mainstem																					
1	Sekong headwaters	2,232.1	98.4		-	12.0	0.5	15.2	0.7	1.7	0.1		-	6.5	0.3		-		-		-	2,267.4
2	Sekong in Kaleum	1,609.5	97.7		-		-		-	30.1	1.8		-	7.7	0.5		-		-		-	1,647.4
4	Sekong above Sekong town	1,593.2	98.6	6.9	0.4		-	3.4	0.2	2.5	0.2		-	9.3	0.6		-	0.7	0.0		-	1,616.1
6	Sekong above Attapeu	936.0	91.9	63.5	6.2		-		-	3.0	0.3		-	14.5	1.4		-	1.3	0.1	0.1	0.0	1,018.5
10	Sekong upper, Cambodia	2,799.5	96.7	18.8	0.7		-	1.6	0.1	38.8	1.3	0.6	0.0	31.5	1.1	0.7	0.0		-	2.0	0.1	2,893.6
11	Sekong lower, Cambodia	2,006.8	92.8	36.5	1.7		-	1.1	0.1	4.5	0.2	9.4	0.4	28.4	1.3	75.0	3.5		-	0.6	0.0	2,162.2
17	Sekong/Se Kamman confluence	1,346.4	89.0	146.7	9.7		-		-		-		-	18.5	1.2		-	0.7	0.0	0.5	0.0	1,512.8
	Tributaries																					
3	Dak e Meule	975.7	99.8		-		-		-	1.0	0.1		-	1.1	0.1		-		-		-	977.9
5	Houay Lamphan Ngai	533.6	98.7		-		-	0.0	0.0	3.9	0.7		-	2.1	0.4		-	0.9	0.2		-	540.5
7	Se Nam Noy	1,219.5	90.6	2.6	0.2		-	115.0	8.5	2.9	0.2		-	5.4	0.4		-		-		-	1,345.4
8	Se Pian	1,552.1	83.9	32.0	1.7		-	236.4	12.8	1.1	0.1	19.8	1.1	9.6	0.5		-		-		-	1,851.0
9	Se Khampho	1,418.7	95.1	36.1	2.4		-	20.3	1.4	0.2	0.0	11.3	0.8	4.9	0.3		-		-		-	1,491.5
13	Upper Se Kamman	2,524.7	99.2	1.4	0.1		-	1.0	0.0	13.5	0.5		-	5.5	0.2		-		-		-	2,546.1
14	Lower Se Kamman	1,866.6	97.9	7.9	0.4		-		-	23.7	1.2		-	8.3	0.4		-		-		-	1,906.4
15	Se Xou	1,697.0	99.8		-		-		-	0.8	0.0		-	3.1	0.2		-		-		-	1,700.9
16	Nam Kong	1,590.1	99.2	2.1	0.1		-		-	7.3	0.5		-	3.1	0.2		-		-		-	1,602.5
12	Prek Samang	1,227.2	93.1	23.8	1.8		-	0.7	0.0	38.8	2.9	2.5	0.2	6.5	0.5	18.3	1.4		-	0.2	0.0	1,318.0
	Totals	**25,901.6**	**95.6**	**354.4**	**1.3**	**12.0**	**0.0**	**394.1**	**1.5**	**135.0**	**0.5**	**41.0**	**0.2**	**159.4**	**0.6**	**75.7**	**0.3**	**3.6**	**0.0**	**3.2**	**0.0**	**27,080.1**

3.9 Protected Areas and Key Biodiversity Areas

As indicated earlier, the Sekong Basin has amongst the highest proportion of Protected Areas and Key Biodiversity Areas (KBAs) of all the tributaries of the Mekong. Figure 3-14 shows the protected areas and KBAs in the Sekong Basin and Table 3-22 shows the distribution of both of these among the sub-catchments in the basin. Within the basin as a whole, about 39% lies within Protected Areas and 37% of the basin has been identified as lying within KBAs.

Figure 3-14: Map of Sekong Basin showing Protected Areas and Key Biodiversity Areas

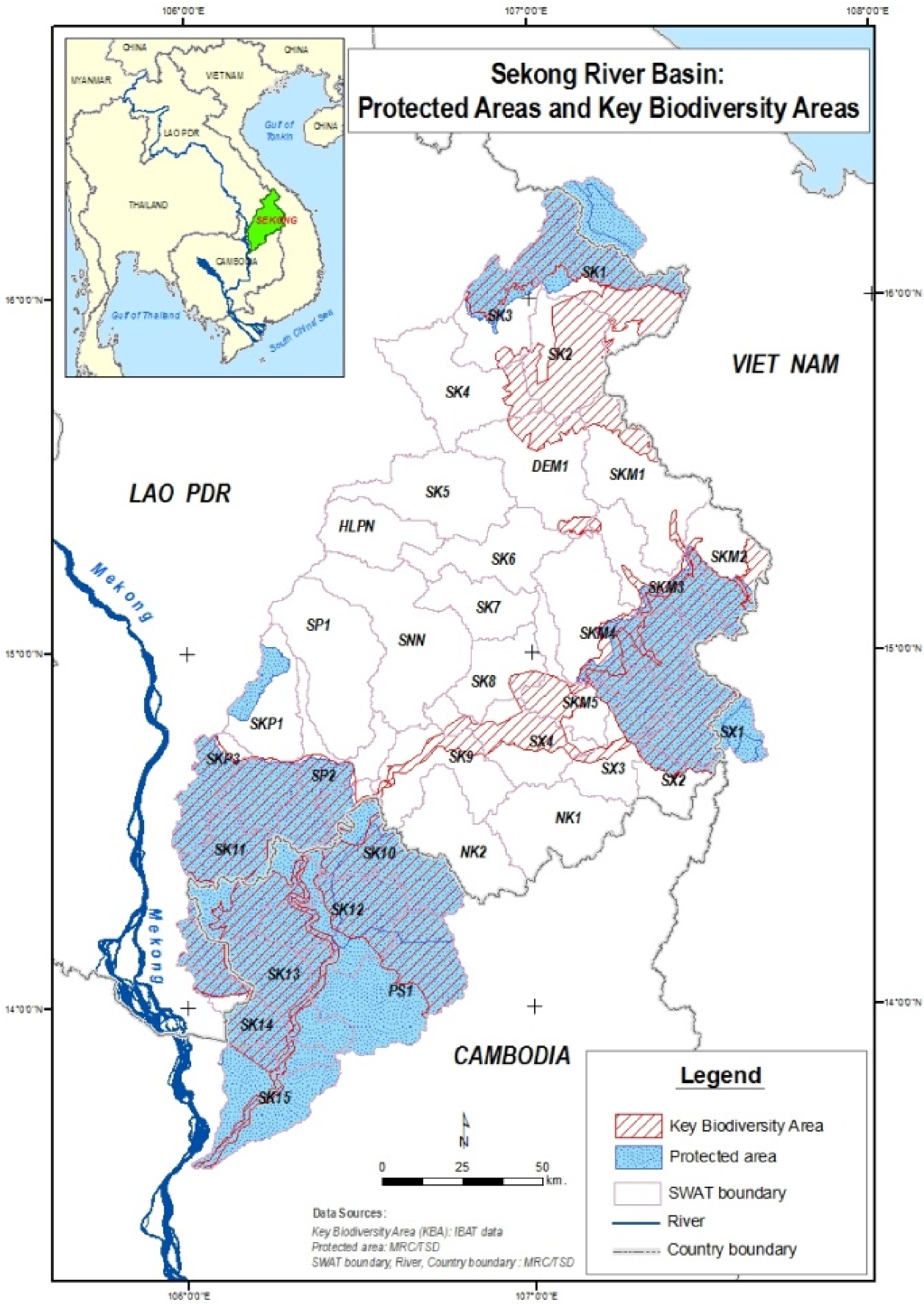


Table 3-22: Distribution of Protected Areas and KBAs through sub-basins of Sekong

Code	Name of consolidated basins	Total area	KBA		PAs	
			sq km	%	sq km	%
1	Sekong headwaters	2,300	1,608.77	69.95	1,018.73	44.30
2	Sekong in Kaleum	1,647	358.23	21.75	263.21	15.98
4	Sekong above Sekong town	1,616		0.00		0.00
6	Sekong above Attapeu	1,019	52.51	5.16		0.00
17	Sekong/Se Kamman confluence	1,514	453.04	29.92	1.21	0.08
10	Sekong upper, Cambodia	2,920	2,260.16	77.41	2,870.97	98.33
11	Sekong lower, Cambodia	2,175	1,168.81	53.74	2,118.88	97.43
	Total for Sekong mainstem	**13,191**	**5,901.52**	**44.74**	**6,273.01**	**47.56**
	Tributaries					
3	Dak e Meule	978	204.03	20.86		0.00
5	Houay Lamphan Ngai	540		0.00		0.00
7	Se Nam Noy	1,345		0.00		0.00
8	Se Pian	1,852	394.04	21.28	376.81	20.35
9	Se Khampho	1,492	793.71	53.20	923.19	61.88
13	Upper Se Kamman	2,439	869.22	35.64	541.94	22.22
14	Lower Se Kamman	1,906	833.56	43.72	592.18	31.06
15	Se Xou	1,725	929.16	53.86	1,116.34	64.71
16	Nam Kong	1,627	18.59	1.14	7.38	0.45
12	Prek Samang	1,318	633.33	48.05	1,317.98	100.00
	Totals	**28,414**	**10,577.16**	**37.23**	**11,148.83**	**39.24**

The following national Protected Areas are recorded on the IBAT website:

Dong Ampham (Lao PDR) - 2000 km^2
Phou Kathong (Lao PDR) - 880 km^2
Xe Sap (Lao PDR) - 1130 km^2
Phou Theung (Lao PDR) - 1130 km^2
Xe Khampho-Bolevan Plateau - 794 km^2
Xe Pian (Lao PDR) – 2400 km^2
Virachey (Cambodia) - 3,325 km^2

The following KBAs have also been identified, some of which extend beyond the boundaries of the Sekong Basin:

A Luoi-Nam Dong (Viet Nam)	Xe Sap (Lao PDR) - 137,120 ha
Dong Ampham (Lao PDR) – 180220 ha	Phou Kathong (Lao PDR)
Upper Xe Kamman (Lao PDR) – 34,780 ha	Phou Ahyon (Lao PDR) - 148,900 ha
Attapeu Plain (Lao PDR) – 71,400 ha	Nam Ghong (Lao PDR)
Bolevan North East (Lao PDR)	Xe Pian (Lao PDR) - 243,100 ha
Nong Khe Wetlands (Lao PDR)	Western Siempang (Cambodia) - 13,817 ha
	Virachey (Cambodia) - 432,415 ha

4 Hydrology

4.1 Flows in the Sekong

During the Integrated Basin Flow Management (IBFM) studies on the Mekong, Adamson and King drafted a paper that starts to identify key environmental flow indicators that define both the morphology and ecology of the tributaries. (Adamson, Draft). That paper identified four hydro-biological seasons measured by six hydrological parameters, namely:

1. Dry/Low flow season, indicated by
    a. Minimum flow and date
    b. Mean daily dry season discharge
    c. Coefficient of variation of dry season daily flows
2. Transition period 1 between low flows and high flows (on the Mekong usually for a few weeks in May/June), indicated by number and magnitude of pre-flood season spates or freshlets.
3. Flood/High flow season as indicated by whether the peak and volume of water passing falls above or below mean flows.
4. Transition period 2 between wet season and dry season, generally a brief one to two weeks during mid-November, as indicated by the average daily rate of flow recession (cumecs/day).

The work generated some original thinking in the definition of flow parameters for the Mekong. The metrics used to define the start and end of the four flow seasons were (Adamson P. , December 2006):

Season	Start	End
Dry season	Average daily flow recession (decrease) is 1% or less over 15 consecutive days, indicative of base flow conditions	Twice the minimum daily discharges for the current dry season occur, indicating that discharges have increased significantly and the low flow season is at an end
Transition season 1	End of dry season	Start of flood season
Flood season	Daily discharges exceed mean annual discharge for the first time	Last date upon which daily discharge falls below the mean annual discharge
Transition season 2	End of flood season	Start of dry season

Data from three hydrological monitoring sites on the Sekong are available from the MRC. These include:

Code	Station	River	Data type	Latitude	Longitude	Start	End
430102	Siempang	Sekong	QH	14.11678	106.39093	1965	1968
430105	Attopeu	Se Kong	QH	14.8067	106.8433	1989	2005
430106	Khoueng Sekong	Se Kong	QH	15.4333	106.7333	2001	2005
430106	Khoueng Sekong	Se Kong	HH	15.4333	106.7333	2001	2006
QH = discharge							
HH = water level							
Data source: MRC HYMOS							

Of these the records from Attapeu represent the most comprehensive data set of flows in the Sekong, and this will be used to do some initial flow modelling. For the other two hydrological monitoring sites the data sets are too short for use on the Flow Health model, which requires at least 10 years for a reference set. However, from the location it would appear that the sampling site at Attapeu is above the confluence with the Se Kamman, and therefore does not include these additional flows. Figure 4-1 shows the average monthly flows of the river at Attapeu, illustrating the very low flows in February to April, where the minimum average flows may be about 80 m^3/sec, rising steeply from May to August when the peak flows average nearly 1,200 m^3/sec. The annual average flows are estimated at448 m^3/sec. The figure also shows the move from the low flow, dry season through to Transition season 1 from beginning of May when flows are double the minimum flows (i.e. about 160 m^3/sec) through to mid-June when the flows pass the mean annual flow of 448 m^3/sec.

High flows in the wet season last from mid-June through to mid-November, when the flows again fall below mean annual flow and into the Transition season 2 which lasts until the end of the year. The exact timing of this second transition is less easy to predict.

Figure 4-1. Average monthly flows of the Sekong River at Attapeu

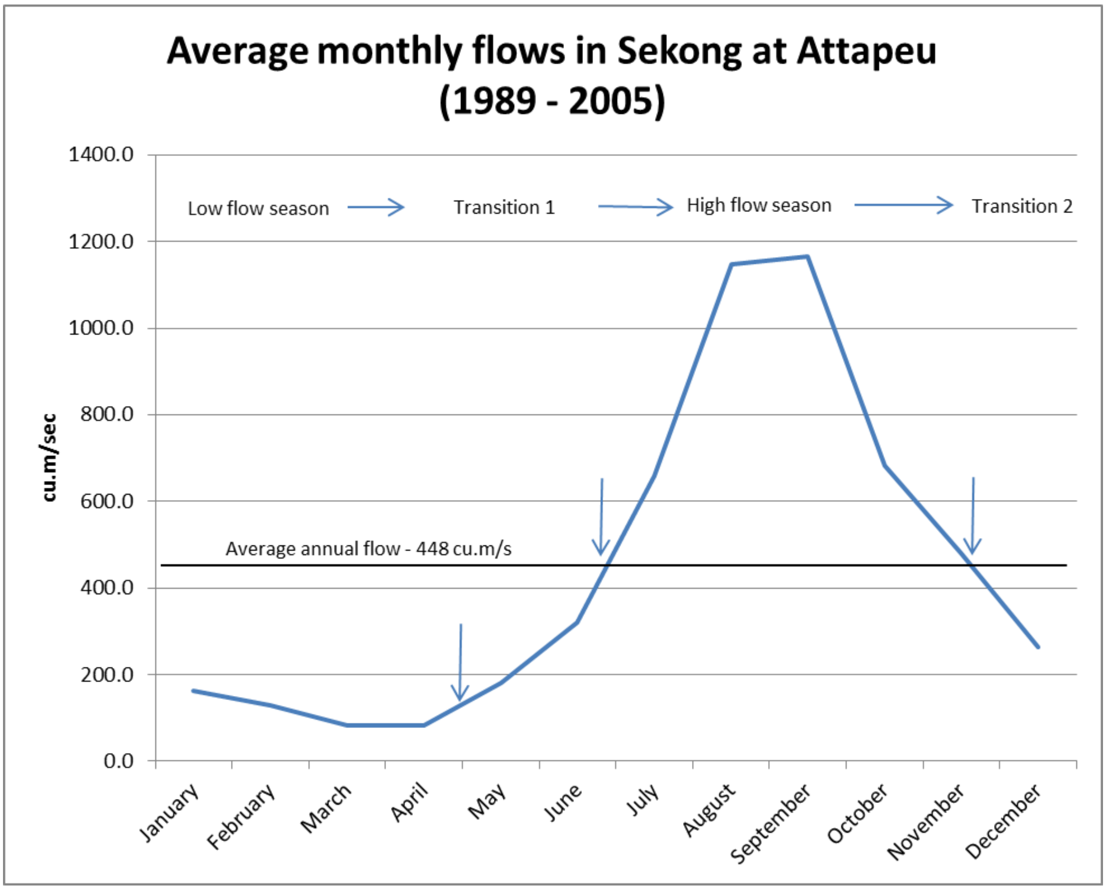
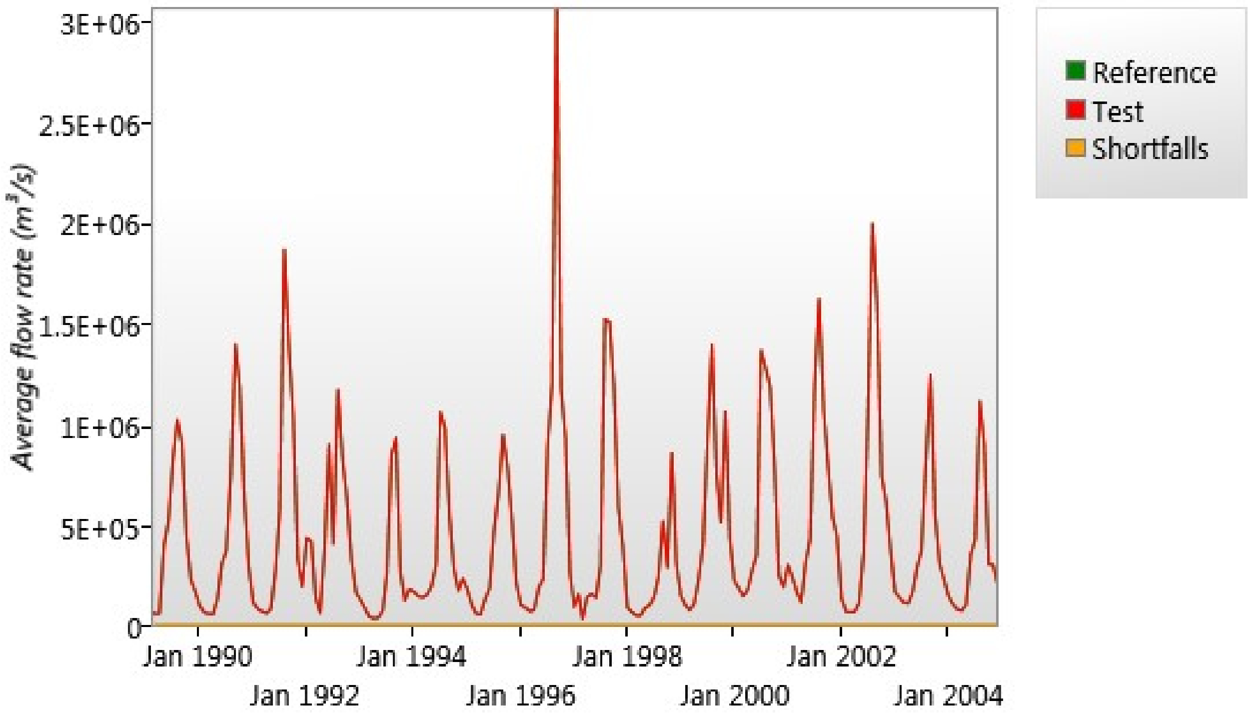


Figure 4-2 shows the annual variation in the average monthly flows over the reference period. It can be seen from this graph that there were three years when the peak flows in August were higher than normal – 1991, 1996 and 2002. There were two years when the peak flows were lowest in 1993 and 1998. There were two years when the minimum flows in March/April were lower than usual in 1993 and in 1997. It also shows that in some years there was a double peak in high flows – 1992, 1998, 1999.

Figure 4-2: Annual variation in average monthly flows (1989 – 2005)



These figures are for the Sekong above Attapeu, where the river is joined by the other major tributary, the Se Kamman. Analysis of catchment areas (Table 4-1) shows that before the Se Kamman confluence, the catchment area above Attapeu is about 33.2% of the total catchment area. The Se Kamman contributes 21.4% of the total catchment, making up 54.6% of the total catchment. By the time it reaches the Lao PDR Cambodia border, the flow in the river has captured water from 77.4% of the catchment.

However, it is not simple to do a straightforward multiplication of the flows at Attapeu by the proportion of the catchment area to get the flows at the mouth of the river, because of the differences in rainfall distribution. Reference to Figure 3-9 shows that the Sekong above Attapeu collects water from the wettest part of the catchment, whilst the Se Kamman comes from a drier area.

The MRC estimates of the total mean annual flow from the Sekong are 998 m^3/sec, i.e. over double the flow at Attapeu. This gives a total annual flow of about 32,000 million m^3 per year compared to about 14,128 million m^3 per year at Attapeu.

Table 4-1: Analysis of the catchment areas of the Sekong

	Catchment area (sq km)	Running total of catchment area (sq km)	% of total catchment	Tributary as % of total catchment
Sekong upper	3,947.2	3,947.2	13.9	
Dak e Meule	977.9	4,925.1	17.3	3.4
Sekong above Sekong town	1,616.1	6,541.2	23.0	
Houay Lamphan Ngai	540.5	7,081.7	24.9	1.9
Sekong above Attapeu	1,018.5	8,100.2	28.5	
Se Nam Noy	1,345.4	9,445.6	33.2	4.7
Upper Se Kamman	2439.14			
Lower Se Kamman	1906.38			
Se Xou	1725.09			
Se Kamman	6070.61	15,516.2	54.6	21.4
Sekong/Se Kamman confluence	1,514.2	17,030.4	59.9	
Nam Kong	1,627.0	18,657.3	65.7	5.7
Se Khampho	1,491.9			
Se Pian	1,851.9			
Se Pian	3,343.8	22,001.1	77.4	11.8
Sekong upper, Cambodia	2,919.9	24,921.0	87.7	
Prek Samang	1,318.0	26,239.0	92.3	4.6
Sekong lower, Cambodia	2,174.8	28,413.8	100.0	
Total catchment area		**28,413.8**		

4.2 Floods and drought

The hydrological analysis above based on the data available does not really capture flood events, since the daily means are averaged by month and then over the whole year. To understand the peak flow potential, the average daily flows for the period July and August 1996 (the highest flow records in the reference set) have been plotted out in Figure 4-3. This shows that there was a series of increasingly high flow events leading up to a peak of nearly 4,000 m^3/sec on 6 August 1996. This is almost 3.4 times the mean maximum monthly flow.

By contrast the lowestdaily flows occurred in 1993 with a minimum recorded flow of 16 m^3/sec at Attapeu on 11 April 1993. The next year when very low flows were recorded was in February 1997 when the lowest flows recorded were between 20 and 25 m^3/sec.

The data set available does not cover the more recent typhoons and tropical storms that have occurred, notably Khetsana in late September 2009, when significant flooding occurred in the Sekong and Se Kamman, with about 90% of the province of Attapeu affected.

Recently theNational Disaster Management Office (NDMO) of Lao PDR has produced a series of maps on flood and storm risk in Attapeu and Sekong[5]. These are shown in Figure 4-5 and Figure 4-6.

[5] NDMO facebook page - https://www.facebook.com/photo.php?fbid=475778165780599&set=a.475778089113940.111041.212398375451914&type=1&theater

Figure 4-3: Average daily flows at Attapeu, July to August 1996

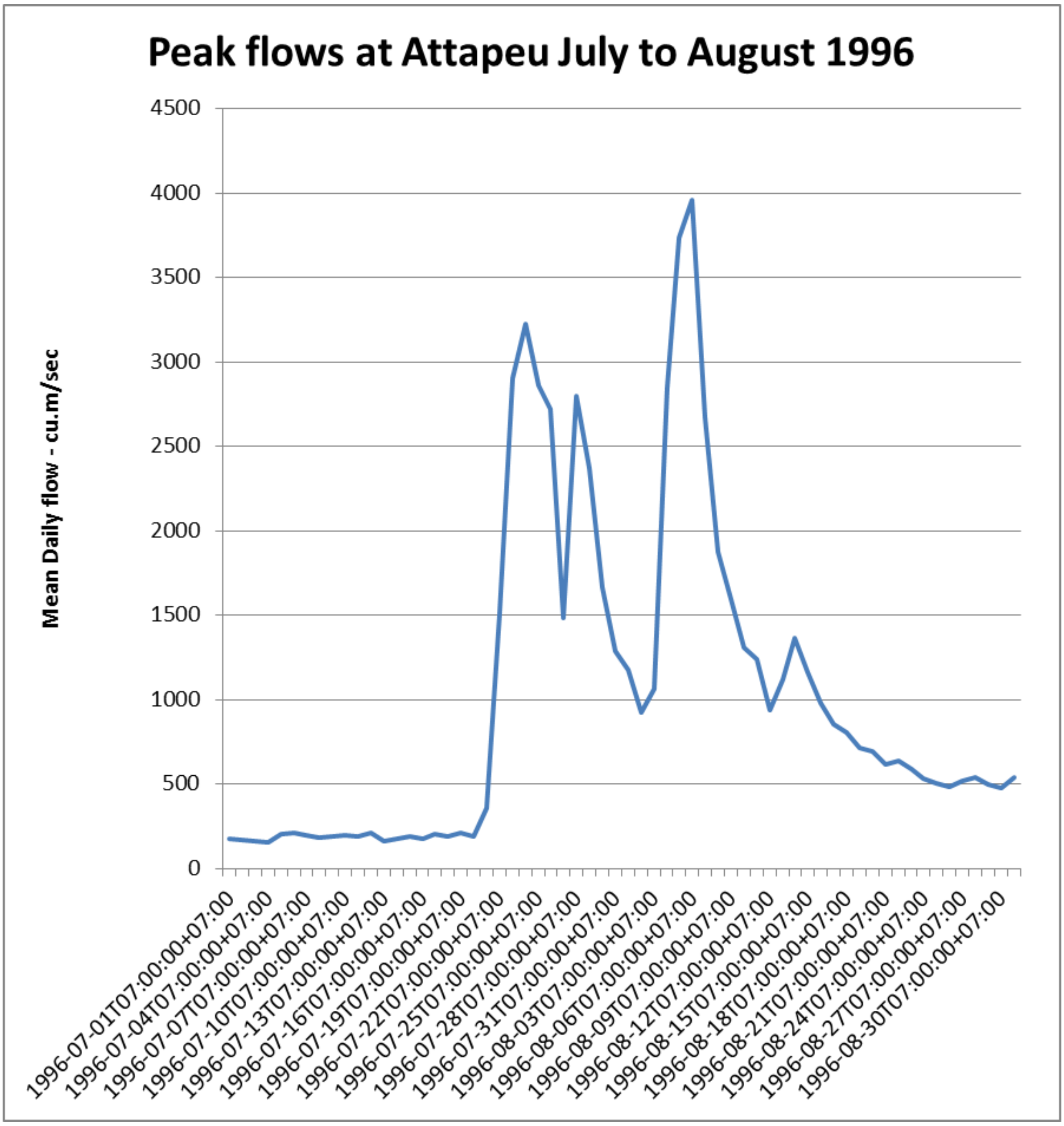


Figure 4-4: Lowest flows at Attapeu in April 1993

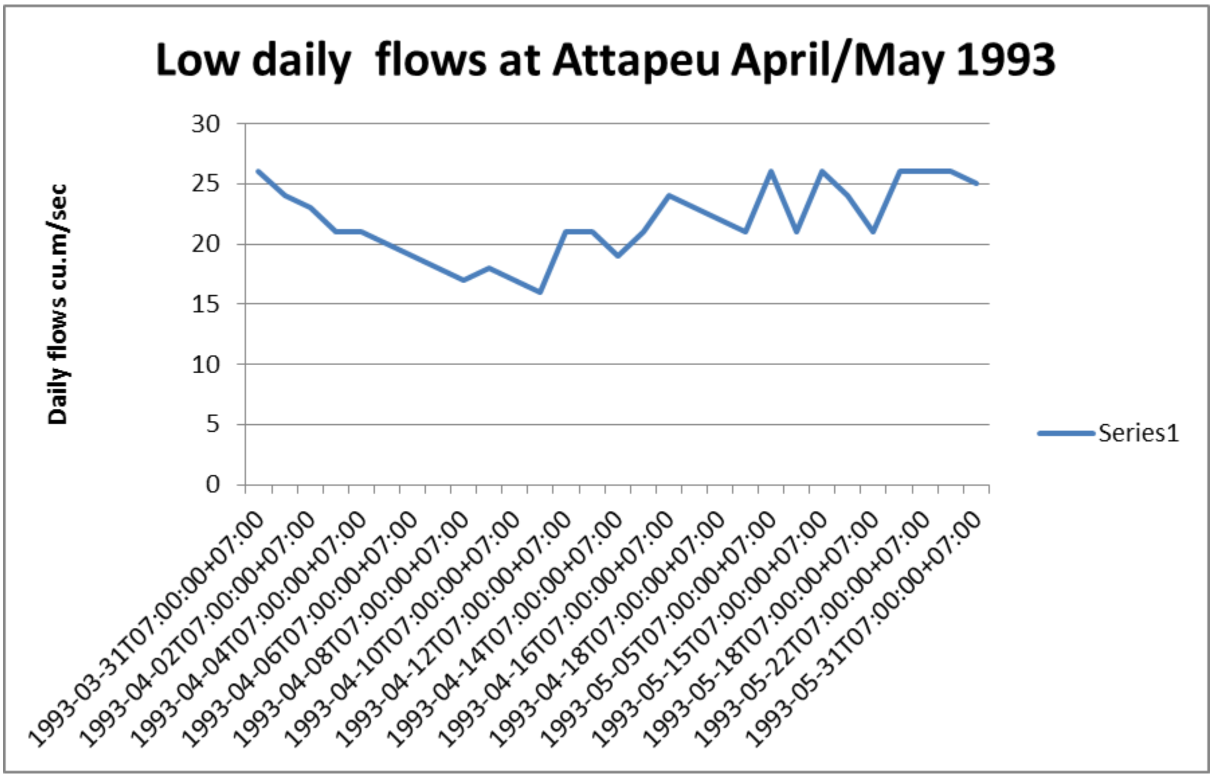
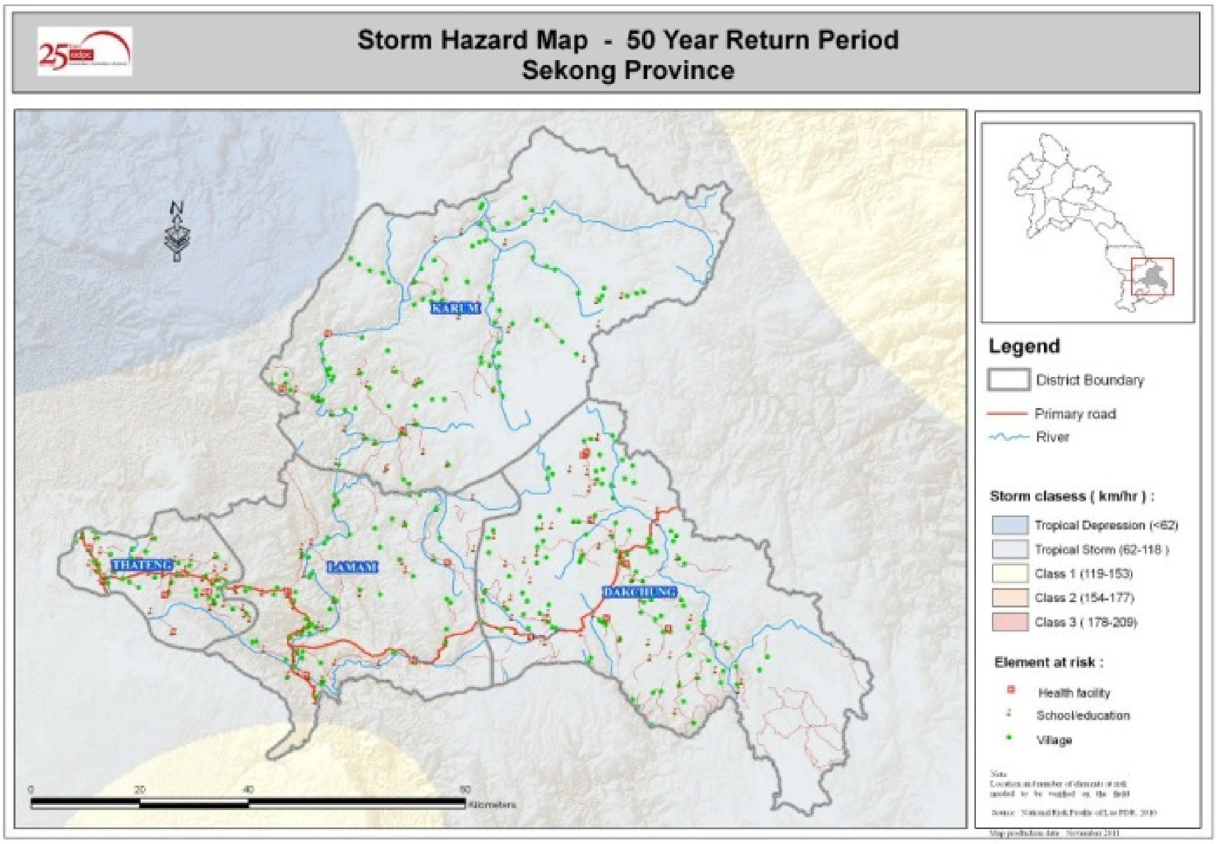


Figure 4-5: Storm hazard maps for Sekong and Attapeu



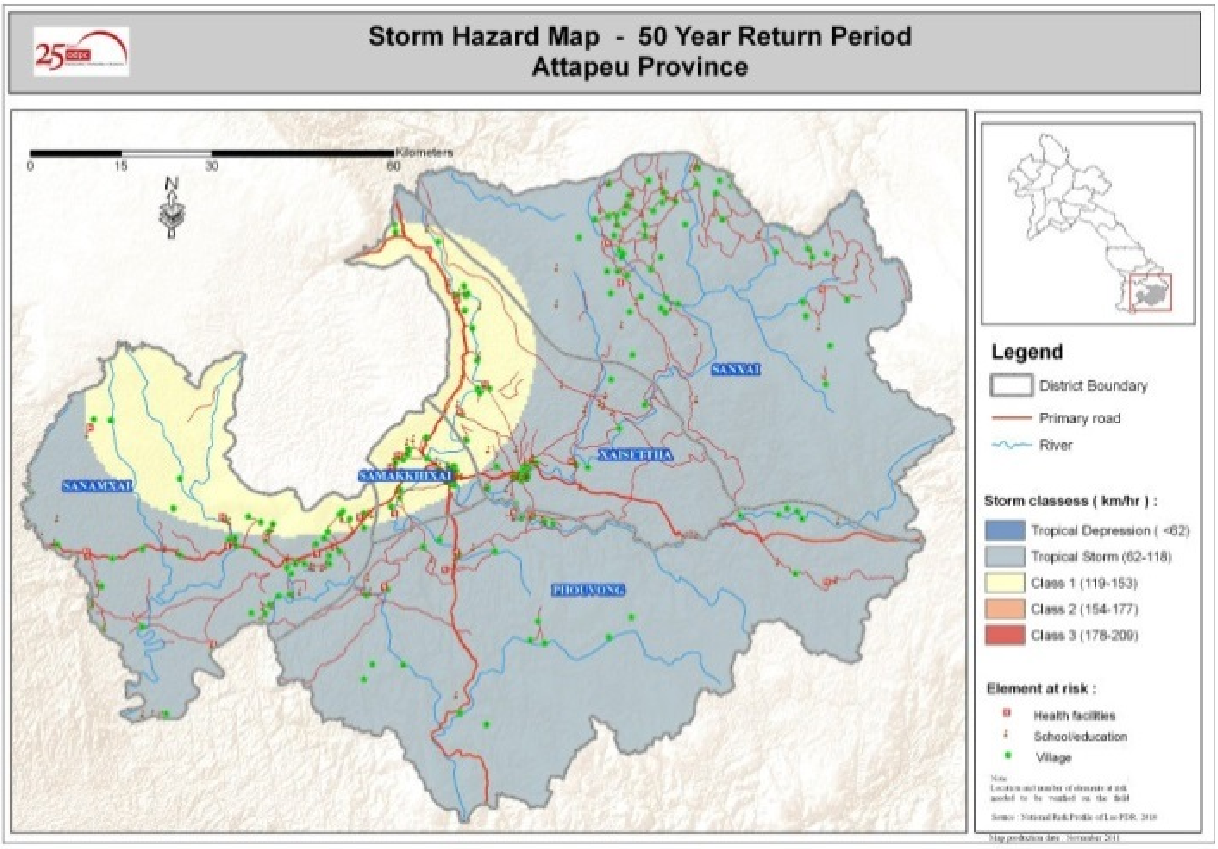
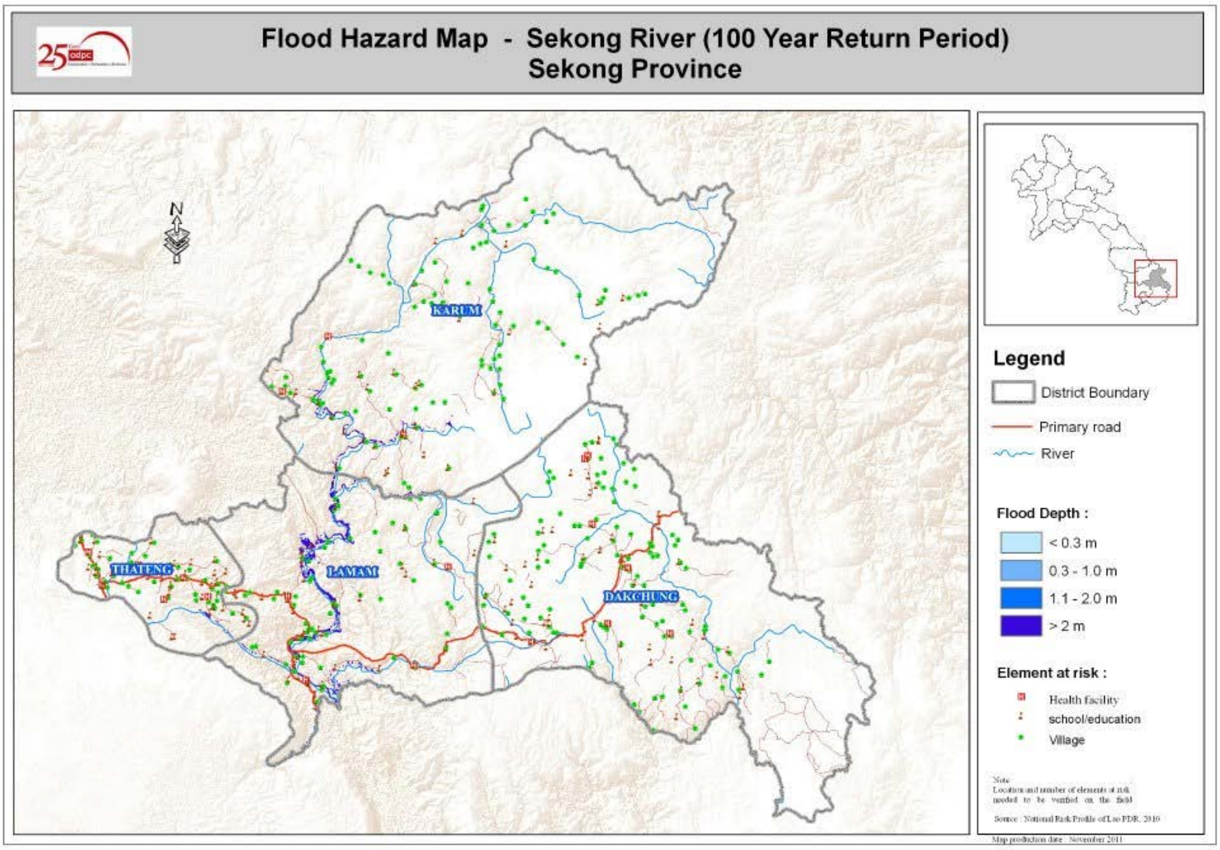
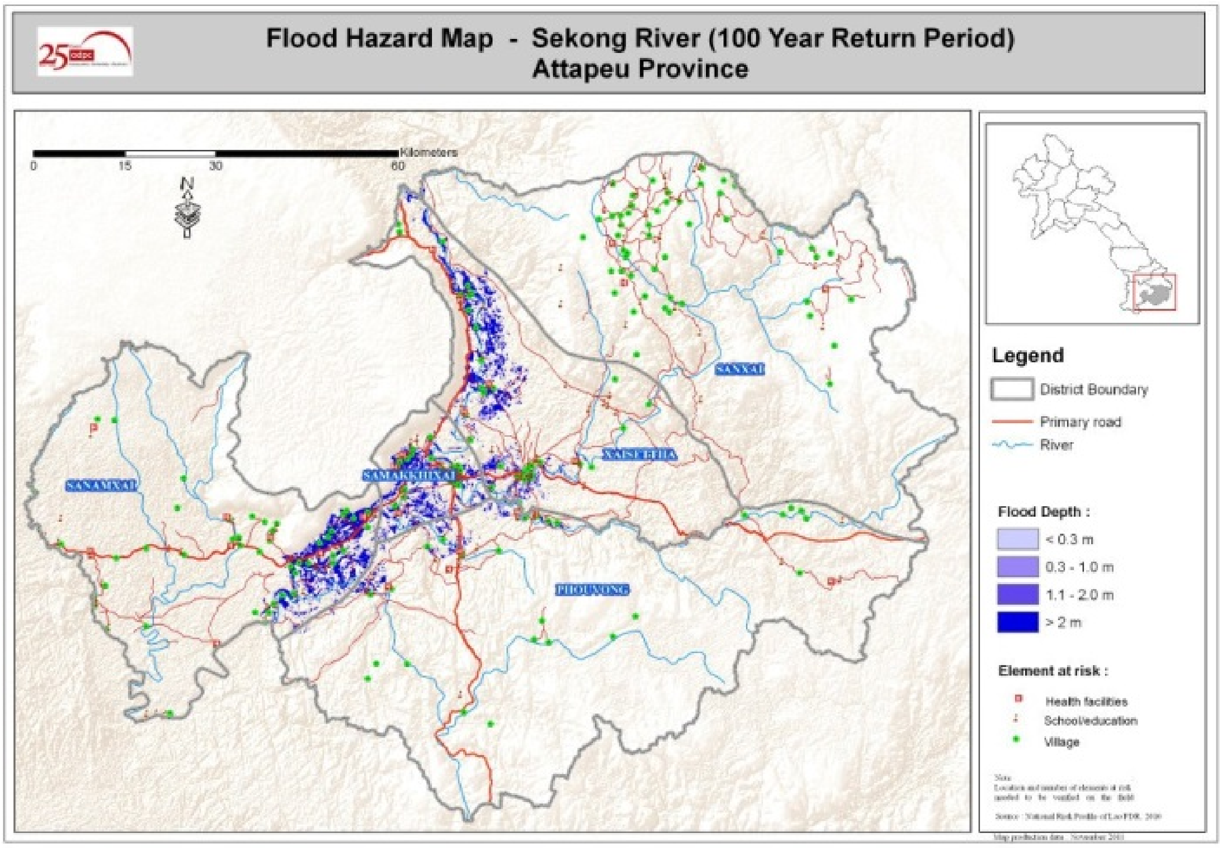


Figure 4-6: Flood hazard maps for Sekong and Attapeu





5 Key features of the river

5.1 Profile of the Sekong River

The elevation profile of the Sekong River is shown in Figure 5-1 showing the locations of the borders, main towns and mainstem dams. The river has been measured over 530 km from the confluence with the Sesan/Sre Pok from about 50 masl to over 600 masl. Figure 5-2 shows the decrease in the width of the river with increasing elevation and distance upstream. In the first 50 km upstream from the confluence the width is around 400 m, then dropping fairly evenly from about 300 m wide at 60 km to about 200 m wide around 270 km and to 100 m wide at about 400 km. Above 400 km the width falls below 50 m, until it reaches the upland plateau are in Viet Nam where the channel is wider and flatter.

Figure 5-1: Elevation profile of the Sekong River

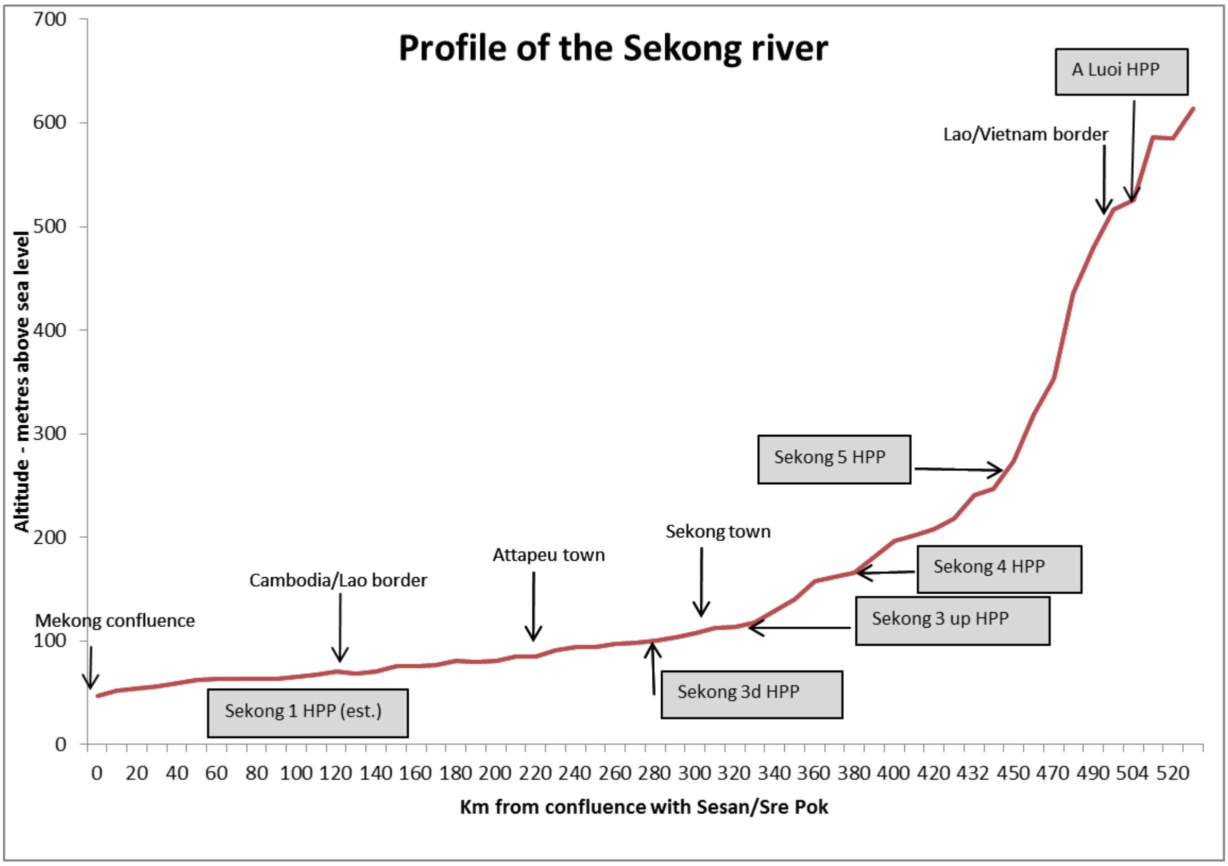
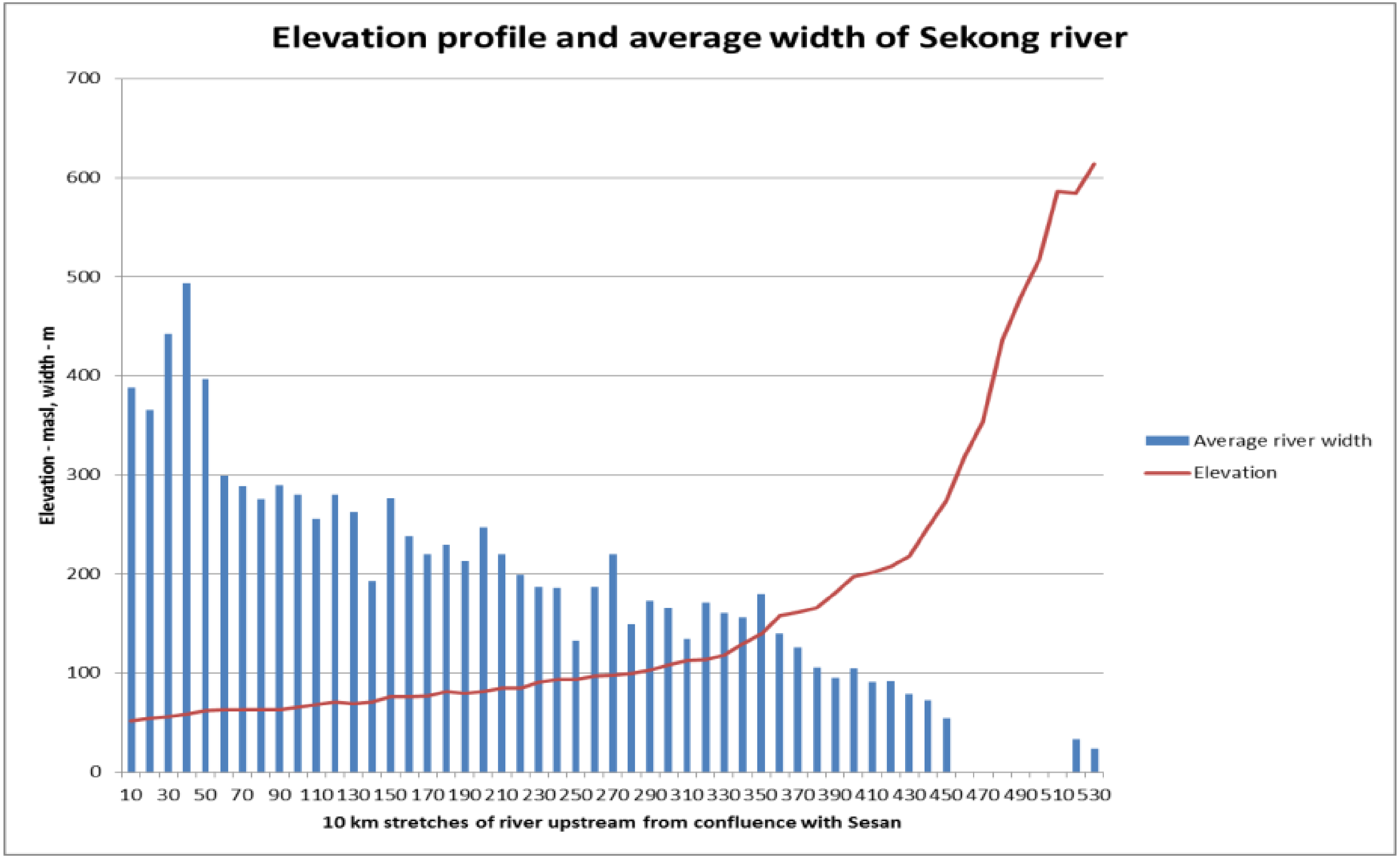


Figure 5-2: Elevation profile and average width of the Sekong River



5.2 Profile of the Se Kamman

The elevation profile of the Se Kamman River is shown in Figure 5-3. The Se Kamman flows into the Sekong River at Attapeu at kilometre 220 at about 80 masl. The Se Sou River joins the Se Kamman at about 14 km upstream of the confluence with the Sekong at about 100 masl. At about 55 km upstream the Se Kamman/Sanxay regulating dam is proposed and this marks a steadily increasing slope, with four additional hydropower projects proposed up to an elevation of 560 masl. Se Kamman 3 HPP is located up a side stream to the north above Se Kamman 2B. The Se Kamman has been measured up to 940 masl at about 170 km upstream from the confluence.

Figure 5-4 shows the width of the river with elevation, ranging from just over 100 m wide at the confluence with the Sekong, falling to less than 30 m wide at the top end. There is a slight broadening of the river up to 100 m wide between 80 and 90 km stretches.

Figure 5-3: Elevation profile of the Se Kamman River

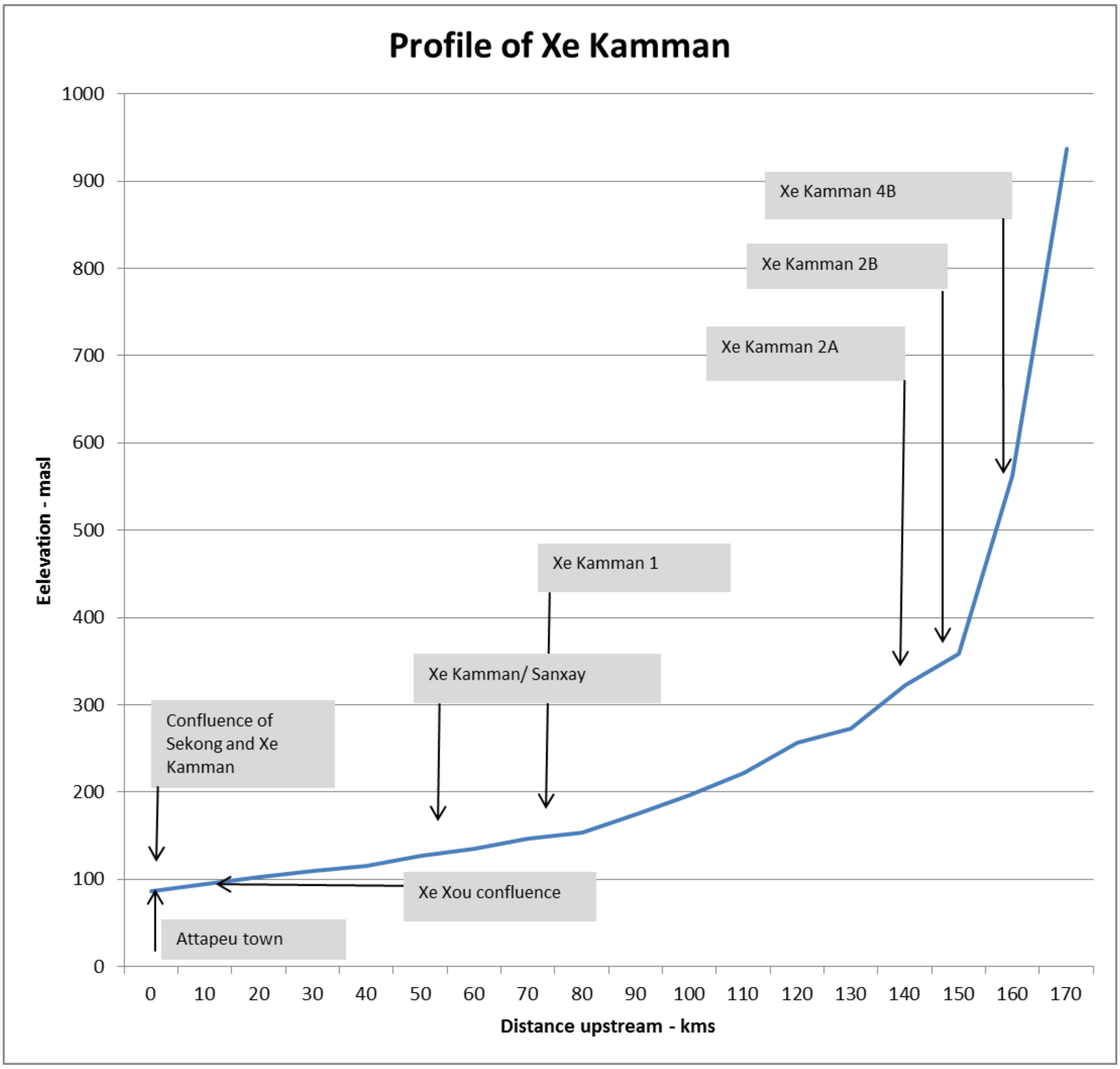
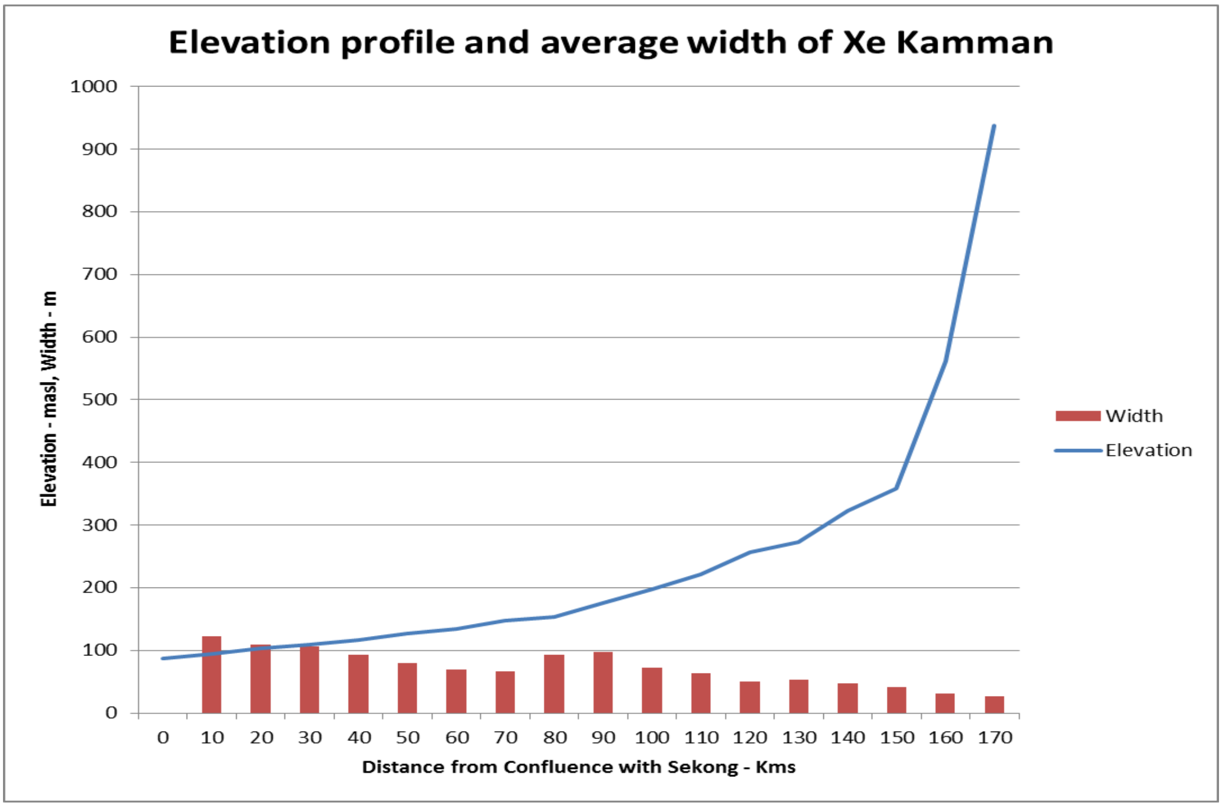


Figure 5-4: Elevation profile and average width of the Se Kamman River



5.3 Sinuosity of the Sekong

The sinuosity of a river is a measure of the number of major bends in the river channel. A sinuosity index has been developed using the 1 km markers mapped on Google Earth and by taking the series of 10 km stretchesof the river, starting at the confluence of the Sekong and the Sesan Rivers. Within each 10 km stretch, the number of bends in the river which are more than 90^o are counted and direct distance between the 10 km markers is measured. The sinuosity index is calculated from the equation:

SI = (Number of bends >90^o X 10 km distance travelled by river)/Direct distance between 10 km markers

Figure 5-5: Sinuosity index for Sekong and Se Kamman rivers

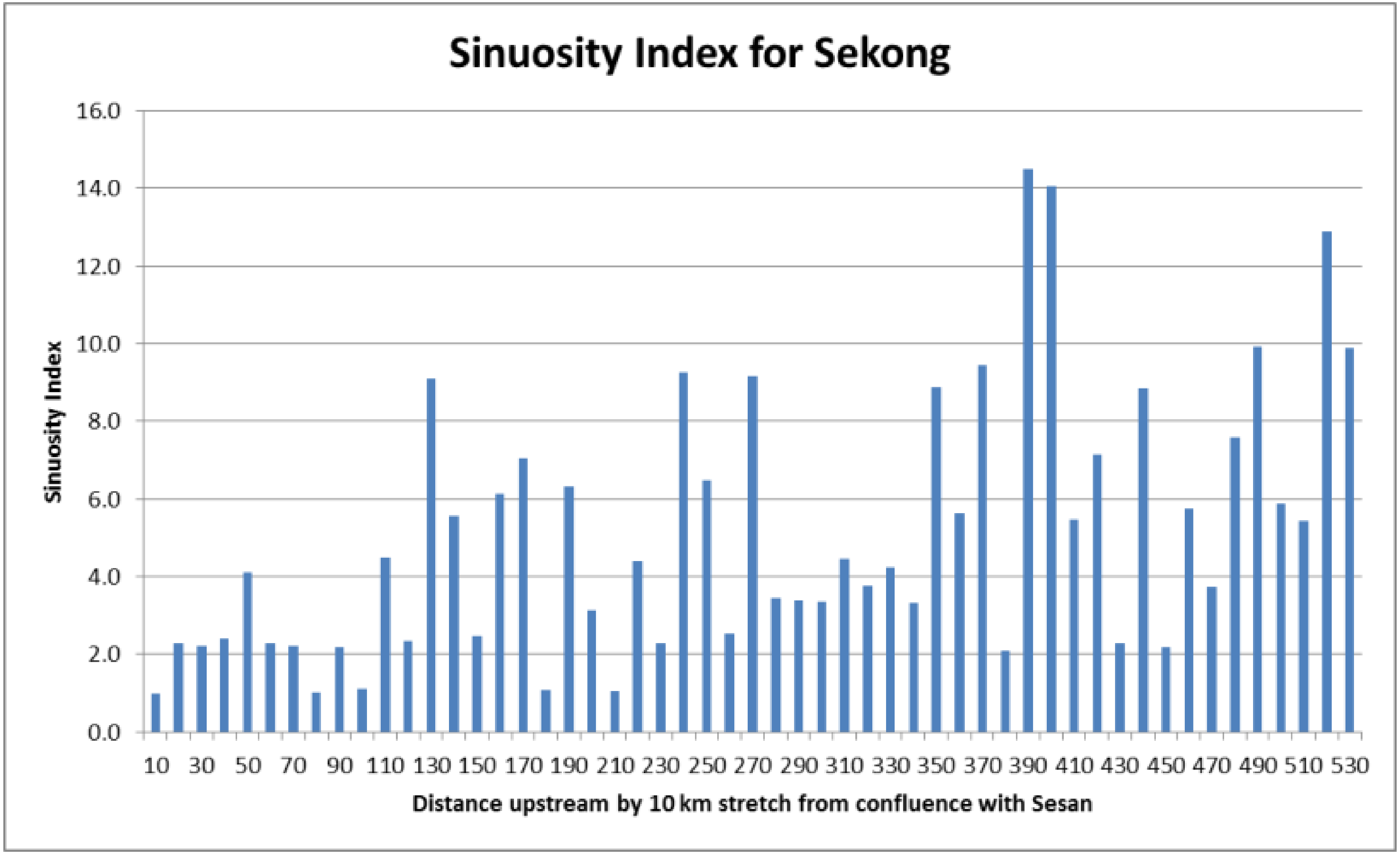
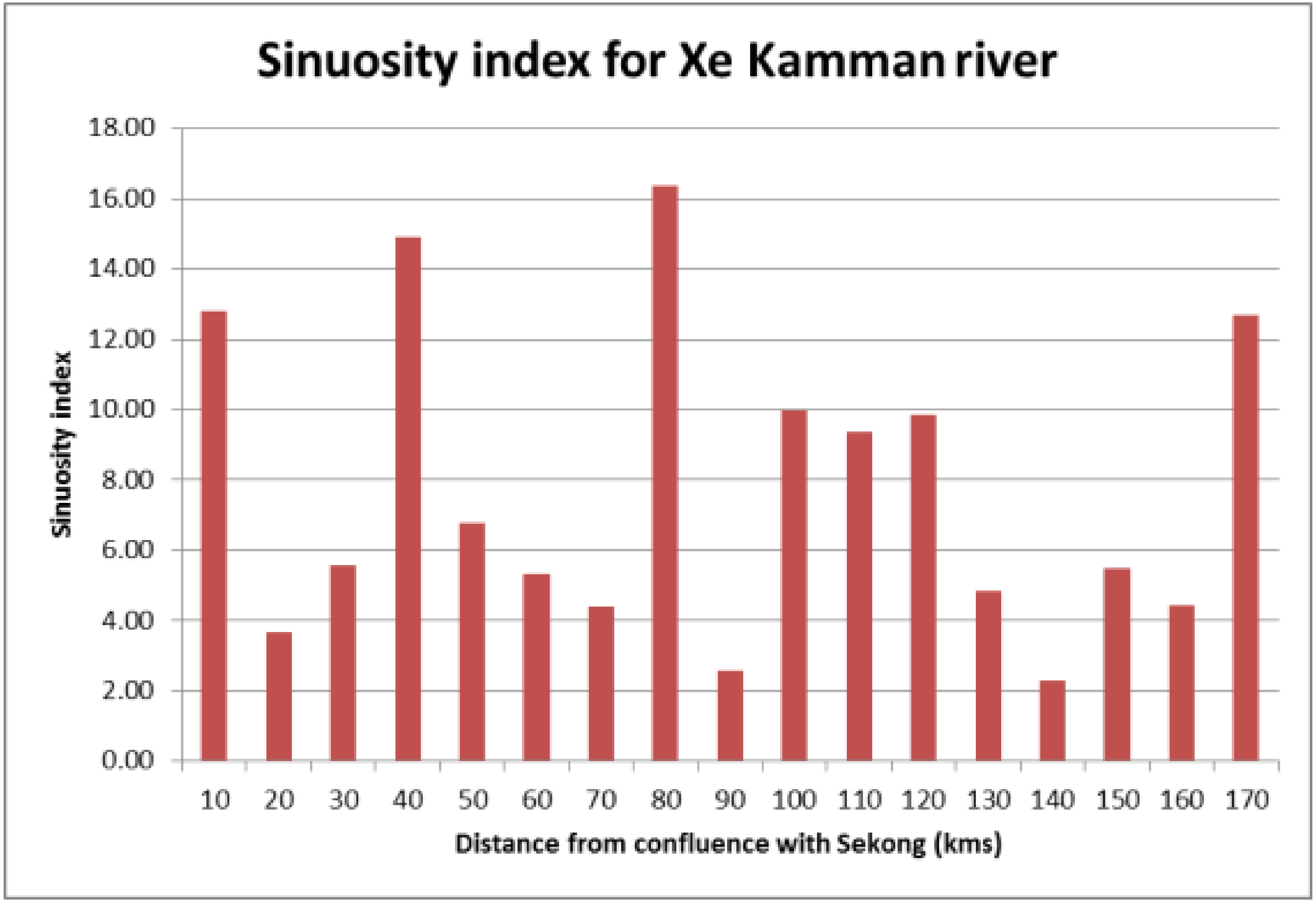


Figure 5-6 continued



Analysis of the sinuosity shows an overall increase in sinuosity of the 10 km stretches with distance upstream. It is clear that the lowland areas up to 100 km upstream have a low level of sinuosity, flowing fairly straight through Cambodia. Between 100 km and 220 km (Attapeu) there are 10 km stretches with variable sinuosity with high levels especially at 130 km, 170 km and 190 upstream. Above Attapeu, in the middle reaches, sinuosity is fairly low with some exceptionally sinuous stretches at 240 km and 270 km. With increasing elevation, the sinuosity increases significantly with very high levels at 390 km and 400 km upstream as it flows through the mountains. In the upland plateau area in Viet Nam, the river has many meanders with a high sinuosity.

The sinuosity of the Se Kamman is more variable with high sinuosity in the Attapeu plain, especially at 10 km, 40 km and 80 km reaches. At the river passes through the mountains the sinuosity is variable, with high levels recorded especially in the highest reaches.

5.4 Mapping the features of the Sekong

The results of the Google Earth survey of the Sekong and Se Kamman rivers showing the 10km reach aggregates of the observations taken every 1 km are shown in Table 5-1 for the Sekong, and for the Se Kamman in Table 5-2.

Along the Sekong, the following discontinuities can be discerned:

- **Lowland zone**: Between confluence with the Sesan and Sre Pok to 210 km – predominantly plain channel with some rocky elements and sandy channels. Presence of exposed rocks and sandbars/beaches tends to be limited. There are some significant areas with more features, especially the large island and wetland area at 30km.
    - The junctions between the Prek Samang and Xe Pian occur at 60 km and 150 km respectively (also the start of the Lao PDR Cambodia border)
    - Km 140 is also interesting because of high exposed rocks, riffles and rapids and a number of islands
    - At 190 km the confluence with the Nam Kong.
- Between 210 km and 230 km there is a **transition zone** up to the junction with the Se Kamman at Attapeu, with high sinuosity. At 230 km Attapeu town is the largest urban area along the Sekong.
- The **middle zone** extends from Attapeu up to 340km, just beyond Sekong town, the other major urban area (at 330km). The middle zone is characterised by mixed plain, rock and sandy channels, with medium exposed rocks, sandy beaches and riffles.
    - Characteristic reaches occur at 260 km and 270 km with many islands, exposed rocks and sand deposition, with evident riffles and rapids.
    - Between 280 km and 320 km there are is significant areas of sand deposition, especially at bends.
- **Upland zone** reaches start with increasing elevation after Sekong town, at 340/350km. The channel is predominantly rock confined with high presence of exposed rocks and deposition of sand in sand bars and beaches, riffles and rapids. There are a few islands.
    - Kaleum district town occurs at 410km
    - Above 450 km the reaches become difficult to describe from Google Earth
    - Viet Nam border occurs at 500 km and the river passes through the hills to 510 km
- **Upland plateau zone**occurs in Viet Nam from above 530 km down to 510 km. These reaches consist of meandering sandy channels with some confined rock channels. The reaches are characterised by extensive deposition of sand.

The Se Kamman has been observed for 60 km upstream of the confluence with the Sekong. It is predominantly a meandering sandy channel for the first 50 km with extensive sandbanks and islands. The Se Xou River joins the Se Kamman at 15km. The transition zone to an upland river occurs between 50 km and 60 km, with the start of a rock-confined channel above 60 km where the Se Kamman/Sanxay HPP is proposed.

Table 5-1: Features of 10 km reaches of the Sekong River

10 km stretches	Elevation range	Average width	Predominant channel type			Presence of					Tributaries		Settlements		Features
	masl	m	Plain	Rock	Sand	exposed rocks	sand bars/ beaches	riffles	rapids	islands	Left bank	Right bank	Left bank	Right bank	
10	47 to 51	388	H		M	L			L	1			M	L	Large island 2.5 km long at km 9
20	51 to 54	366	H	L		L	L			1					Rocks in channel at km 20
30	54 to 56	442	M	M	M	H	M			5	1	1			Braided channel with large island, 2 km long at km 30
40	54 to 59	494	H		L	M	L		L	2			L		Rocks in channel at km 40
50	59 to 63	397	H		L		L			1		1	L		Sandy island at km 43. Possible site of Sekong HPP
60	63	299	H				L			1	1	1			
70	63 / 66	289	H											M	Villages and cultivation on both sides, Ban Huoy
80	63/66	276	H			L	L			2	1		H	H	Siempang on both banks, Prek Samang joins on left bank at km 77
90	64/66	290	H										L	M	Siempang hydrological station
100	64 to 67	280	H	L						1	1			L	
110	66 to 69	256	H			L	L	L		1	1				
120	68 to 71	280	H	L		L	M	L	L	2		2		L	Sandy islands, beaches before km 120
130	69 to 70	263	H	L	L	L	M			3					Sandy and wooded 2 km island at km 125
140	70 to 71	193	L	H		H	L	H	M	5	1	1		L	Extensive rock confined channel for most of stretch
150	72 to 74	277	M	M	L	M	L	L	L	5	1				Lao/Camb. Border: Se Pian/Se Khampho confluence at border km 143. Rapid and FCZ at km 145
160	73 to 77	238	H			L					1			L	Along border
170	77 to 78	220	H		L	L	L			1				L	Deep pool and rapids
180	78 to 79	230	H			L				2	1			L	
190	79 to 83	213	H			M	L			3	2			M	Deep pools and rapids, Nam Kong enters on left bank at kmn 189
200	84 to 82	247	H	L	L	M	L	L		3				L	Deep pool and 1 km sandy island opposite Sanamxay town at km 194
210	81 to 85	220	H	L	L	L	M			5		1		L	Rapids at 204
220	84 to 87	199	M	M		M	H	M	L	2				M	3 Deep pools, 1 rapid, sandy islands and beaches on bends
230	86 to 87	187	M	M	M	L	H	L		1				H	1 deep pool and sadny beaches. Attapeu town begins on right bank
240	88 to 97	186	L		H	L	M			2	1		M	H	Attapeu town. Confluence with Xe Kamman. Deep pool. Sattapeu hydrological station
250	96 to 97	133	L	M	M	L	M	M	L	1			L	L	Rapid and deep pool near km 250
260	96 to 97	187	H	L		M	H	H	L	5	1	4	M		2 Deep pools, 1 rapid, 1 km island
270	97 to 103	220	M	M		M	M	H	L	4	2		H	L	3 Deep pools, 2 large sandy islands and beaches on bends
280	101 to 102	149	M	L	H	L	M	H		1	1	2	L	L	1 rapid, road from Sekong to Attapeu along right bank
290	104 TO 105	173			H	L	M	M	L	1	1	1	L	M	1 deep pool 2 rapids, tail race and discharge from Houay Ho HPP at km 285. Site of Sekong 3d HPP at km 290
300	107 TO 112	166	M	L	M	H	M	M	M	2			L	L	3 Deep pools 2 rapids, 1 FCZ
310	112 TO 114	135	L	M	M	L	M	M	L	1	1	1			3 deep pools, Xe Katam confluence at km 304
320	113 TO 116	171	L	M	M	H	H	L		2		1		M	5 deep pools 1 rapid. Confluence with Houay Lamphan Ngay on right bank at km 313
330	114 TO 122	161	L	M		M	H	M	L	1	1			H	2 deep pools, 1 rapid. Sekong town on right bank
340	122 TO 130	156	L	H		H	L	H	M		2		L		Rock confined channel starts. Site of Sekong 3up HPP at km 342
350	134 TO 145	180		H		M	M	H	M		1	3		L	Rock channel, Extensive rapids, Keng Louang, 3 deep pools, Keng Tang rapids at km 350
360	146 TO 160	140		H		H	M	H	H		2	1	L	L	3 rapids, 2 deep pools at river exit from hills. Proposed site for Sekong 4 HPP at km 367
370	159 TO 162	126		H		H	H	H	H		2		L	L	3 deep pools 3 rapids. Confluence with Dak-e-Meule at km 368 on left bank
380	168 TO 176	106		H		H	M	H	H				L		Rock confined channel, extensive rapids, with deep pool upstream of start.
390	176 TO 189	95		H		H	H	H	M		2		L		4 deep pools 1 rapid, extensive sandy beaches on bends
400	199 TO 202	105		H	L	M	H	M	M	1	2	1	L	L	3 rapids I deep pool, extensive sandy beaches along bends
410	195 TO 212	91		M	M	M	H	L	L		1	3	L	M	Kaleum district town on right bank. 1 deep pool 1 rapid
420	208 TO 214	92		H		H	H	H	H	1	2	2	M	L	4 rapids 2 deep pools
430	233 TO 258	79		H		H	M	H	H			1	L		1 deep pool, rocky channel, rapids
440	254 TO 267	73		H		H	H	H	H		1	1	L		rocky channel and sand deposition on bends
450	284 TO 326	54		H		H	L	H	H		1			L	Proposed site of Sekong 5 HPP
460				H											rocky channel and rapids
470				H											rocky channel and rapids
480				H											rocky channel and rapids
490				H											rocky channel and rapids
500				H											rocky channel and rapids, Lao/Vietnam border
510				H											rocky channel and rapids. A Luoi HPP operational at km 502
520	553 TO 562	33		M	M	H	H	H	L	1	1	1		M	Meandering upland plateau river, sand deposition, rapids. Hong Quang town on right bank. Road follows river on right bank
530	562 TO 572	24	L		H	M	H	H	M	2				L	Meandering upland plateau river, sand deposition, rapids

Table 5-2: Features of 10 km reaches of the Se Kamman River

10 km stretches	Elevation range	Average width	Predominant channel type			Presence of					Tributaries		Settlement		Features
from confluence with Sekong	masl	m	Plain	Rock	Sand	exposed rocks	sand bars/ beaches	riffles	rapids	islands	Left bank	Right bank	Left bank	Right bank	
10	91 to 97	123	L		H		M			4				H	Attapeu town, confluence with Sekong, Xaisi district at 10 km
20	97 to 101	128			H		H			3	1		L	M	Confluence with Xe Xou, left bank. Xaisetha town at km 20 right bank
30	105 to 110	118			H		H			3			L	L	Long vegetated island, Road bridge with evidence of construction disturbance. 1 deep pool
40	110 to 115	102			H		H	L	L	1		1	L	M	Small villages and cultivation. Large sandy islands. 1 deep pool, 1 rapid
50	119 to 122	80	H	L	L		M			1	2			L	
60	122 to 125	70	L	M		M	H	L	L	3					Rock confined channels. Proposed site of Se Kamman Sanxay HPP at km 56

5.5 Rapids and deep pools

Rapids and deep pools are important geomorphological features with significant ecological functions. Rapids are important for aeration of the water, and may represent barriers to upstream fish migration and to navigation. Deep pools are important refuges during the dry season for larger fish. The rapids and deep pools that have been mapped by WWF are shown inFigure 5-1. More detailed maps of different sections of the river are collected in Annex 1.

The dimensions of the deep pools are shown in Table 5-1. The areas of these deep pools range from about 0.5 ha to 20 ha, with an average of about 4.2 ha. The deepest pools are 25 m deep, found in upstream reaches, whilst the average depth is 8 m.

The rapids and deep pools have not been mapped in Cambodia, although close observation of Google Earth images can pinpoint where such features may be found.

Figure 5-7: Rapids and deep pools on the Sekong mainstream in Lao PDR

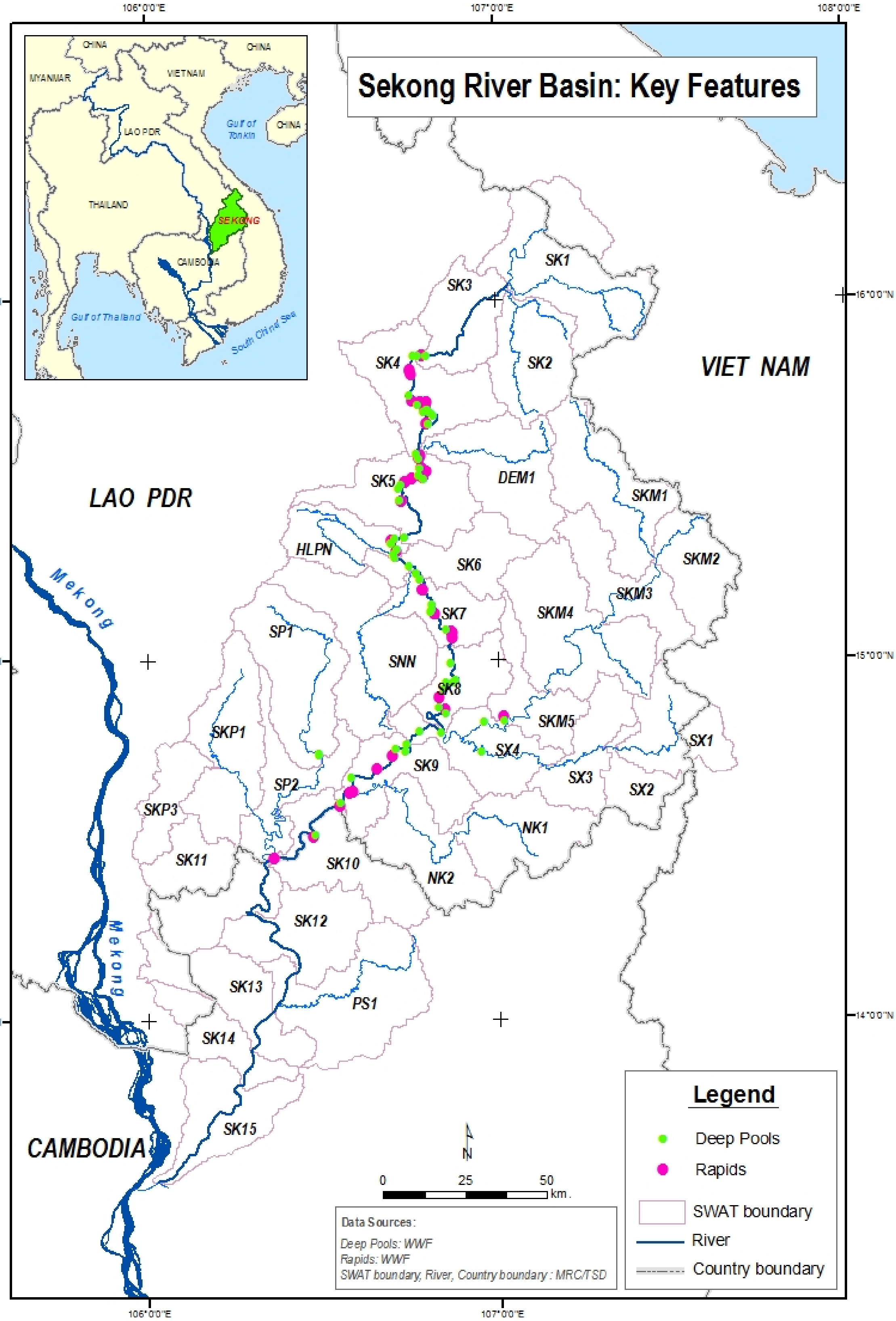


Table 5-3: Dimensions of deep pools on the Sekong River in Lao PDR

WWF Code	FCZ Name	N	E	Deep pool dimensions (m)				Associated Village	Population	Women
				Wide	Length	Area	Depth			
XKN020	Van Priew	691226	1728312	100	500	5	25	Hatvy		
XKN018	Vang Priew	689819	1743999	150	400	6.07	25	Kroung		
XKN014	Vang Houakenglouang	684981	1708256	200	500	10	11.15	Kenglouang	1864	920
XKN017	Vang Hintang	683326	1693724	150	300	10	5	Pakthone	1027	484
XKN021	Vang Pakhouaykor	68336	1693724	100	500	5	20	Nangyong	322	160
	Vang Pakhouayhinlat			200	1000	20	14			
XKN015	Vang Tover	751630	1715702	40	100	0.4	5	Daktaoknoy	201	100
XKN016	Vang Kongkrune	751630	1715702	15	150	0.22	5	Dakbong	340	176
XKN019	Vang Chalieng	753953	170956	20	200	0.4	3	Daktaokyai	305	142
ATP028	Boung Hinxang	701759	1666751	40	200	0.8	1.5	Sokkham	936	436
ATP029	Vang Veunva	700149	1652531	100	600	8.41	13	Halangnoy	283	134
ATP041	Vang Saitok	704303	1639953	25	500	1.25	1.6	Phork	2214	1140
ATP039	Vang Lavae	62936	1627553	70	600	4.2	8	Phonemany	267	124
ATP040	Vang Pakhoaypin	616432	1626841	100	500	5	6	Hinlat/Mai	607	312
ATP032	Vang Yang	697960	1625434	30	250	0.75	4	Vangyang	320	112
ATP033	Vang Khaen			30	240	0.72	4	Vongsamphan		
ATP034	Vanghinlat	68287	1618652	100	1000	10	8	Vongsai	252	125
ATP035	Nongpadouk			70	100	0.7	1.5			
ATP036	Vang Roy	767317	1631171	50	1000	6.39	6	Phoukeua	248	113
ATP037	Vang Chalongboom	668501	1607682	50	100	0.15	5	Vonglakhone	379	196
ATP030	Vang Sai	720694	1652112	30	250	0.75	3	Vangsai/Phousai	240	113
ATP038	Vang Kongkoy	705596	1667445	20	150	0.3	6	Moun	884	450
ATP039	Vang Houangnan	730616	1683595	20	250	0.5	2.5	Namngone	910	474

5.6 Suggested E-flow reference sites

The following sites have been identified as possible locations for flow management studies to consider the impacts of changes in flow regimes. They contain features that are characteristic of the different zones:

- Lowland river zone, A - km 30 and B - km 140
- Transition middle to lowland zone, C - km 210 and D - confluence with Se Kamman
- Middle river zone, E – km 260 and F - km 280
- Upland river zone, G – km 340, H - km 400 and I – km 430
- Upland plateau river zone, J – km 520

On the Se Kamman, the following locations have been identified:

- Confluence with Se Xou – K - km 15
- Lowland river – L – km 40
- Transition zone – M – km 55
- Upland river – N – km 80

5.6.1 Lowland river

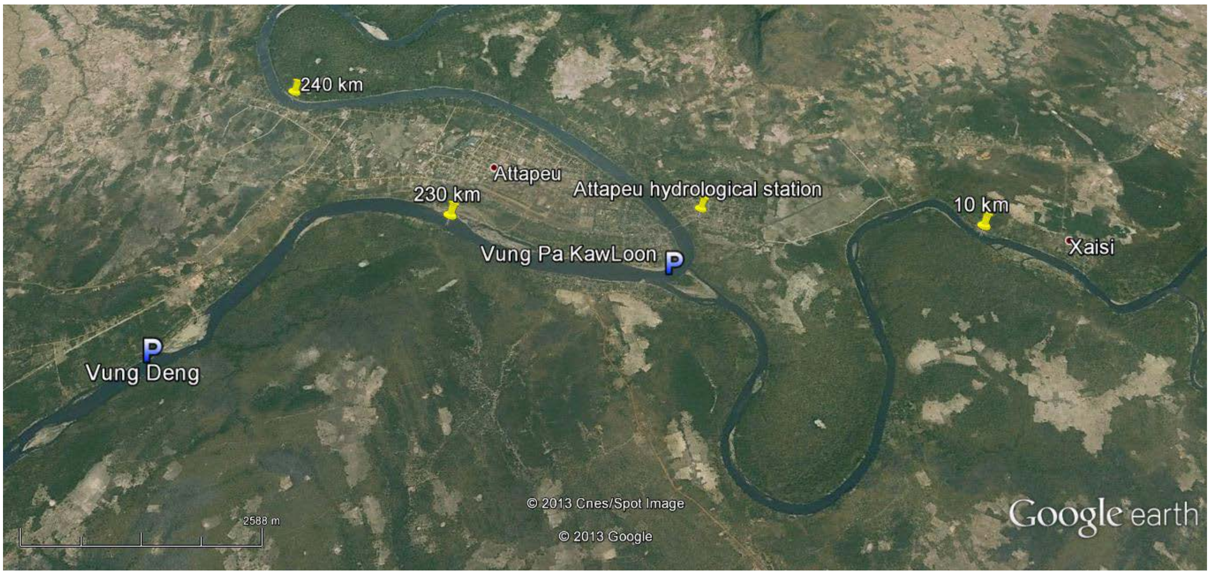
A. Km 30 - Lowland braided channel with in-channel wetlands

B. Km 140 - Lowland rock-confined channel

5.6.2 Transition zone reaches

A. Middle reaches to lowland – rapids and deep pools

B. Confluence with Se Kamman



5.6.3 Middle reaches

A. Km 260 - Deep pools and islands

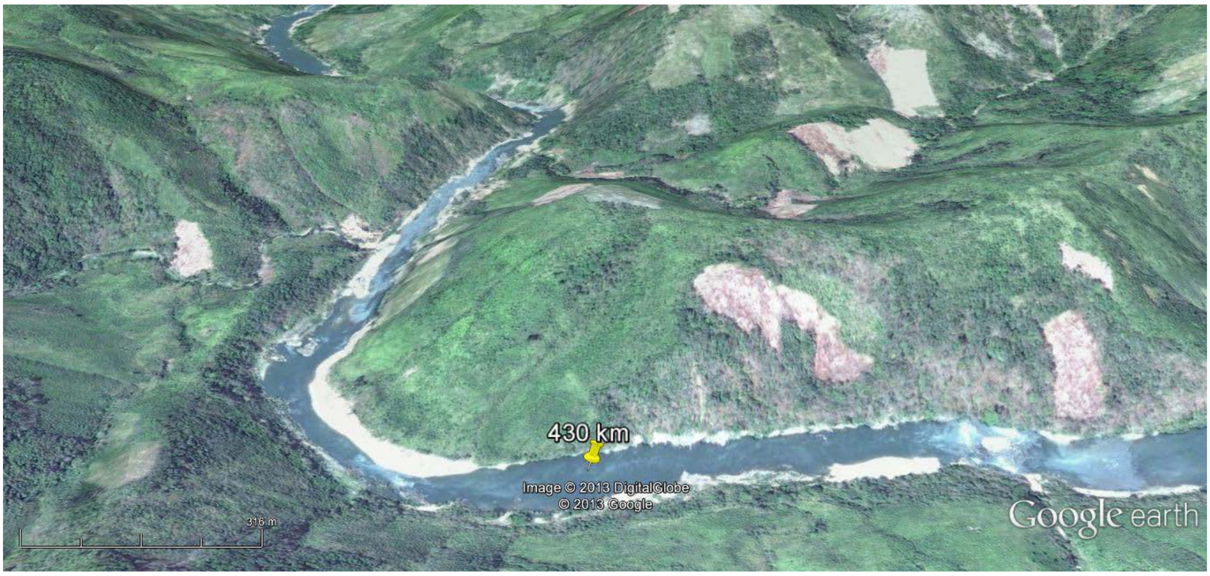
B. Km 280 - Sand banks, deep pools and rapids

5.6.4 Upland river

A. Km 340 - Transition from upland to middle reaches – rapids, confined rock channels, sand bars and beaches

B. Km 400 - Upper reaches - bends, sand bars, rapids and deep pools

C. Km 430 - Upland river – rapids, sand beaches, small villages



5.6.5 Upland plateau

A. Km 520 - Upland plateau river, Viet Nam - Rapids and deposited sand beaches

5.6.6 Se Kamman

A. Km 15 - Se Kamman – Confluence with Se Xou

B. Km 40 - Se Kamman – lowland river – bends, deposited sand, rapids and pools

C. Km 55 - Se Kamman – transition zone from upland to lowland river, rock-confined channel and rapids

D. Km 80 - Se Kamman – upland river, rock-confined channel, rapids

6 Biological information

6.1 Fishbiodiversity

The 3S Rivers constitute one ecological unit, and fish fauna and migrations in the Sekong, Sesan and Sre Pok are considered.[6]The current review of fish species in the Sekong, Sesan and Sre Pok Rivers is derived from six main lists of fish detailed in Baird 1995, MFD 2003, Baird and Meach Mean 2005, Nguyen Huu Duc *et al.* 2006, Chan Sokheng *et al.* 2008 and Kottelat 2009. Kottelat 2011 described fish species sampling on the Se Kamman, and these latter two papers provide details of locations sampled on both Sekong and its tributaries.[7][8]

Baran et al. compiled these species lists, updated their taxonomy using FishBase (www.fishbase.org) as a reference, and the result is detailed in Annex 1. Overall, the 3S system is characterized by 329 fish species, i.e. 42% of the 781 fish species found in the Mekong (although the surface area of the 3S, i.e. 78,600 km^2, represents only 10% of the 800,000 km^2 of the Mekong watershed area). This qualifies this area as being very rich from a fish biodiversity viewpoint**.**

More specifically, the Sekong River is characterized by 213 fish species, the Sre Pok River by 240 species, and the Sesan River by 133 species only.

Table 6-1: Fish species richness in the 3S.

	Sekong	Sesan	Sre Pok
Families	33	26	33
Species	213	133	240

6.1.1 Fish endemism in the 3S Rivers

The above data set combined with the identification of endemic species in FishBase indicates that among the 161 Mekong endemics (i.e. fish species found in no other river basin than in the Mekong Basin), 17 are "super-endemic species" found in the 3S but nowhere else in the world.

This analysis (Table 6-2) shows in particular that:

- Fifteen super-endemic species are found exclusively in the Sekong River:
  - *Devario salmonata, Poropuntius lobocheiloides, Schistura bairdi, Schistura bolavenensis, Schistura clatrata, Schistura fusinotata, Schistura imitator, Schistura khamtanhi, Schistura nomi, Schistura rikiki, Schistura tizardi, Serpenticobitis octozona, Sewellia diardi, Sewellia elongata, Sewellia speciosa.*
- Two "super-endemic" species are found exclusively in the Sre Pok River:
  - *Sinibrama affinis and Toxabramis hotayensis*
- The Sesan River does not feature any species that are not found in other Mekong rivers.

These results highlight the exceptional value of the Sekong River in terms of biodiversity conservation.

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[6] This information is drawn largely from Eric BARAN, SARAY Samadee, TEOH Shwu Jiau, TRAN Thanh Cong (2013) *Fish and fisheries in the Sekong, Sesan and Sre Pok basins (3Srivers, Mekong watershed), with special reference to the Sesan river.* Paper prepared for CPWF MK3 project. Published in e-book by ICEM, Hanoi.

[7] Kottelat (2009) Fishes of the Xe Kong drainage in Lao PDR. Report for WWF project "Aquatic Resources Management to Improve Rural Livelihoods of the Xe Kong Basin"

[8] Kottelat (2011) Fishes of the Xe Kong drainage in Lao PDR, especially from the Xe Kaman. Report for WWF project "Co-Management of freshwater biodiversity in the Sekong Basin"

Table 6-2: Fish endemism in the 3S Rivers.

	Sekong River	Sesan River	Sre Pok River
Mekong endemics found in the 3S Rivers and in other Mekong tributaries	62	24	45
Mekong endemics found in only one of the 3S Rivers	15	0	2

6.1.2 Endangered species in the 3S Rivers

The IUCN Red List of endangered species, updated in July 2011, was used to assess the endangered species present in the 3S Rivers. **The 3S Rivers are home to 14 endangered or critically endangered fish species**, as detailed in Table 6-3:

Table 6-3: Endangered and critically endangered species found in the 3S Rivers.

3S species	Red List status
Aaptosyax grypus	Critically endangered
Catlocarpio siamensis	Critically endangered
Pangasianodon gigas	Critically endangered
Dasyatis laosensis	Endangered
Luciocyprinus striolatus	Endangered
Pangasianodon hypophthalmus	Endangered
Poropuntius bolovenensis	Endangered
Poropuntius deauratus	Endangered
Probarbus jullieni	Endangered
Probarbus labeamajor	Endangered
Schistura bairdi	Endangered
Schistura bolavenensis	Endangered
Sewellia patella	Endangered
Yasuhikotakia sidthimunki	Endangered

6.2 Fish migrations in the 3S Rivers

Baran et al. combined the list of fish species in the 3S with an extensive review of migratory species in the Mekong Basin published, for the whole Mekong, in Ziv et al. (2012). The latter review used the ecological information available in Mekong Fish Database (MFD 2003), FishBase (www.fishbase.org), Baran *et al.* (2006) amended by So Nam (pers. comm.), Halls and Kshatriya (2009) and Halls (2010).

For each species of the 3S, the migratory nature of the species was reviewed, and for disputable cases additional literature was used. The resulting list is presented in Table 6-4 and detailed in Annex 2.

Before the present review, the MRC had identified 23 migratory species basinwide (MRC 2001, MRC 2003, Poulsen *et al*. 2002, 2004). Out of these, 16 were known at that time to migrate in the 3S system, but among them *Labeo chrysophekadion* is disputable since this species can also spawn in reservoirs (Kamonrat *et al.* 1972, Boonmon and Kantejit 1977, Watanadirokul *et al.* 1983, Chabjinda *et al.* 1992).

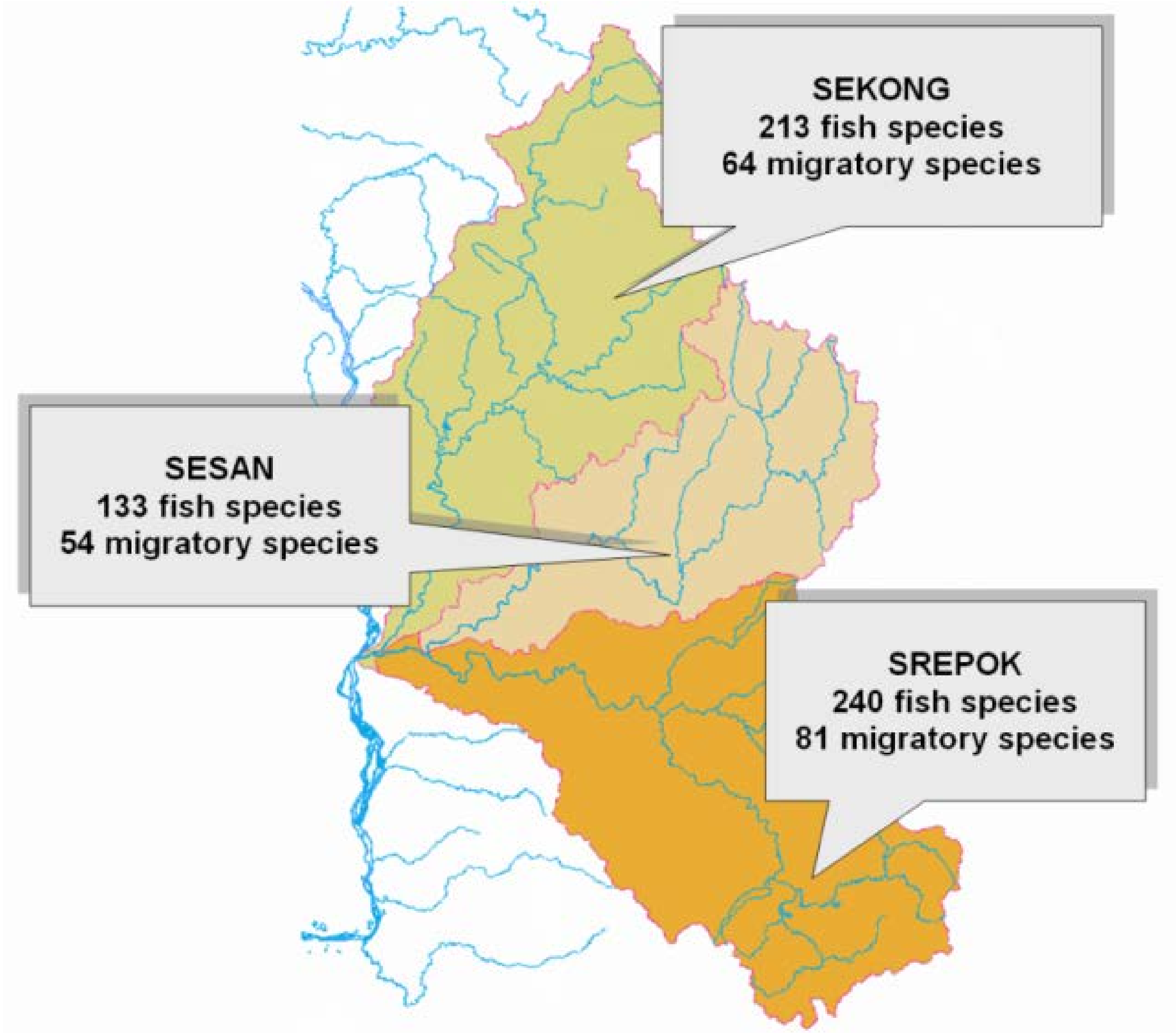
Migratory species of the 3S system are also detailed in Baird *et al.* (1999), Mekong Fish Database (MFD 2003) and Baird and Shoemaker (2008); however among them two species are disputable: *Labeo erythropterus* is also able to proliferate in impoundments (Rainboth 1996), and *Wallago attu* is believed toundertake only short longitudinal migrations to the nearest stream, as well as some localized movements (Poulsen and Valbo-Jørgensen (2000).

Baird *et al.* (2003) also list 28 species[9] believed to migrate from the Tonle Sap to Khone Falls and therefore possibly to the 3S. Among these, six are doubtful: there is to date no study confirming that *Crossocheilus oblongus*, *Henicorhynchus lineatus*, *Parambassis wolffii* or *Yasuhikotakia caudipunctata* are migratory, and *Barbonymus altus or Osteochilus melanopleurus* do not fully depend on migrations, since they can breed in impoundments or floodplains.

All the species indisputably migratory in the above studies are present in our review.

This comprehensive review leads to the conclusion that **the 3S system is characterized by at least 89 migratory fish species belonging to 15 families** (Table 7-4)**.**More specifically, the Sekong, Sesan and Sre Pok Rivers are characterized by 64, 54 and 81 migratory species respectively (**Figure 7-1**).

Figure 7-1: Total number of species and number of migratory fish species in the 3S



[9]*Amblyrhynchichthys truncatus, Barbonymus altus, Cosmochilus harmandi, Crossocheilus oblongus, Cyclocheilichthys enoplus, Epalzeorhynchos frenatus, Garra fasciacauda, Gyrinocheilus pennocki, Henicorhynchus lineatus, Labiobarbus leptocheilus, Leptobarbus hoevenii, Lobocheilos melanotaenia, Osteochilus melanopleurus, Osteochilus microcephalus, Parambassis wolffii, Puntioplites falcifer, Sikukia gudgeri, Syncrossus helodes, Thynnichthys thynnoides, Yasuhikotakia caudipunctata.*

Table 6-4: Migratory species in the 3S Rivers.

Family	Species	Found in the 3S
Anguillidae	Anguilla marmorata	Sekong, Sre Pok
Bagridae	Hemibagrus filamentus	Sekong, Sesan, Sre Pok
	Hemibagrus wyckii	Sekong, Sesan, Sre Pok
	Hemibagrus wyckioides	Sekong, Sesan, Sre Pok
Clupeidae	Tenualosa thibaudeaui	Sekong, Sesan
	Tenualosa toli	Sre Pok
Cobitidae	Acanthopsoides delphax	Sesan, Sre Pok
	Syncrossus beauforti	Sekong, Sesan, Sre Pok
	Syncrossus helodes	Sesan, Sre Pok
	Yasuhikotakia modesta	Sekong, Sesan, Sre Pok
Cynoglossidae	Cynoglossus microlepis	Sre Pok
Cyprinidae	Aaptosyax grypus	Sesan
	Amblyrhynchichthys truncatus	Sekong, Sre Pok
	Bangana behri	Sekong, Sesan, Sre Pok
	Bangana pierrei	Sekong
	Barbichthys laevis	Sre Pok
	Catlocarpio siamensis	Sekong
	Cirrhinus jullieni	Sekong, Sesan, Sre Pok
	Cirrhinus microlepis	Sekong, Sesan, Sre Pok
	Cirrhinus molitorella	Sekong, Sesan, Sre Pok
	Cosmochilus harmandi	Sekong, Sesan, Sre Pok
	Crossocheilus atrilimes	Sekong, Sesan, Sre Pok
	Crossocheilus reticulatus	Sekong, Sesan, Sre Pok
	Cyclocheilichthys apogon	Sekong, Sre Pok
	Cyclocheilichthys armatus	Sekong, Sesan, Sre Pok
	Cyclocheilichthys enoplus	Sekong, Sesan, Sre Pok
	Cyclocheilichthys furcatus	Sre Pok
	Cyclocheilichthys heteronema	Sre Pok
	Epalzeorhynchos frenatus	Sekong
	Garra fasciacauda	Sekong, Sre Pok
	Henicorhynchus lobatus	Sekong, Sesan, Sre Pok
	Henicorhynchus siamensis	Sekong, Sesan, Sre Pok
	Hypsibarbus lagleri	Sekong, Sesan, Sre Pok
	Hypsibarbus malcolmi	Sekong, Sesan, Sre Pok
	Hypsibarbus pierrei	Sre Pok
	Hypsibarbus wetmorei	Sekong, Sesan, Sre Pok
	Labiobarbus leptocheilus	Sekong, Sesan
	Labiobarbus lineatus	Sesan
	Labiobarbus siamensis	Sre Pok
	Leptobarbus hoevenii	Sekong, Sesan, Sre Pok
	Lobocheilos melanotaenia	Sekong, Sesan, Sre Pok
	Luciocyprinus striolatus	Sekong
	Luciosoma bleekeri	Sekong, Sesan, Sre Pok
	Mekongina erythrospila	Sekong, Sesan, Sre Pok
	Osteochilus microcephalus	Sekong, Sesan, Sre Pok
	Osteochilus schlegelii	Sre Pok
	Osteochilus waandersii	Sekong, Sesan, Sre Pok
	Paralaubuca harmandi	Sre Pok
	Paralaubuca riveroi	Sekong, Sre Pok
	Paralaubuca typus	Sekong, Sesan, Sre Pok
	Probarbus jullieni	Sekong, Sesan, Sre Pok
	Probarbus labeamajor	Sekong, Sesan, Sre Pok
	Probarbus labeaminor	Sre Pok
	Puntioplites bulu	Sre Pok
	Puntioplites falcifer	Sekong, Sesan, Sre Pok
	Puntioplites proctozystron	Sekong, Sre Pok
	Raiamas guttatus	Sekong, Sesan, Sre Pok
	Rasbora aurotaenia	Sre Pok
	Scaphognathops bandanensis	Sekong, Sesan, Sre Pok
	Sikukia gudgeri	Sekong, Sre Pok
	Thynnichthys thynnoides	Sekong, Sesan, Sre Pok

Family	Species	Found in the 3S
	Tor sinensis	Sekong, Sre Pok
	Tor tambroides	Sekong, Sre Pok
Dasyatidae	Dasyatis laosensis	Sekong, Sesan, Sre Pok
	Himantura krempfi	Sre Pok
Datnioididae	Datnioides undecimradiatus	Sekong, Sesan, Sre Pok
Gyrinocheilidae	Gyrinocheilus pennocki	Sekong, Sesan, Sre Pok
Notopteridae	Chitala blanci	Sekong, Sesan, Sre Pok
Pangasiidae	Helicophagus waandersii	Sekong, Sesan, Sre Pok
	Pangasianodon gigas	Sre Pok
	Pangasianodon hypophthalmus	Sekong, Sesan, Sre Pok
	Pangasius bocourti	Sekong, Sesan, Sre Pok
	Pangasius conchophilus	Sekong, Sesan, Sre Pok
	Pangasius djambal	Sre Pok
	Pangasius krempfi	Sekong, Sesan, Sre Pok
	Pangasius kunyit	Sre Pok
	Pangasius larnaudii	Sekong, Sesan, Sre Pok
	Pangasius macronema	Sekong, Sesan, Sre Pok
	Pangasius mekongensis	Sre Pok
	Pangasius polyuranodon	Sre Pok
	Pseudolais micronemus	Sre Pok
	Pseudolais pleurotaenia	Sekong, Sesan, Sre Pok
Schilbeidae	Clupisoma sinense	Sesan, Sre Pok
Siluridae	Hemisilurus mekongensis	Sre Pok
	Phalacronotus apogon	Sekong, Sre Pok
	Phalacronotus bleekeri	Sekong, Sesan, Sre Pok
	Wallago leerii	Sekong, Sesan, Sre Pok
Sisoridae	Bagarius yarrelli	Sekong, Sesan, Sre Pok
Soleidae	Brachirus harmandi	Sekong, Sre Pok

6.3 Fish breeding and spawning sites

In the 3S watersheds, Srun Lim Song (2002) lists five creeks as being good places for fish breeding and spawning during the wet season. These main creeks are:

- **O Khampha in Thokeo commune of Siempang district. (Sekong tributary)**
- **O Smong in Sekong commune of Siempang district (Sekong tributary)**
- **O Kleang in Siempang district (Sekong tributary)**
- O So in Kbal Romeas commune of Sesan district (Sre Pok tributary)
- O Anchanh in Talat commune of Sesan district (Sesan tributary)

6.4 Fish conservation zones

Fish conservation zones (FCZs) can also be taken as indicators of ecological importance of certain features in the river, such as rapids and deep pools. The WWF ComFish project has mapped these features in the Sekong as well as promoting the establishment of FCZs with associated conservation measures and regulations. These are shown in Table 5-1.

Evaluation visits by WWF to villages with FCZs provide interesting insight into the importance and effectiveness of FCZs. Eight villages from two districts with a total of 660 families were visited in Sekong provinceand 22 villages from three districts with a total of 4454 families were visited in Attapeu province. There were 11 FCZs with 25 villages benefiting in Sekong and 27 FCZs with 82 beneficiary villages. The preferred and illegal fishing methods are shown in Table 6-5.[10]

[10] Personal communication from Vic Cowling, WWF Greater Mekong

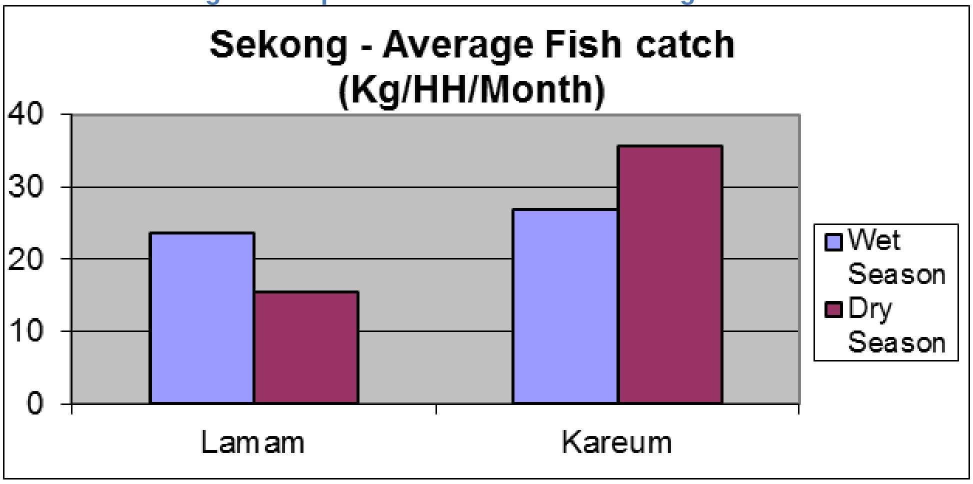
Table 6-5: Preferred and illegal fishing methods near FCZs along the Sekong River

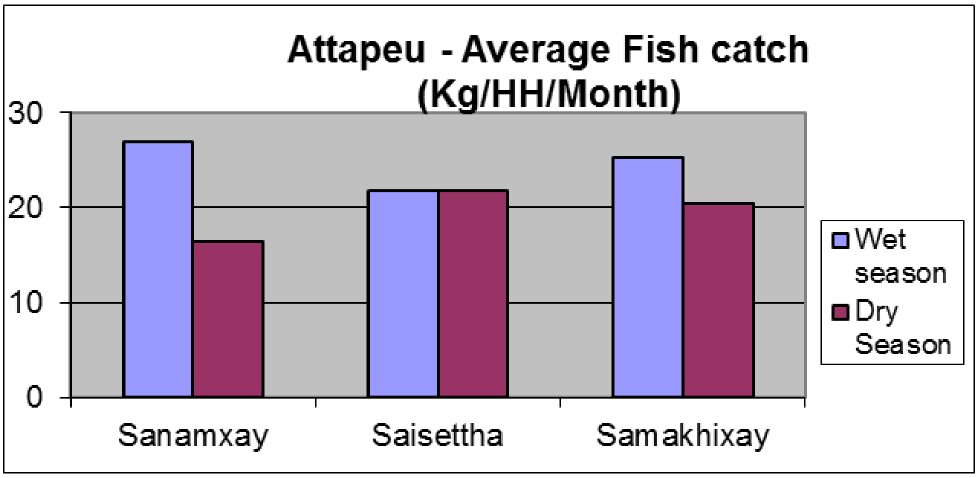
Sekong province	Attapeu province
Gill net – 47%	Gill net – 52%
Cast net – 28%	Cast net – 24%
Hook and line – 19%	Hook and line – 17%
Various types of fish trap – 5%	Various types of fish trap – 3%
Scoop nets and other nets – 1%	Scoop nets and other nets – 2%
Order of importance of illegal fishing methods:	Order of importance of illegal fishing methods:
Using electricity – 2	Using electricity – 1
Using poison – 3	Using poison – 2
Using gun or spear-gun - 1	Using gun or spear-gun - 3

The large majority of villagers were satisfied with the performance of the FCZs (90% in Sekong and 93% in Attapeu) and their management. Between 70% and 80% of villagers understand the regulations of the FCZs and management committees and between 68% and 76% of villagers considered that these rules were well observed. 85% of fishermen interviewed thought that fish numbers had increased, and only 15% in Attapeu thought that fish numbers had not increased.The fish catch per household varies between wet and dry season and the district as shown in Table 6-6.

The fish species that appeared to benefit from establishing FCZs include: *Poropuntus spp., Mystocoleucus spp.,Henicorhynchus sp. , Hampala spp., Hemibagrus wyckiodes, Puntopilites spp., Bagarius yarelli, Pangasius larnaudii, Pangasius polyuranodon, Cirrhinus molitorella, Onychostoma spp., Labeo barbatulus, Puntius rhombius, Micronema spp., Helicophagus waandersii, Wallago micropogon.* Other aquatic fauna also benefit including shrimp, snails, waterfowl.

Table 6-6: Average catch per household on the Sekong in different districts





7 People and communities

7.1 Viet Nam

The Sekong River rises in A Luoi district of Thua Thien-Hue Province of Viet Nam, with a total area of 1,229 km^2. The total population of A Luoi district in 2003 was 38,616 with a population density of 31 people per km^2. The population contains three main ethnic groups: Bru, Hoa and Tà Ôi people. The main riparian communes are Hong Quang, Phu Vinh, Son Thuy, and Huong Phong.

7.2 Lao PDR

In Lao PDR there are many riparian villages along the length of the Sekong and Se Kamman. The total population of the two provinces, Sekong and Attapeu, amounts to just under 200,000 people as shown in Table 7-1. Of these only two districts in Sekong – Kaleum and Lamam, are considered as riparian to the Sekong and three districts in Attapeu – Xaisettha, Sanamxai and Sanamxai. These villages have a total population of 124,338 people.

The Se Kamman River has three riparian districts – Dakchung, Sanxai and Phouvong, with a total population of 45,696 people.

Table 7-1: Populations of Sekong and Attapeu provinces and riparian districts

Province	District	Total pop.	sex ratio	pop density	HH size
Sekong	Dakchung	18,461	95.13	6.93	6.94
Sekong	Karum	12,869	97.29	3.91	7.03
Sekong	Laman	26,584	101.24	15.03	6.41
Sekong	Thateng	27,081	95.57	48.48	6.64
	Total Sekong	**84,995**			
Attapeu	Sanxai	16,515	91.81	4.98	5.88
Attapeu	Samakkhixai	30,182	99.38	53.49	5.46
Attapeu	Xaisettha	28,359	93.83	38.8	5.68
Attapeu	Sanamxai	26,344	96.85	12.97	5.64
Attapeu	Phouvong	10,720	92.25	2.94	5.46
	Total Attapeu	**112,120**			
Sekong Riparian districts					
Sekong	Karum	12,869	97.29	3.91	7.03
Sekong	Laman	26,584	101.24	15.03	6.41
Attapeu	Xaisettha	28,359	93.83	38.8	5.68
Attapeu	Samakkhixai	30,182	99.38	53.49	5.46
Attapeu	Sanamxai	26,344	96.85	12.97	5.64
	Total	**124,338**			
Se Kamman Riparian districts					
Sekong	Dakchung	18,461	95.13	6.93	6.94
Attapeu	Sanxai	16,515	91.81	4.98	5.88
Attapeu	Phouvong	10,720	92.25	2.94	5.46
	Total	**45,696**			

Source: Lao PDR Bureau of Statistics, www.decide.la

7.3 Cambodia

The Sekong in Cambodia passes through two districts of Stung Treng province – Siempang and Sesan districts. The total population of Siempang is 18,323 and of Sesan, 17,506 people. However, the bulk of these people live away from the river. A breakdown of the communes and villages that are located along the Sekong River is shown in Table 7-2. This is a relatively low-density populated area, with only 18 villages in 150 km and with a total riparian population of 12,114 people. They are generally focused in the reaches around km 70 – 100 with Siempang being the main district town.

Table 7-2: Total riparian population of Sekong in Cambodia

River reach (km)	Commune	Villages	Total pop.	Male	Female
10	Samkhuoy	Srea Ta Pan	526	270	256
30	Sdau	Sdau Muoy	1235	616	619
		Sdau Pir	523	261	262
70	Sre Sambour	Kanhchanh T	721	354	367
		Ket Moeang	366	180	186
		Pean Khes	596	306	290
80	Sekong	Ban Huoy	358	195	163
		Dan Loung	547	266	281
		Lon	196	87	109
		Kaeng Nhai	773	392	381
		Ban Muong	631	311	320
85		Siempang	1181	596	585
90	Santepheap	Kiri Bas Krao	554	266	288
		Teak tem	437	206	231
		Ou Chay	762	351	411
100	Thma Khaev	Pha bang	1223	595	628
		Lakay	628	312	316
		Nheang Sum	857	416	441
	Total riparian population		**12,114**	**5,980**	**6,134**

Source: Census 2005, http://www.opendevelopmentcambodia.net

8 Infrastructure development

8.1 Hydropower

At present there are two hydropower schemes that are operational in the Sekong in Lao PDR at present – Houay Ho and Xe Kamman 3, and one in Viet Nam – A Luoi HPP. The latter has the potential to divert about 8 m^3/sec from the A Sap River in the Sekong catchment into the Bo River in Viet Nam. Figure 8-1 shows the map with the dam locations in the Sekong Basin. Table 8-1 shows the characteristics of the operational, construction and planned future dams in the Sekong Basin. Table 8-2 shows the main hydrological characteristics of these dams that may influence the hydrology of the Sekong.

Figure 8-1: Map of the Sekong Basin showing locations of hydropower and irrigation projects

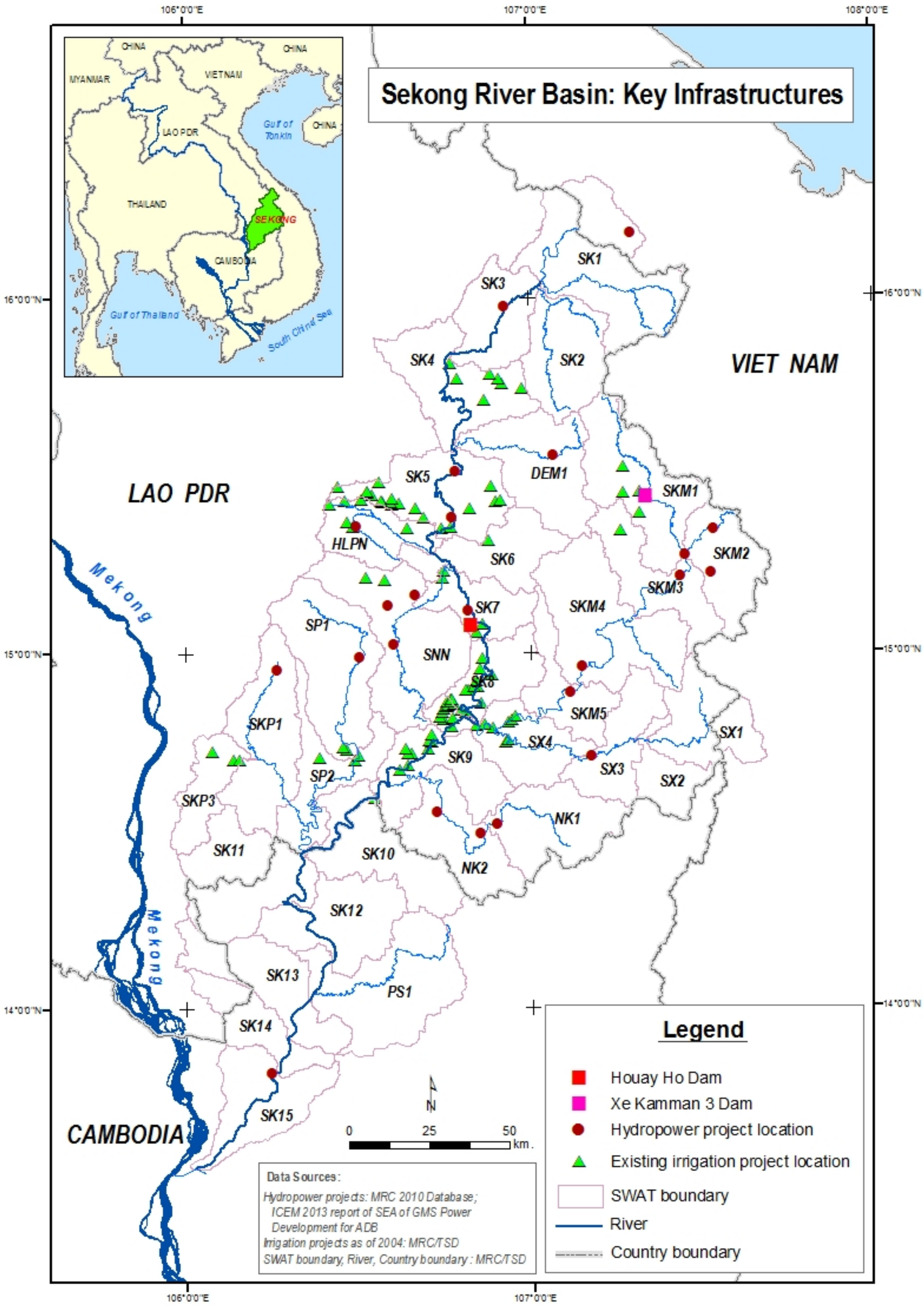


Table 8-1: Characteristics of the large hydropower projects on the Sekong

Dam name	Height	Length	Construction	Type	Head	Design flow	Installed capacity	Mean Annual Energy
Sekong Basin	m	m			m	cu.m/sec	MW	GwH
A Luoi HPP	44/25/11	291/114/85	E	S/BT	NA	11.6	62.0	173.4
Xe Kong 5	213.7	500	A	S	188.1	146.0	400.0	1,201.0
Xekong 4	169	1027	G	S	140.0	240.0	600.0	2,119.0
Dak E Mule	103.2	622/401	RE/RE	S	433.8	27.4	130.0	506.0
Houay Lamphan Gnai	55	982/561	RCU/RE	S	592.0	11.4	86.7	266.4
Xe Kong 3up	41.5	571.7	G	S	33.7	460.0	144.6	598.7
Xe Kong 3d	25.9	283	G	S	17.2	568.0	91.1	375.7
Houayho	76.5	600	RCU	S	748.3	23.0	150.0	487.0
Xe Katam	41.4	420/1340/18/21	R/E/G/G	S/BP	450.0	16.0	60.8	380.0
Xepian-Xenamnoy	75	1430/831/720/409	R/E/E/E	S/BT	642.0	70.0	390.0	1,748.0
Xe Nam Noy 5	55	188.2	RCU	S	572.3	3.9	20.0	124.0
Xe Kaman 4A	60	237.6	G	RoR	423.6	26.0	96.0	375.0
Xe Kaman 4B	61.4	231.6	G	RoR	459.1	18.4	74.0	301.0
Xekaman 3	99	467.4	RCU	S	477.3	62.5	250.0	982.8
Xe Kaman 2A	63.5	188.4	G	S	48.6	155.0	64.0	241.6
Xe Kaman 2B	85	294	G	RoR	78.8	90.0	100.0	380.5
Xekaman 1	110	186	C	S	99.0	336.6	240.0	1,096.0
Xekaman-Sanxay	28	180	G	Reg	12.2	378.0	32.0	123.0
Xe Xou	62.1	331	RE/RE	S	51.8	131.3	63.4	286.2
Nam Kong 1	86.9	386	C	S/BP	186.0	44.5	75.0	469.0
Nam Kong 2	72.1	265/214	RE/RE	S	106.5	76.5	70.0	309.5
Nam Kong 3	15	90		S	76.0	40.0	25.0	109.7
TOTAL							3,224.6	12,653.5

Operation	
Construction	
Planning	
Potential future	

Source: MRC hydropower database

There is little information about the Sekong HPP in Cambodia although it features on the Cambodian power development plan. A Vietnamese company has been carrying out feasibility studies. The location of the dam on the Sekong is not available, but has been approximated on the maps. It would be a run-of-river dam with 150 MW installed capacity and generating 550 GWh per year. The estimated reservoir area would be 6,600 ha with an active storage of 61 m. m^3.[11]

[11] Estimates from ADB RETA 7764 (2013) Hydropower database for SEA of GMS power development

Table 8-2: Hydrological characteristics of large hydropower projects on the Sekong

Dam name	Mainstream / Tributary	Catchment size	Mean monthly discharge	Spillway peak design flows	Draw down	Reservoir area	Gross storage volume	Active storage volume	People resettled
Sekong Basin	M / T	Sq.km	cu.m/sec	cu.m/sec	m	Sq.km	m.cu.m	m.cu.m	Numbers resettled
A Luoi HPP	M	292.0	11.6	3,034.0	0.5	N/A		1.2	N/A
Xe Kong 5	M	2,615.0	137.0	3,700.0	30.0	52.3		1,355.5	440.0
Xekong 4	M	5,400.0	205.0	16,950.0	20.0	170.3	10,500.0	3,100.0	4,458.0
Dak E Mule	T	127.0	16.1	1,917.0	24.0	8.2		154.0	0.0
Houay Lamphan Gnai	T	140.0	6.5	820.0	NA	6.8	141.0	122.0	1,030.0
Xe Kong 3up	M	5,882.0	240.3	15,685.0	5.0	21.6		95.1	1,080.0
Xe Kong 3d	M	9,700.0	316.4	24,960.0	6.0	36.3		168.4	240.0
Houayho	T	191.7	205.0	298.0	23.0	39.3		649.0	0.0
Xe Katam	T	263.0	9.1	640.0	20.0	7.8	126.0	121.0	265.0
Xepian-Xenamnoy	T	820.0	18.7	1,061.0	26.5	50.0	1,116.0	908.0	800.0
Xe Nam Noy 5	T	60.2	3.6	416.0	20.0	0.7		8.8	0.0
Xe Kaman 4A	T	265.0	10.2	2,500.0	20.0	1.2		16.5	0.0
Xe Kaman 4B	T	192.0	7.4	2,500.0	15.0	1.8		21.2	0.0
Xekaman 3	T	712.0	614.0	5,676.0	35.0	5.2	141.5	108.5	1,226.0
Xe Kaman 2A	T	1,970.0	77.5	3,640.0	5.0	0.8		3.7	0.0
Xe Kaman 2B	T	1,740.0	68.4	3,270.0	30.0	10.7		216.8	0.0
Xekaman 1	T	3,580.0	157.0	6,789.0	12.0	157.1		1,683.0	1,094.0
Xekaman-Sanxay	T	3,740.0	103.0	11,800.0	Reg	0.0		0.0	0.0
Xe Xou	T	1,273.0	77.2	2,214.0	NA	122.5		1,714.0	n/a
Nam Kong 1	T	1,250.0	42.0	9,530.0	33.0	21.8	679.0	505.0	0.0
Nam Kong 2	T	860.0	45.0	2,038.0	NA	8.6		139.6	0.0
Nam Kong 3	T	630.0	23.3		4.0	1.5	29.7	8.6	n/a
TOTAL						724.5		11,099.9	10,633.0

In addition to economic and financial indicators, such as the cost per MW installed, and the internal rate of return on investment, there are a number of other indicators that may be used to identify the more effective or least environmentally and socially damaging schemes. These are shown in Table 8-3 and explained below:

MW Installed/Reservoir area. This index has two uses: as an indicator of the effectiveness of inundation, it indicates the trade-off between hydropower and change in land use. A variation of this would be MW installed/agricultural land or forest land inundated. The higher the value of the index, the more effective the scheme.

Contribution to climate change: It has been used by the IPCC to assess the contribution of hydropower to greenhouse gas emissions in comparison to fossil fuels. If the index is more than 10, the performance of the scheme is considered good, if between five and 10, the scheme is moderate, but if below five, then the scheme needs to be more carefully assessed. It can be seen from the tables below, that there is considerable variation in this index for the 3S dams, with some of the run-of-river dams performing exceptionally well, but some of the larger storage dams being very low.

Population and resettlement indices: two other indices compare the numbers of people to be resettled with the installed capacity and the density of the population in the reservoir area. Again there is considerable variation in these indices between the dams in the 3S Basin. Obviously those that require little or no resettlement have good low scores on both of these counts, but some are much higher and should be viewed with concern, not least because of the much higher costs in economic and social terms to address resettlement.

Active storage indices:

- Active storage per MW installed index is a measure of the relative influence of the scheme on flows. The higher the index, the greater change in seasonal flow patterns in the river. The true run-of-river schemes have very low scores or even zero, with storage for at most a few days. However, this does not indicate the effect that any scheme has upon the daily changes in flow, which results from a peaking operation of the dam – operating for a few hours per day – at full discharge and reducing to base flows when the demand for electricity falls at night.
- Active storage/mean annual flow at the dam location is an indicator of the average length of time required at mean flow rates. The higher the value of the index, the longer it takes to fill the active storage.
- Active storage/mean annual flow at the mouth of the river is an indication of the contribution of the scheme to regulating the flow in the whole river. The higher the value of the index the greater the contribution to flow regulation in the river.
- Active storage/length of the river system is an indication of the contribution of the scheme to regulation in the overall river. This is also useful when combined with the distance of the scheme from the mouth of the river, or from the headwaters, since it can help to identify the length of river that will be isolated by the dam.
- Active storage/total storage capacity is an index of the size of the reservoir and its capacity to absorb sediment. When combined with sediment load trapping efficiency, this can give an indication of the length of life of the reservoir, before it fills with sediment

Catchment regulated:

- The percentage of the total catchment used by the scheme is an indicator of the contribution of the scheme to the overall regulation of the flows. The higher the percentage the greater the degree of regulation. Thus dams at the bottom end of the river, e.g. Lower Sesan 2 have a very high percentage, while those at the top of the river, or in the tributaries have low values. (In the tables below, the schemes that lie at the bottom end of rivers and major tributaries are shaded slightly, showing high values for the % catchment regulated)
- MW installed/% of catchment gives an indication of the effectiveness of energy generation in terms of the catchment regulated (or length of river). The higher the value the more effective the scheme.

Table 8-3: Calculated indices for the Sekong hydropower projects

Dam name	MW Installed/ Reservoir area	People resettled / MW installed	People resettled/ Reservoir area	Active storage / MW installed	Active storage/ mean annual flow at dam site	Active storage/ mean flow at mouth of river	Active storage/ length of river system	% of basin catchment regulated	MW installed/ % catchment regulated	% Active storage / total storage
Sekong Basin	MW/Sq km	No/MW	No/sq km	m. cu.m/MW	Mcu.m./ cu.m/sec	Mcu.m./ cu.m/sec x 1000	Mcu.m./km x 1000	%	MW/%	%
A Luoi	NA	NA	NA	1.9	0.10	1.18	2.29	1.01	61.19	NA
Xe Kong 5	7.6	1.1	8.4	338.9	9.89	1,358.22	2,632.04	9.07	44.08	NA
Xekong 4	3.5	7.4	26.2	516.7	15.12	3,106.21	6,019.42	18.74	32.02	29.52
Dak E Mule	15.9	0.0	0.0	118.5	9.57	154.31	299.03	0.44	295.01	NA
Houay Lamphan Gnai	12.8	11.9	151.5	140.7	18.77	122.24	236.89	0.49	178.48	86.52
Xe Kong 3up	6.7	7.5	50.0	65.8	0.40	95.28	184.64	20.41	7.08	NA
Xe Kong 3d	2.5	2.6	6.6	184.8	0.53	168.72	326.95	33.66	2.71	NA
Houayho	3.8	0.0	0.0	432.7	3.17	650.30	1,260.19	0.67	225.51	NA
Xe Katam	7.8	4.4	34.0	199.0	13.25	121.24	234.95	0.91	66.63	96.03
Xepian-Xenamnoy	7.8	2.1	16.0	232.8	48.58	909.82	1,763.11	2.85	137.07	81.36
Xe Nam Noy 5	28.6	0.0	0.0	44.0	2.42	8.82	17.09	0.21	95.75	NA
Xe Kaman 4A	80.0	0.0	0.0	17.2	1.63	16.53	32.04	0.92	104.40	NA
Xe Kaman 4B	41.1	0.0	0.0	28.6	2.88	21.24	41.17	0.67	111.08	NA
Xekaman 3	48.1	4.9	235.8	43.4	0.18	108.76	210.76	2.47	101.19	76.71
Xe Kaman 2A	80.0	0.0	0.0	5.8	0.05	3.71	7.18	6.84	9.36	NA
Xe Kaman 2B	9.3	0.0	0.0	216.8	3.17	217.23	420.97	6.04	16.56	NA
Xekaman 1	1.5	4.6	7.0	701.3	10.72	1,686.37	3,267.96	12.42	19.32	NA
Xekaman-Sanxay	0.0	0.0	0.0	0.0	0.00	0.00	0.00	12.98	2.47	NA
Xe Xou	0.5	NA	NA	2,703.9	22.20	1,717.43	3,328.16	4.42	14.35	NA
Nam Kong 1	3.4	0.0	0.0	673.3	12.02	506.01	980.58	4.34	17.29	74.37
Nam Kong 2	8.1	0.0	0.0	199.4	3.10	139.88	271.07	2.98	23.46	NA
Nam Kong 3	16.3	0.0	NA	34.6	0.37	8.66	16.78	2.19	11.44	29.09

Source: ADB (2010) 3S River Basins development study.Technical sheets No 8a: Large-scale infrastructure in the 3S - Hydropower

In addition to these dams listed above there are three other smaller hydropower projects in the planning stages for the Sekong Basin:

1. The Upper Xekhampho HPP is designed as a run-of-river project consisting of a number of open lined canals, small dams and weirs located on the edge of the Bolevan Plateau. The project will have no reservoirs/storage capacity. The powerhouse, located at the base of the Bolevan Plateau has a proposed installed generating capacity of 21 MW. The powerhouse is expected to operate at full capacity during the wet season and reduced capacity during the dry season.[12]
2. Nam Ang/Nam Ngon HPP would have intakes on both these streams at about 850 masl and pipe them to a power house at 286 masl about 1 km from the reservoir of Se Kamman 1 HPP. With a gross head of about 500 m, the installed capacity may be between 4 – 7 MW generating 30 – 40 GWh per year for local electrification.
3. Nam Pouang HPP is also located on a small stream feeding into the Se Kamman River in Attapeu. Several alternatives for the powerhouse are under consideration with the best option having a gross head of 112 m and an installed capacity of 5MW.[13]

8.2 Irrigation

There are a number of small irrigation schemes as shown in Figure 8-1. For Lao PDR, the total irrigated area in the wet season is 3,605 ha and 2,743 ha in dry season. In Attapeu Province, raw water is lifted by pumps installed on pontoons along the Sekong, Se Kamman, Se Pian and Se Sou Rivers. In total, 19 irrigation schemes have been established servicing 2,060 hectares with a water volume of about 42 million m^3/year. In Sekong province, 383 irrigation schemes are reported but most of them (361) are only traditional weirs for water diversion of rainy season flow. Storage capacity remains very low.

In Cambodia, there are a total of 82 irrigation schemes listed in the lower 3Ss Basin. Eight schemes are located in the Sekong Basin, 39 in Sesan and 35 in Sre Pok. Of these, only eight are functional and operational. Of 56,418 ha of wet season rice land, only 10% could receive irrigation water from the existing operational systems in the wet season and approximately 1% in the dry season. The 82 schemes, if running, would have the potential to irrigate 2,803 ha in the dry season and 14,878 ha in the wet season, although only 520 ha are, in fact, irrigated in the dry season. Most irrigation schemes are small-scale schemes able to irrigate an average of 180 ha. Only three schemes have a potential to irrigate more than 1,000 ha. Most schemes were built and used for providing supplementary irrigation water to the wet season crop production. All schemes use water from small reservoirs filled with rainfall during the rainy season. Those reservoirs have very limited capacity for providing water during the dry season.[14]

[12] Information note from Earth Systems Consulting Ltd. for Norconsult Ltd.
[13] ADB 2012. Small and mini hydroelectric development project. Final report.
[14] ADB (2010) 3S Rivers Basins development study: 3S Technical sheets No 8b Large-scale infrastructure in the 3S – Irrigation.

9 Changing flows

9.1 Degree of regulation of the river with all hydropower

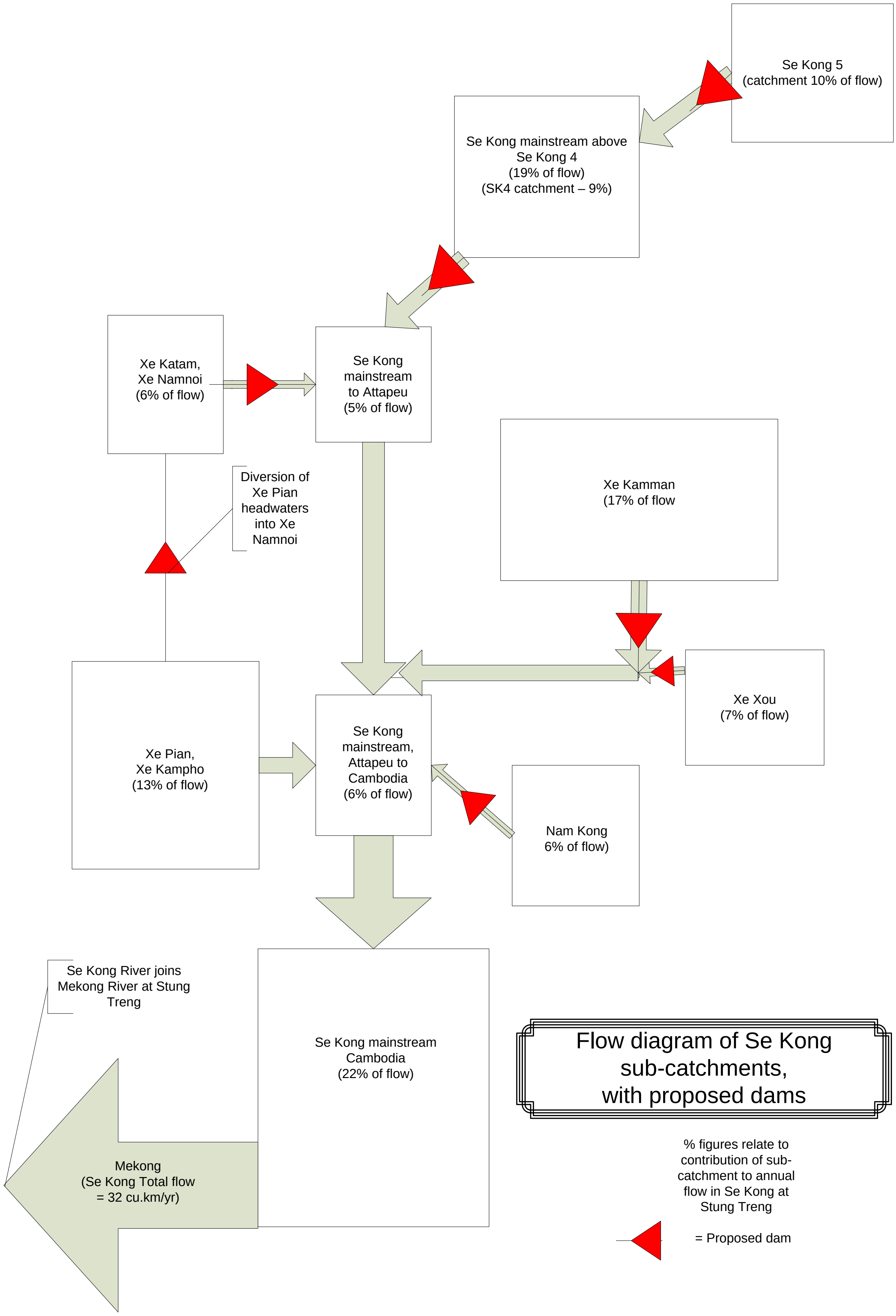
When all the proposed dams are constructed on the Sekong, the storage capacity in the reservoirs will have an impact upon the hydrology of the river. Table 9-1 shows the total active storage of proposed dams on the 3S Rivers and the proportion of the total annual flow. This shows that the Sekong would be the most regulated of the three rivers with the active storage capacity amounting to nearly 40% of the total annual flow in the river.

Table 9-1: Active storage of proposed dams on the 3S Rivers

	Sekong	Sesan	Sre Pok	Total	Mekong at Kratie
Mean annual discharge (cu.m./sec)	998	610	1,014	**2,622**	13,000
Mean Annual total (m. cu.m.)	32,000	19,500	32,500	**84,000**	467,000
Reservoir Active Storage capacity (m.cu.m)	12,543	2,925	10,389	**25,857**	
% of annual total	39.2	15.0	32.0	**30.8**	5.5

Source: ADB (2010) 3S Rivers Basins development study: 3S Technical sheets No 8a Large scale infrastructure in the 3S - Hydropower

Figure 9-1: Flow diagram of main Sekong sub-catchments with proposed dams



Source: P.J.Meynell. 2007 EIA for Sekong 4 Hydropower project

Figure 9-1 shows a diagram of the contributions that each of the sub-catchments makes to the flow in the Sekong and the locations of some of the main proposed dams. It was produced for an environmental impact assessment (EIA) of the Sekong 4 dam and is not comprehensive of all the proposed dams. However, it does provide the basis for a flow model of the river.

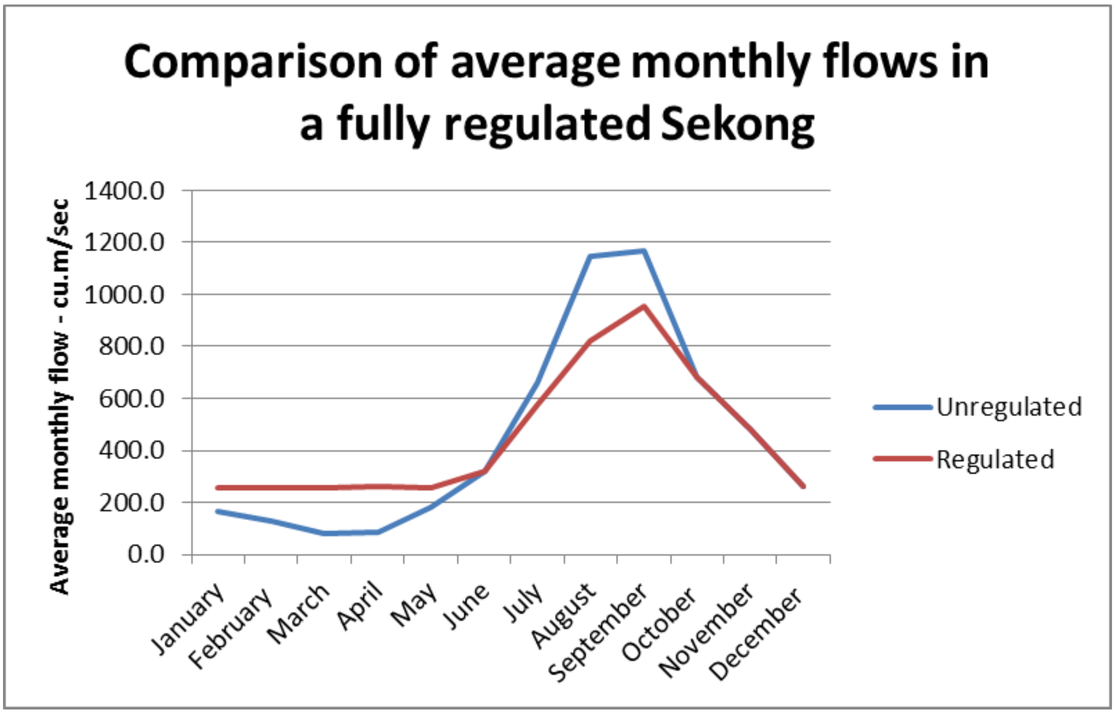
Storage dams are designed to collect water during the wet season for more regulated release during the dry season. So-called run-of-river dams store water for much shorter periods, i.e. a few days or weeks, and their reservoirs are much smaller and provide a balancing of the daily fluctuation in flows, enabling peak generation capacity, i.e. generating at times of peak demand in electricity.

The implication of storage capacity of nearly 40% on the Sekong means that the wet season flow would be substantially decreased and the dry season flows would be higher and more evenly balanced. Using the Flow Health model, a simulated hydrograph of the flows at Attapeu has been modeled by increasing the monthly average dry season flows and decreasing the peaks of the wet season flows. This is used to illustrate the flow implications of a regulated river. The comparison between the unregulated flows with the regulated flows at Attapeu is shown in Figure 9-2.

The table associated with Figure 9-2 shows that the lowest dry season flows in March and April are set to increase by over 200%, while there are increases in average flows in January and February of 56% and 98%, and of 41% in May. The wet season peaks are simulated to be reduced by up to nearly 30% in August, with smaller reductions in July and September.

As has already been shown, average monthly flows do not reflect the peak daily flows that may occur during storm events. The reduction in peak monthly flows may help to manage the flood flows over dams, provided that there is enough spare storage capacity in the reservoirs. If a storm occurs when the reservoir is full, spillways would have to be operated in an emergency situation and this could exacerbate the flood condition.

Figure 9-2: Comparison of average monthly flows between unregulated and regulated conditions



Source: Simulations using Flow Health model

	Unregulated	Regulated	Change %
	cu.m/sec	cu.m/sec	
January	163.3	255.6	56.5
February	127.7	253.6	98.6
March	81.0	257.3	217.5
April	83.1	259.4	212.2
May	180.7	256.2	41.8
June	320.7	320.7	0.0
July	659.8	575.8	-12.7
August	1148.0	820.6	-28.5
September	1166.9	957.0	-18.0
October	683.3	683.3	0.0
November	481.7	481.7	0.0
December	262.9	262.9	0.0

9.2 Application of Flow Health model

The Flow Health model is a publicly accessible application to assist in the assessment, design and management of river flow regimes. Its main purpose is to provide an annual score for hydrology in river health assessment, but it can also be used as a tool to assist environmental flow assessment.

Flow Health has four main functions:

1. To provide an annual score for the hydrology indicator in river health assessment

Flow Health analyses a time series of river flow or water level data based on a comparison with a reference flow series (such as data collected prior to regulation, or a modelled natural flow series). For each year of the test data being analysed, Flow Health calculates scores for nine pre-defined ecologically relevant hydrological sub-indicators, which when given a value are called flow metrics. A score of one is close to reference and a score of 0 is distant from reference. The nine metric scores are also combined to form an overall Flow Health score for each year of record. The results are displayed in a number of different graphical forms.

2. To recommend a minimum monthly environmental flow regime

Flow Health automatically produces the minimum monthly flow regime that achieves a score of one for all flow metrics. This regime follows the natural pattern of the reference flows, and requires a fairly high percentage of the natural flow. Using simple slider controls, users can interactively reduce the score of some or all of the flow metrics to tailor a monthly regime that uses less water and achieves an acceptable Flow Health score.

3. To test the hydrological health of any monthly environmental flow regime

Flow Health can be used interactively to design a monthly flow regime. The monthly flows can be simply set as a proportion of the reference flow, or users can choose any value for the flow in each month. As the user interactively adjusts the monthly flow regime using simple slider controls, the volume of water required, and the flow metrics are continuously updated and displayed.

4. To generate a synthetic monthly flow time series based on the designed environmental flow regime

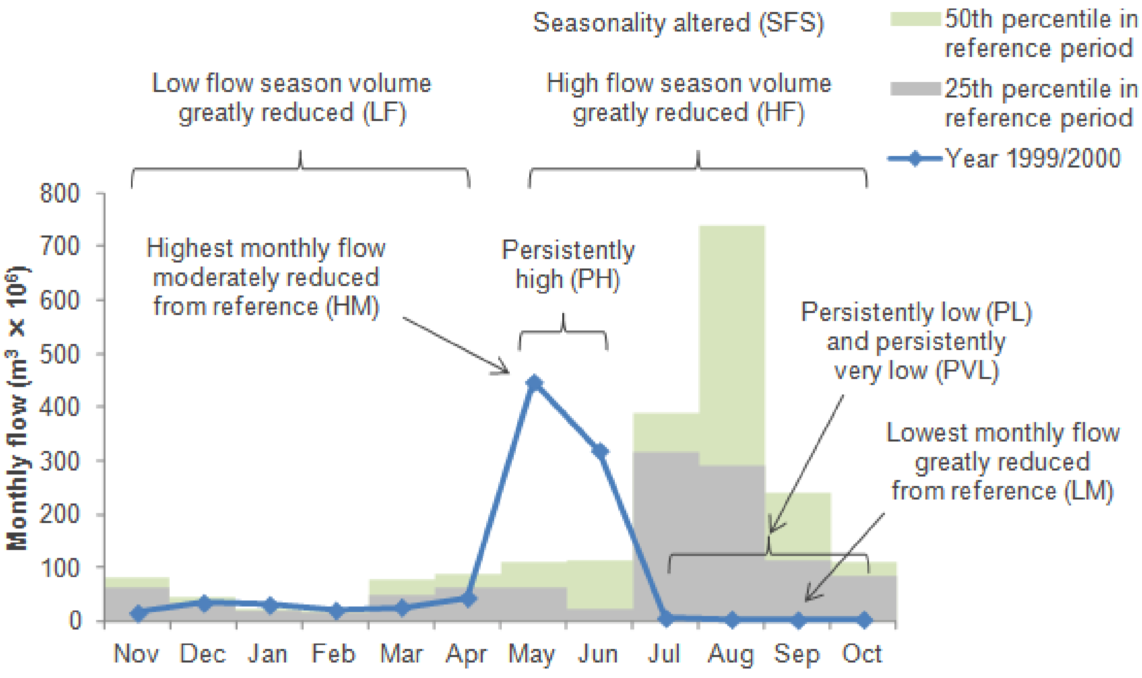
After designing a potential monthly environmental flow regime, a time series of monthly flow data can be generated that has the characteristics of that regime. This can be a simple repeating series, or one that is based on the pattern of flows that occurred during the reference period. These synthetic data series can then be substituted in the analysis as the reference or test flow series, and the Flow Health scores recalculated.

The sub-indicators used in Flow Health were devised on the basis of their ecological relevance, and because they characterise the way river flows are usually affected by regulation (from dams and/or diversions).As well as metric scores, Flow Health provides basic statistics that describe the data, such as the global flow class, mean annual flow, mean monthly flows, flow percentiles, and shortfalls in the environmental flow regime compared to the reference flow regime.

Quoted from: Gippel, C.J., Marsh, N. and Grice, T. 2012. *Flow Health - Software to assess the deviation of river flows from reference and to design a monthly environmental flow regime. Technical Manual and User Guide,* Version 2.0. ACEDP Australia-China Environment Development Partnership, River Health and Environmental Flow in China. International WaterCentre, Brisbane, Fluvial Systems Pty Ltd, Stockton, and Yorb Pty Ltd, Brisbane, September.

Flow Health uses nine sub-indicators as illustrated in the diagram below: High Flow (HF), Low Flow (LF), Highest Monthly (HM), Lowest Monthly (LM), Persistently Higher (PH), Persistently Lower (PL), Persistently Very Low (PVL), Seasonality Flow Shift (SFS) and Flood Flow Interval (FFI). The metric of each Flow Health sub-indicator characterises the degree of deviation in a specific aspect of the flow regime that is conceptually linked to ecological health (Figure 9-3).

Figure 9-3: River hydrograph illustrating the nine sub-indicators used by Flow Health[15]



The ecosystem significance of the HFand LF sub-indicators is that the total seasonal volume will reflect the prevailing hydrological conditions (in particular, highlighting very dry years) and also indicate any major reductions in total flow volume (and hence gross habitat area availability) due to flow regulation. Significant regulation impacts would tend to be characterised by a sustained reduction in HF, perhaps also with a sustained reduction in LF.

The ecosystem significance of the HM sub-indicator relates to the magnitude of flood flows which are critical for inundating wetlands, cuing fish spawning behaviour, facilitating fish migration and mobilising sediment for creation of physical habitat. The ecosystem significance of the LM sub-indicator is related to the magnitude of the lowest flow of the year, when minimum flows are required for survival. HM and LM are not determined for the high flow and low flow seasons respectively, but for the entire year. This is because the occurrence of a month of very low flow can be problematic for the biota at any time of the year, and a significant flood or flow pulse event (associated with the month of highest flow) can be beneficial to the biota at any time of year. Also, in regulated rivers, the month of lowest flow could occur in the natural high flow season. It is recognised that the benefit of a flow pulse may be greater in certain months, and in some months a pulse might have a negative impact on the biota. If the highest flow month is aseasonal in the reporting year, this will be detected by the HF, LF, and SFS sub-indicators.

The ecosystem significance of the PH sub-indicator relates to the situation of flows being artificially regulated at significantly higher than reference magnitude for long periods through the natural low flow period. This can reduce light penetration to the bed, and hence reduce primary production of benthic algae. Persistently elevated low flows might also mean that invertebrates are not seasonally stressed, which could be a natural disturbance process that plays a role in maintaining diversity. Higher than normal flows in the low flow period can also stressriparian vegetation by waterlogging root zones, or

[15]Figure shows a comparison of monthly flows for water year 1999/2000 at Liaoyang on the Taizi River, China with reference period median monthly flows and 25th percentile monthly flows

preventing recruitment in exposed soils. In some places this may hinder recruitment of fish species dependent on slackwaters and warm temperatures associated with low flows.

The ecosystem significance of the PL sub-indicator relates to the situation of flows, either in the low or high flow season, being depressed for long periods. This sub-indicator would usually indicate persistently depressed low flow season flows, which would have implications for gross habitat area availability for fish and macroinvertebrates. This flow condition would potentially allow colonisation of the stream bed by invasive vegetation, or accumulation of fine sediments that settle out during periods of low flow.

The ecosystem significance of the PVL sub-indicator relates to the situation of flows being artificially regulated at very low levels for long periods. The consequences of this drying or near-drying of the channel can be critical for all organisms in the stream. Very low flows are often associated with the loss of riffle habitats, crowding of organisms in pools, and degraded water quality, such as temperature extremes and increased risk of hypoxia and high salinity.

The ecosystem significance of the SFS sub-indicator relates to the situation of the seasonal pattern of flows being reversed, or partly reversed, due to storage of flows in reservoirs in the natural high flow season, and release of water for downstream supply in the natural low flow season. The consequences of this can be disruption of the natural timing of flow pulses and baseflows that stimulates the behaviour of aquatic organisms whose life cycle has adapted to a particular seasonal pattern of flow.

The ecosystem significance of the FFI sub-indicator mainly relates to the occurrence of floods that inundate floodplain wetlands. In some rivers such floods might also play an important role in scouring hardy plants from channels and re-shaping channel morphology. During the interval between floods, wetlands can dry out, riparian vegetation can become stressed, succession processes give rise to changes in the composition of floodplain plant communities, plants that rely on regular floods for seed dispersal and propagation do not regenerate, and channels can become overgrown due to lack of disturbance.[16]

When the Flow Health model is used to simulate shifts in the hydrology of the Sekong due to water storage during the wet season and release in the dry season due to regulation by hydropower projects, Table 9-2, the following changes in the sub-indicators can be appreciated between the regulated and unregulated (natural) state. The unregulated values for the indices are based upon the reference flows at Attapeu between 1989 and 2005. The regulated values are calculated from the simulated hydrograph assuming a significant degree of regulation by the storage dams.

Table 9-2: Changes in the Flow Health sub-indicators between regulated and unregulated flows at Attapeu

Sub-indicators	Unregulated	Regulated	% Change
Flow health score (FH)	0.875	0.68	-22.1
High flow (HF)	1	1.00	0.0
Highest monthly (HM)	1	0.62	-38.4
Low flow (LF)	1	0.82	-18.5
Lowest monthly (LM)	1	0.75	-25.0
Persistently higher (PH)	1	0.20	-80.0
Persistently lower (PL)	1	1.00	0.0
Persistently very low (PVL)	1	1.00	0.0
Seasonality flow shift (SFS)	1	0.92	-7.7
Flood flow interval (FFI)	0	0.00	0.0

In order to explain these changes:

[16] Gippel, C.J., Marsh, N. and Grice, T. 2012. Flow Health - Software to assess the deviation of river flows from reference and to design a monthly environmental flow regime. Technical Manual and User Guide.

1. High Flows: There is no change in the overall volume of water flowing in the river during the high flow season, which is why the HF indicator is 1 for both regulated and unregulated. This would imply that there would be no major change in the overall wetted habitat availability.
2. Highest Monthly Flow: The HM indicator is reduced from 1 to 0.62 because the highest monthly flow in August is significantly reduced. This means that there may be changes due to reduced flood for inundating riparian wetlands, lowered cues for fish spawning behaviours, and lowered ability to mobilise downstream sediment for creation of physical habitat.
3. Low Flow: the LF indicator is changed from 1 to 0.82, because the volume of water discharged during the low flow season is significantly increased compared to the reference flows. The implication of this is that there may be habitats and associated flora and fauna in the river channel that depend upon a season of exposure, that will permanently under water under the regulated flows.
4. Lowest Monthly Flow: the LM indicator is changed from 1 to 0.75, because the lowest flows simulated for March/April will be significantly higher than the reference. The implications of this indicator change may be similar to the LF indicator, in that habitats that depend upon a season of low flow, may be threatened or reduced in extent.
5. Persistently High Flows: The PH is changed dramatically from 1 to 0.2 reflecting the overall increase in flows during the low flow season e.g. by 2 or 3 x the natural flow in March/April. This can have implications for habitats, flora and fauna that rely upon low flows during the dry season, e.g. for the productivity of the deep pools.
6. Persistently Low Flows: the PL is unchanged reflecting the fact that the regulated flows never fall below the reference low flows.
7. Persistently Very Low Flows: the PVL is also unchanged for the same reasons as PL. In fact PVL is less relevant to rivers in which there is unlikely to be abstraction of water during the dry season.
8. Seasonality Flow Shift: the SFS is slightly shifted with the peak of the wet season flows moved a week or two later in the year as the reservoirs fill up. There is also a less clear transition 1 period between dry and wet seasons, because the rainfall that might have caused the increased flows at the beginning of the wet season will now be trapped within the reservoirs, and not passed on until the storage is complete. The implication of this is the disruption of flow pulses and baseflows that stimulate behaviour of aquatic organisms, especially migration and spawning.
9. The Flood Flow Interval: the FFI does not change.

Overall the Flow Health index which is a composite of all the nine indicators, reduces from a natural level of 0.875 to 0.68, an overall reduction of 22% of the regulated flows compared to unregulated. Following the above analysis the key components of the flow regime to be considered for the Sekong would be:

- The reduction in peak flows which will affect the geomorphology of the river, especially in channels that are not rock-confined, and the distribution of sediments. The confluences with the tributaries are areas to watch for changes in sediment build up if peak flows no longer transport these sediments desposited at the confluences.
- The increase in dry season flows and water levels which will change the aquatic habitats in the channel that depend upon seasonal exposure. Such habitats are likely to decrease in area.
- Changing seasonality of flood pulse and transitions from dry to wet season, which may be important triggers for fish migration and spawning.
- The changing daily flows and water levels resulting from peak load generating operations of hydropower may be locally significant downstream of certain dams, but are not considered here.

10 Conclusion

The aim of this sourcebook is to provide information about the ecological character of the Sekong River and its tributaries in an ordered way so that further studies and consultations may be carried out considering a more integrated flow management of the river, as hydropower and increased storage and regulation of the river is being planned.

This sourcebook does not draw any conclusions about the impacts of changing flow regimes, although it does highlight the aspects that are most important for the health of the river. In developing any flow management regimes it must be recognised that the people living in communities adjacent to the river are an important group of stakeholders whose livelihoods depend upon the river and its natural resources.

Annex 1: Data sources

Dataset	Description	Coordinate System	Data Sources	Source Agency
Streams	Steams/rivers in Sekong basin	UTM Zone 48, Indian 1960	Stream dataset digitizing from topographic map 1:50,000; Update with stream order in 2009	MRC/Technical Support Division - The master catalogue
Sub-catchments	Sub-catchment boundary within Sekong basin	UTM Zone 48, Indian 1960	Topographic maps 1:50000 (Cambodia, Lao PDR, Viet Nam) - 2000	MRC/Technical Support Division - The master catalogue
SWAT sub-catchment	Sub-catchments within Sekong basin generated using SWAT model (done by Modeling Team/WUP)	UTM Zone 48, Indian 1960	DEM cell resolution 50m (2000)	MRC/Technical Support Division -Modeling team
Land use/landcover	Land use/ Land cover in Sekong basin	UTM Zone 48, Indian 1960	Cambodia: Ministry of Public Works and Transportation; statistical data 2003 Lao PDR: Department of Geography 2003 Viet Nam: Ministry of Agriculture and Rural Development, and National Institute of Agriculture and Planning Projection 2000	MRC/Agriculture Programme
Elevation	Elevation of Sekong basin (cell resolution 50m.)	UTM Zone 48, Indian 1954	Topographic maps 1:50000 (Cambodia, Lao PDR, Viet Nam)	MRC/Technical Support Division - The master catalogue
Slope	Slope classes in Sekong basin (FAO slope classification)	UTM Zone 48, Indian 1954	Topographic maps 1:50000 (Cambodia, Lao PDR, Viet Nam)	MRC/Technical Support Division - The master catalogue
WWF ecozone	WWF ecological zone	UTM Zone 48, Indian 1960	?	WWF
	Geology categories of Sekong basin	UTM Zone 48	Unknown	MRC/Technical Support Division - Old data
Soil types	Soil types of Sekong basin- adopted FAO/UNESCO Classification system	UTM Zone 48, Indian 1960	Data was complied in 2001. Cambodian Agriculture Soil Unit (ASU), Department of Planning, MAF; Lao Soil Survey and Land Classification Centre (SSLCC), MAF; Thai Soil Survey and Classification Division, Land Development Dept., Ministry of Agriculture and Cooperatives; Vietnam Integrated Resources Mapping Center (IRMC), Sub-national Institute of Agricultural Planning (Sub-NIAPP)	MRC/Technical Support Division - The master catalogue
Protected area (PA)	Protected area of Sekong basin	UTM Zone 48, Indian 1960		MRC/Technical Support Division - The master catalogue
	KBAs of Sekong basin	UTM Zone 48	KBA data of Cambodia, Lao PDR, Viet Nam	https://www.ibat-alliance.org/ibat-conservation
Mean annual rainfall	Mean annual rainfall (1985-2000)	UTM Zone 48, Indian 1960	DSF Knowledge Base/MRC	MRC/Technical Support Division - DSF Knowledge Base
Mean annual temperatur	Mean annual temperature (1985-2000)	UTM Zone 48, Indian 1960	DSF Knowledge Base/MRC	MRC/Technical Support Division - DSF Knowledge Base
Hydropower projects	Location of hydropower projects in Sekong basin	UTM Zone 48, Indian 1960	Data dated 2008	MRC/Technical Support Division - The master catalogue
Irrigation projects	Irrigation projects in Sekong basin as of 2000	UTM Zone 48, Indian 1960	Cambodia: 1:50000 Topographic maps; Lao PDR: 1:100000 Topomaps and Spot Images 2000; Viet Nam: 1:100000 Topomaps with supplementary information from Sub Institute of Water Resource Planning	MRC/Technical Support Division - The master catalogue
Fish conservation zones	Fish conservation zones and deep pools	UTM Zone 48, Indian 1960	?	WWF Greater Mekong, Lao office

Annex 2: Fish species of the Sekong, Sesan and Sre Pok Rivers

Source: Baran, E. (2013)

Species	Sekong	Sesan	Sre Pok
Aaptosyax grypus		1	
Acanthopsoides delphax		1	1
Acanthopsoides gracilentus	1		1
Acanthopsoides gracilis	1		
Acanthopsoides hapalias	1	1	
Achiroides leucorhynchos			1
Achiroides melanorhynchus			1
Akysis ephippifer	1		1
Akysis varius	1		
Albulichthys albuloides			1
Amblyceps serratum	1	1	
Amblyrhynchichthys truncatus	1		1
Anabas testudineus	1	1	1
Anguilla marmorata	1		1
Annamia normani	1		1
Auriglobus nefastus	1		
Bagarius bagarius			1
Bagarius suchus			1
Bagarius yarrelli	1	1	1
Bagrichthys macracanthus	1	1	1
Bagrichthys macropterus	1	1	
Bagrichthys obscurus	1		1
Balitora annamitica	1	1	1
Bangana behri	1	1	1
Bangana pierrei	1		
Barbichthys laevis			1
Barbonymus altus	1	1	1
Barbonymus gonionotus			1
Barbonymus schwanenfeldii	1	1	1
Belodontichthys truncatus	1	1	1
Betta splendens			1
Boesemania microlepis	1		
Brachirus harmandi	1		1
Brachirus orientalis			1
Carinotetraodon lorteti			1
Catlocarpio siamensis	1		
Channa gachua	1	1	1
Channa lucius			1
Channa marulia	1		
Channa marulioides			1
Channa micropeltes	1	1	1
Channa orientalis	1	1	1
Channa striata	1	1	1
Chitala blanci	1	1	1
Chitala lopis			1
Chitala ornata	1	1	1
Cirrhinus cirrhosus			1
Cirrhinus jullieni	1	1	1
Cirrhinus microlepis	1	1	1
Cirrhinus molitorella	1	1	1
Clarias batrachus		1	1
Clarias fuscus	1		
Clarias gariepinus			1
Clarias macrocephalus			1
Clarias meladerma			1
Clupeichthys aesarnensis	1		
Clupisoma sinense		1	1

Species	Sekong	Sesan	Sre Pok
Coilia lindmani			1
Coilia macrognathos			1
Corica laciniata			1
Corica soborna			1
Cosmochilus harmandi	1	1	1
Crossocheilus atrilimes	1	1	1
Crossocheilus oblongus	1	1	
Crossocheilus reticulatus	1	1	1
Ctenopharyngodon idella			1
Cyclocheilichthys apogon	1		1
Cyclocheilichthys armatus	1	1	1
Cyclocheilichthys enoplus	1	1	1
Cyclocheilichthys furcatus			1
Cyclocheilichthys heteronema			1
Cyclocheilichthys lagleri			1
Cyclocheilichthys repasson	1	1	1
Cynoglossus feldmanni			1
Cynoglossus microlepis			1
Cyprinus carpio carpio			1
Dasyatis laosensis	1	1	1
Datnioides polota			1
Datnioides undecimradiatus	1	1	1
Dermogenys pusilla			1
Devario acrostomus			1
Devario gibber	1		1
Devario leptos			1
Devario salmonata	1		
Discherodontus ashmeadi	1	1	1
Doryichthys contiguus	1		
Epalzeorhynchos frenatus	1		
Esomus danricus			1
Esomus metallicus	1	1	
Garra cambodgiensis	1	1	1
Garra fasciacauda	1		1
Garra fuliginosa			1
Glossogobius aureus	1		
Glyptothorax filicatus	1		
Glyptothorax fuscus		1	1
Glyptothorax lampris	1		1
Glyptothorax laosensis	1	1	1
Gyrinocheilus aymonieri	1		1
Gyrinocheilus pennocki	1	1	1
Hampala dispar	1	1	1
Hampala macrolepidota	1	1	1
Helicophagus waandersii	1	1	1
Hemibagrus filamentus	1	1	1
Hemibagrus guttatus			1
Hemibagrus microphthalmus	1		
Hemibagrus nemurus	1	1	
Hemibagrus spilopterus	1	1	1
Hemibagrus wyckii	1	1	1
Hemibagrus wyckioides	1	1	1
Hemimyzon khonensis	1		
Hemimyzon papilio			1
Hemisilurus mekongensis			1
Henicorhynchus lineatus	1	1	
Henicorhynchus lobatus	1	1	1
Henicorhynchus ornatipinnis			1
Henicorhynchus siamensis	1	1	1
Himantura chaophraya	1		1
Himantura imbricata			1
Himantura krempfi			1
Homaloptera confuzona	1	1	

Species	Sekong	Sesan	Sre Pok
Homaloptera leonardi		1	
Homaloptera orthogoniata	1		
Homaloptera smithi	1	1	
Homaloptera tweediei	1		
Homaloptera yunnanensis	1		
Homaloptera zollingeri	1		
Hypophthalmichthys molitrix			1
Hypophthalmichthys nobilis			1
Hyporhamphus limbatus			1
Hypsibarbus lagleri	1	1	1
Hypsibarbus malcolmi	1	1	1
Hypsibarbus pierrei			1
Hypsibarbus suvattii			1
Hypsibarbus wetmorei	1	1	1
Kryptopterus bicirrhis	1	1	
Kryptopterus cheveyi			1
Kryptopterus cryptopterus	1	1	1
Kryptopterus limpok	1		
Labeo chrysophekadion	1		1
Labeo dyocheilus	1		1
Labeo erythropterus		1	
Labeo rohita			1
Labiobarbus leptocheilus	1	1	
Labiobarbus lineatus		1	
Labiobarbus siamensis			1
Laides longibarbis	1		1
Lepidocephalichthys berdmorei		1	1
Lepidocephalichthys hasselti	1	1	1
Leptobarbus hoevenii	1	1	1
Lobocheilos melanotaenia	1	1	1
Lobocheilos rhabdoura	1		1
Luciocyprinus striolatus	1		
Luciosoma bleekeri	1	1	1
Luciosoma setigerum	1		
Lycothrissa crocodilus			1
Macrochirichthys macrochirus	1	1	1
Macrognathus circumcinctus			1
Macrognathus maculatus			1
Macrognathus semiocellatus	1		1
Macrognathus siamensis	1	1	1
Macrognathus taeniagaster		1	1
Mastacembelus armatus	1	1	1
Mastacembelus erythrotaenia			1
Mastacembelus favus	1		
Mekongina erythrospila	1	1	1
Misgurnus anguillicaudatus		1	1
Monopterus albus	1	1	1
Mystacoleucus atridorsalis	1		
Mystacoleucus chilopterus			1
Mystacoleucus marginatus	1		
Mystus albolineatus			1
Mystus atrifasciatus	1		1
Mystus bocourti			1
Mystus gulio			1
Mystus multiradiatus			1
Mystus mysticetus			1
Mystus singaringan	1	1	1
Mystus wolffii			1
Nemacheilus longistriatus	1	1	
Nemacheilus pallidus		1	1
Nemacheilus platiceps	1	1	1
Neolissochilus stracheyi	1		1
Notopterus notopterus	1	1	1

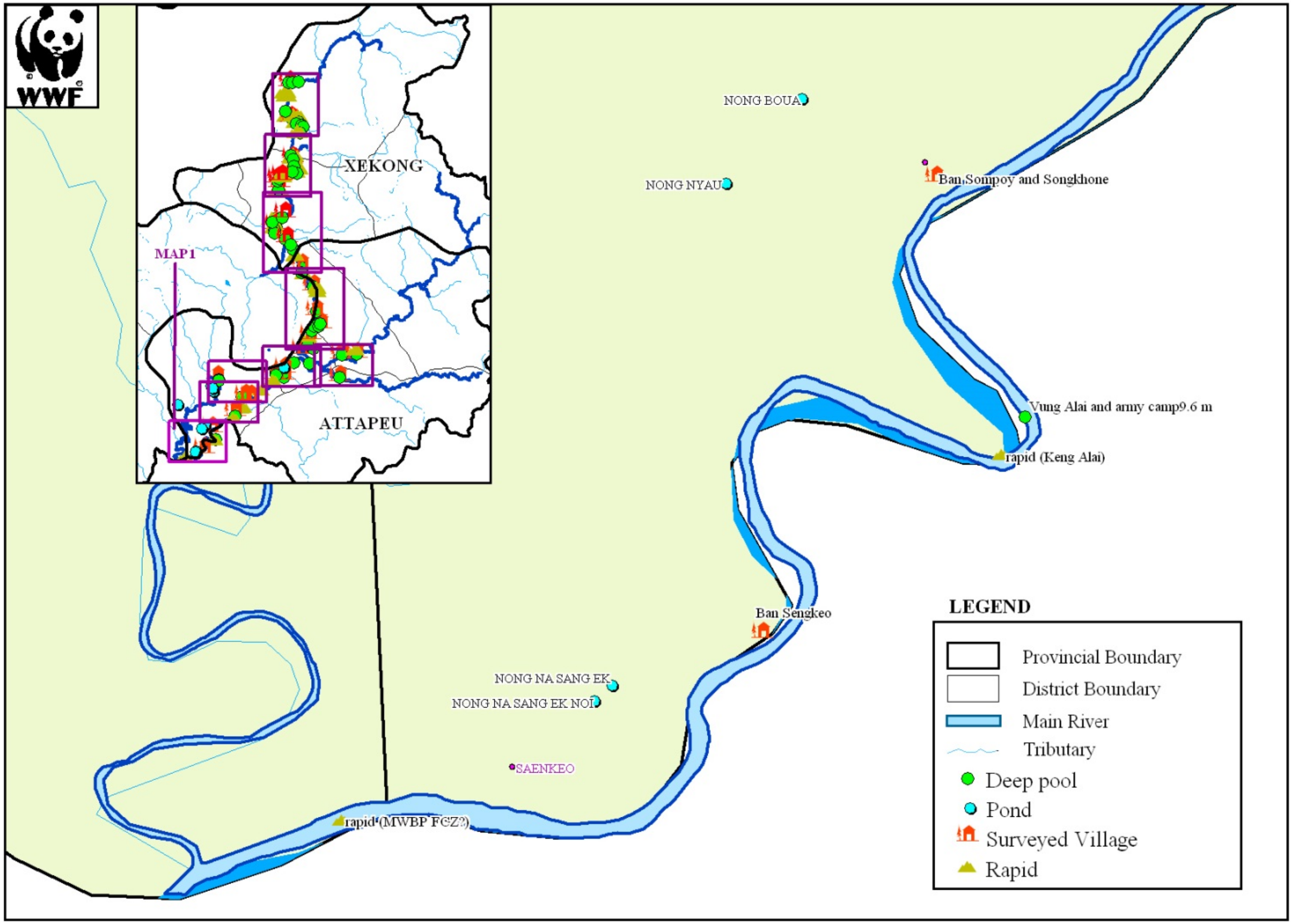
Species	Sekong	Sesan	Sre Pok
Ompok bimaculatus	1	1	1
Onychostoma meridionale	1		
Ophisternon bengalense			1
Opsarius koratensis	1	1	
Opsarius pulchellus	1	1	1
Oreochromis mossambicus			1
Oreochromis niloticus niloticus			1
Osphronemus exodon	1	1	1
Osphronemus goramy			1
Osteochilus lini	1		1
Osteochilus melanopleurus	1	1	1
Osteochilus microcephalus	1	1	1
Osteochilus schlegelii			1
Osteochilus vittatus	1	1	1
Osteochilus waandersii	1	1	1
Oxyeleotris marmorata	1		1
Pangasianodon gigas			1
Pangasianodon hypophthalmus	1	1	1
Pangasius bocourti	1	1	1
Pangasius conchophilus	1	1	1
Pangasius djambal			1
Pangasius krempfi	1	1	1
Pangasius kunyit			1
Pangasius larnaudii	1	1	1
Pangasius macronema	1	1	1
Pangasius mekongensis			1
Pangasius polyuranodon			1
Pangio anguillaris	1	1	1
Pangio fusca		1	
Pangio oblonga		1	1
Papuligobius ocellatus	1	1	1
Parachela maculicauda	1		
Parachela siamensis	1		
Paralaubuca barroni	1		1
Paralaubuca harmandi			1
Paralaubuca riveroi	1		1
Paralaubuca typus	1	1	1
Parambassis apogonoides			1
Parambassis siamensis	1	1	1
Parambassis wolffii	1		1
Phalacronotus apogon	1		1
Phalacronotus bleekeri	1	1	1
Phalacronotus micronemus	1	1	
Polynemus dubius			1
Poropuntius bolovenensis	1		1
Poropuntius consternans	1		
Poropuntius deauratus	1	1	
Poropuntius laoensis			1
Poropuntius lobocheiloides	1		
Poropuntius normani	1		1
Pristolepis fasciata	1	1	1
Probarbus jullieni	1	1	1
Probarbus labeamajor	1	1	1
Probarbus labeaminor			1
Pseudobagarius inermis	1		
Pseudolais micronemus			1
Pseudolais pleurotaenia	1	1	1
Pseudomystus siamensis	1	1	1
Pseudomystus stenomus	1		
Puntioplites bulu			1
Puntioplites falcifer	1	1	1
Puntioplites proctozystron	1		1
Puntius aurotaeniatus	1	1	

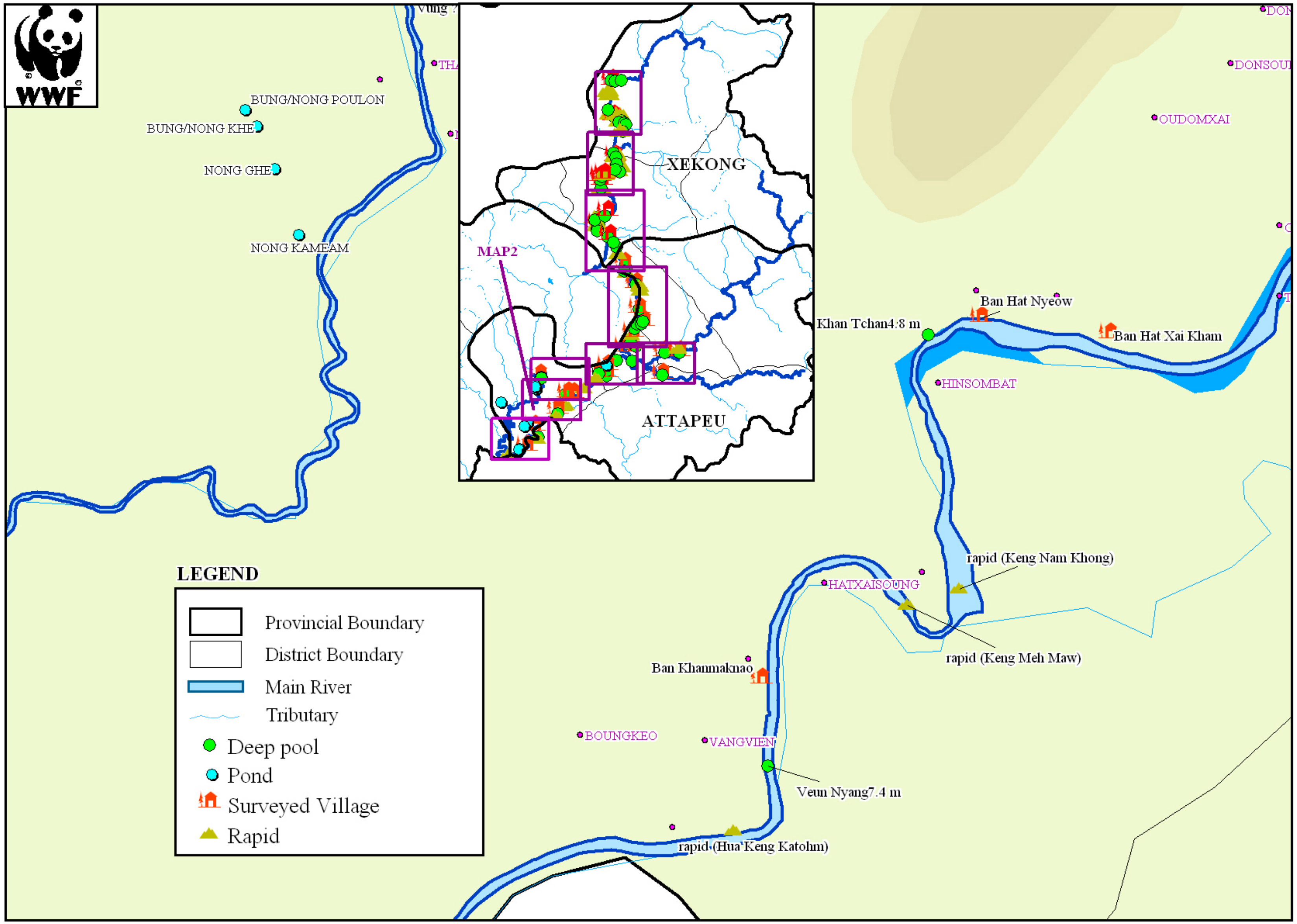
Species	Sekong	Sesan	Sre Pok
Puntius binotatus		1	1
Puntius brevis	1		1
Puntius orphoides	1		1
Puntius partipentazona	1	1	
Puntius rhombeus	1		1
Raiamas guttatus	1	1	1
Rasbora amplistriga	1	1	1
Rasbora atridorsalis			1
Rasbora aurotaenia			1
Rasbora borapetensis	1	1	
Rasbora dusonensis	1	1	1
Rasbora hobelmani			1
Rasbora paviana	1	1	1
Rasbora rubrodorsalis	1		
Rasbora tornieri			1
Rasbora trilineata	1	1	
Rhinogobius giurinus			1
Rhinogobius taenigena	1		
Scaphiodonichthys acanthopterus	1		
Scaphognathops bandanensis	1	1	1
Scaphognathops stejnegeri	1		1
Schistura bairdi	1		
Schistura bolavenensis	1		
Schistura clatrata	1		
Schistura coruscans			1
Schistura daubentoni		1	1
Schistura defectiva			1
Schistura dorsizona	1		
Schistura fusinotata	1		
Schistura imitator	1		
Schistura kengtungensis			1
Schistura khamtanhi	1		
Schistura kongphengi	1		
Schistura nomi	1		
Schistura rikiki	1		
Schistura tizardi	1		
Serpenticobitis octozona	1		
Sewellia diardi	1		
Sewellia elongata	1		
Sewellia patella		1	
Sewellia speciosa	1		
Sikukia gudgeri	1		1
Sinibrama affinis			1
Sinohomaloptera kwangsiensis			1
Sundasalanx mekongensis	1		
Syncrossus beauforti	1	1	1
Syncrossus helodes		1	1
Tenualosa thibaudeaui	1	1	
Tenualosa toli			1
Tetraodon baileyi	1		1
Tetraodon barbatus			1
Tetraodon cambodgiensis	1		
Tetraodon cochinchinensis	1		
Tetraodon leiurus	1	1	
Tetraodon suvattii	1		
Tetraodon turgidus	1		
Thynnichthys thynnoides	1	1	1
Tor laterivittatus	1		1
Tor sinensis	1		1
Tor tambra	1		
Tor tambroides	1		1
Toxabramis hotayensis			1
Toxotes chatareus	1		

Species	Sekong	Sesan	Sre Pok
Toxotes microlepis		1	
Trichogaster microlepis			1
Trichogaster pectoralis			1
Trichogaster trichopterus	1	1	1
Trichopsis schalleri	1		
Trichopsis vittata	1		1
Tuberoschistura cambodgiensis			1
Wallago attu		1	1
Wallago leerii	1	1	1
Xenentodon cancila	1	1	1
Xenentodon canciloides	1		1
Yasuhikotakia caudipunctata			1
Yasuhikotakia eos	1	1	1
Yasuhikotakia lecontei		1	1
Yasuhikotakia longidorsalis			1
Yasuhikotakia modesta	1	1	1
Yasuhikotakia morleti			1
Yasuhikotakia nigrolineata	1	1	1
Yasuhikotakia sidthimunki	1		
Yasuhikotakia splendida	1		
Grand Total	*213*	*133*	*240*

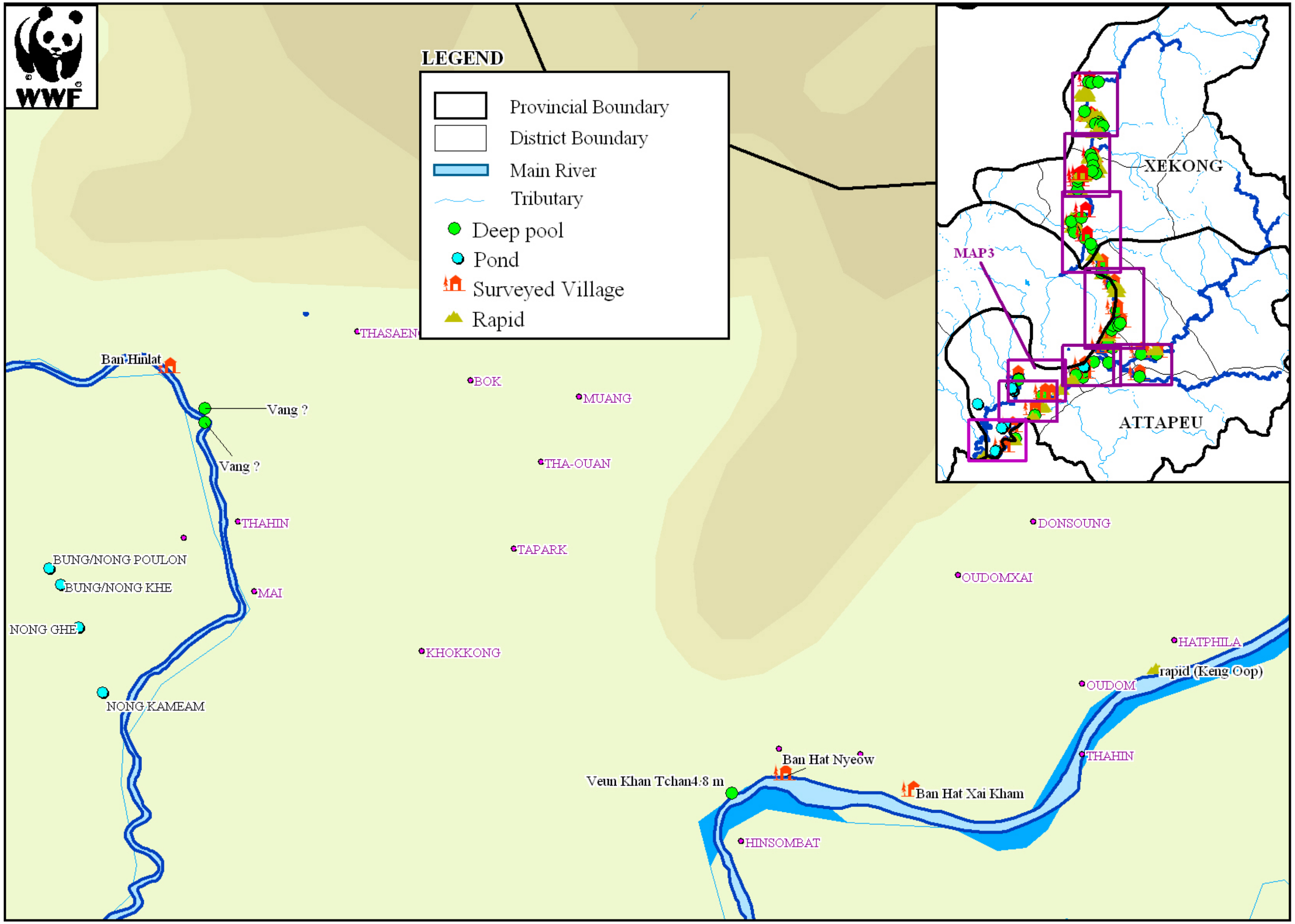
Annex 3: Maps of deep pools and rapids

Source: WWF ComFish project 2005/2006

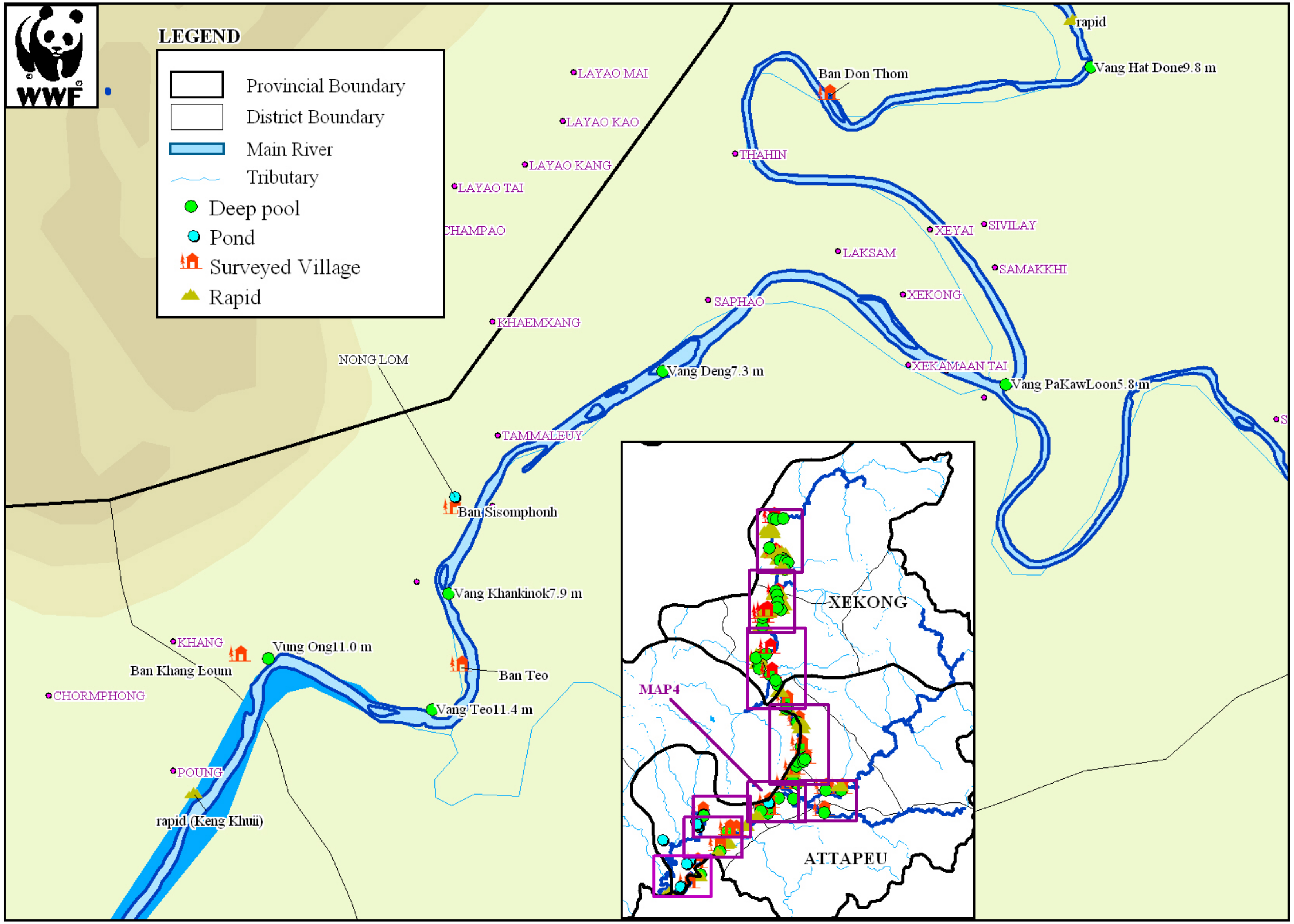


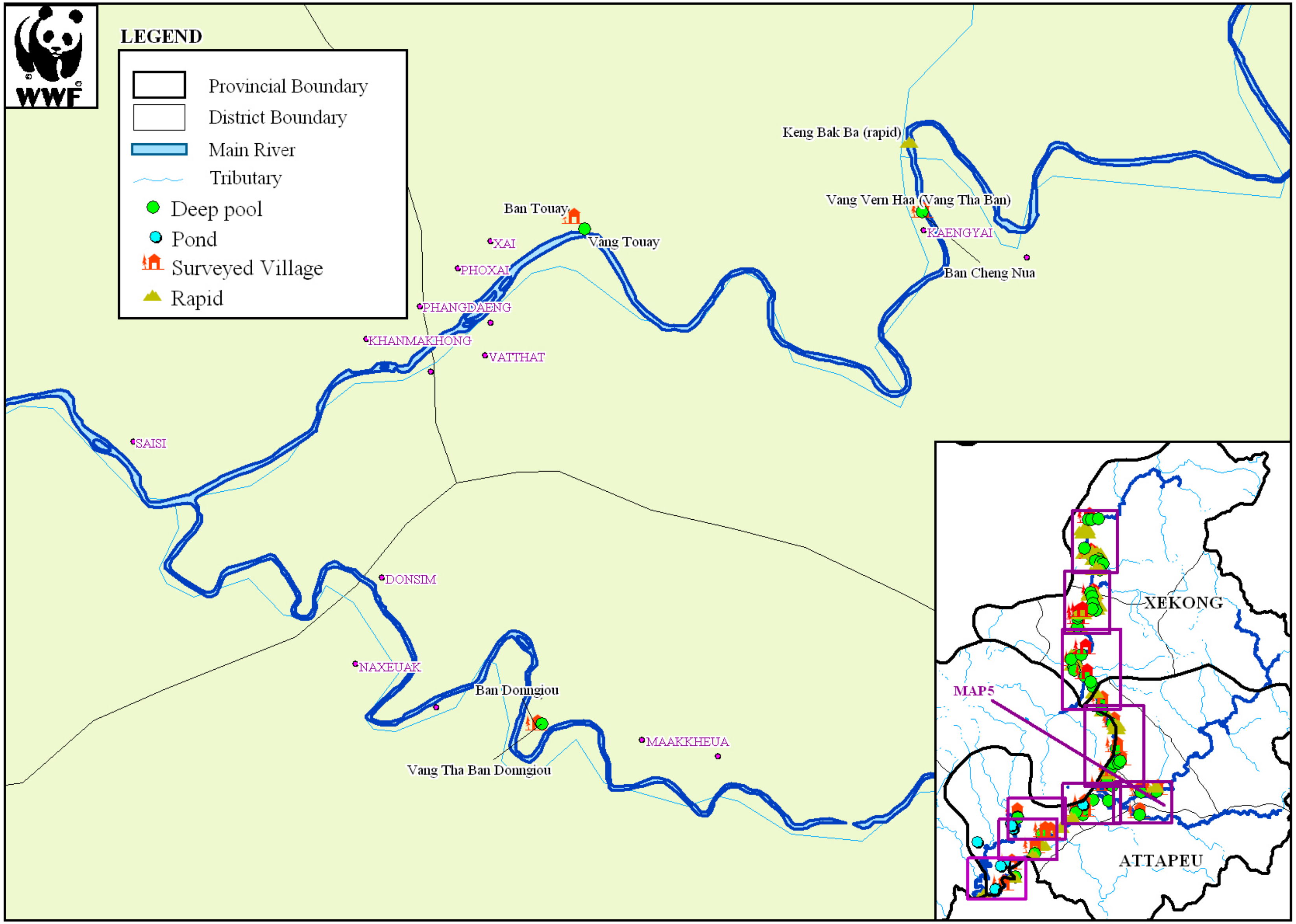


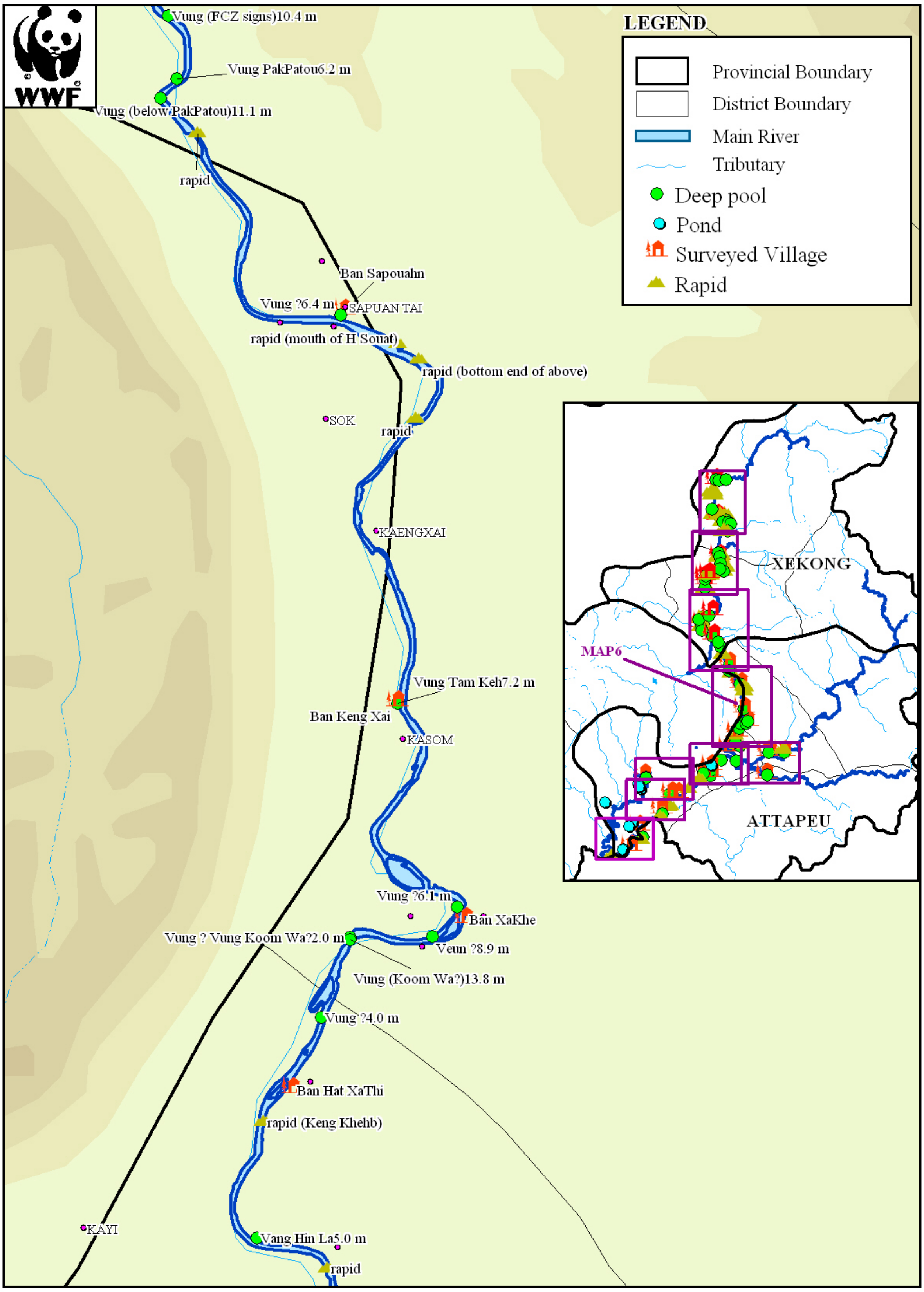
WWF
BUNG/NONG POULON
BUNG/NONG KHE
NONG GHE
NONG KAMEAM
XEKONG
MAP2
ATTAPEU
OUDOMXAI
Ban Hat Nyeow
Khan Tchan4.8 m
Ban Hat Xai Kham
HINSOMBAT
rapid (Keng Nam Khong)
HATXAISOUNG
rapid (Keng Meh Maw)
Ban Khanmaknao
BOUNGKEO
VANGVIEN
Veun Nyang7.4 m
rapid (Hua Keng Katohm)
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid

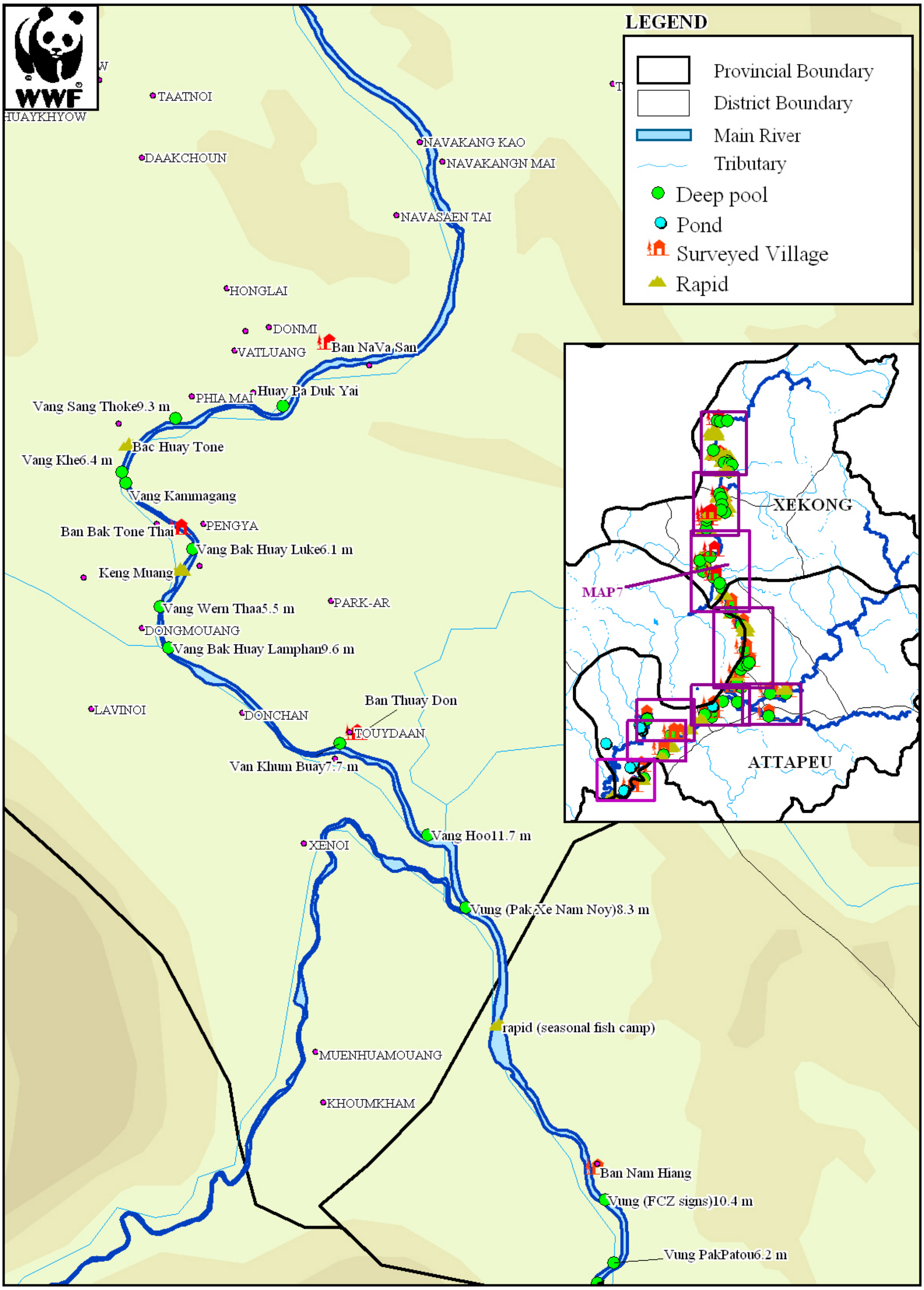


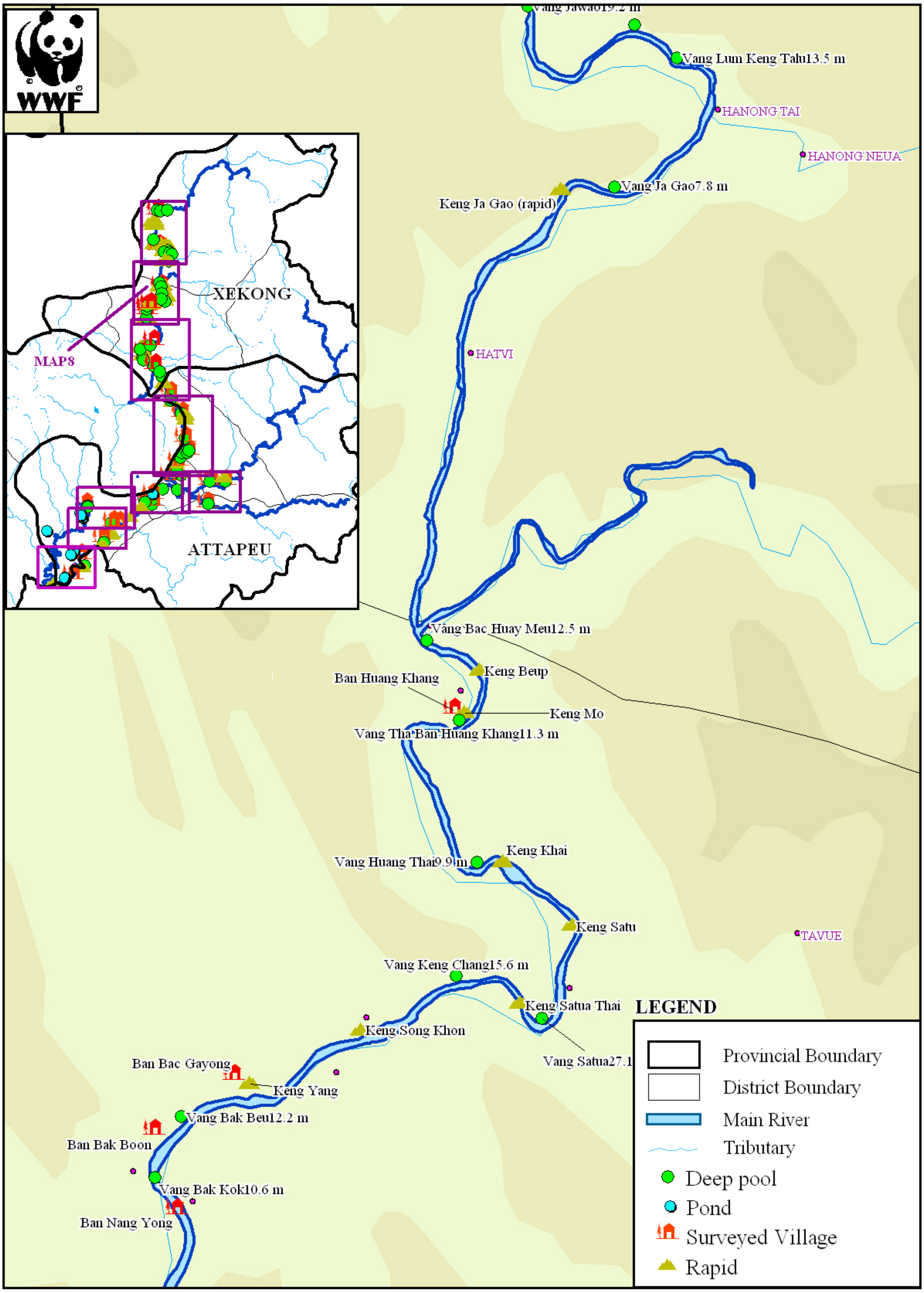
WWF
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid
XEKONG
MAP3
ATTAPEU
THASAEN
Ban Hinlat
BOK
MUANG
Vang ?
Vang ?
THA-OUAN
THAHIN
TAPARK
DONSOUNG
BUNG/NONG POULON
BUNG/NONG KHE
MAI
OUDOMXAI
NONG GHE
KHOKKONG
HATPHILA
rapid (Keng Oop)
OUDOM
NONG KAMEAM
THAHIN
Ban Hat Nyeow
Veun Khan Tchan4:8 m
Ban Hat Xai Kham
HINSOMBAT

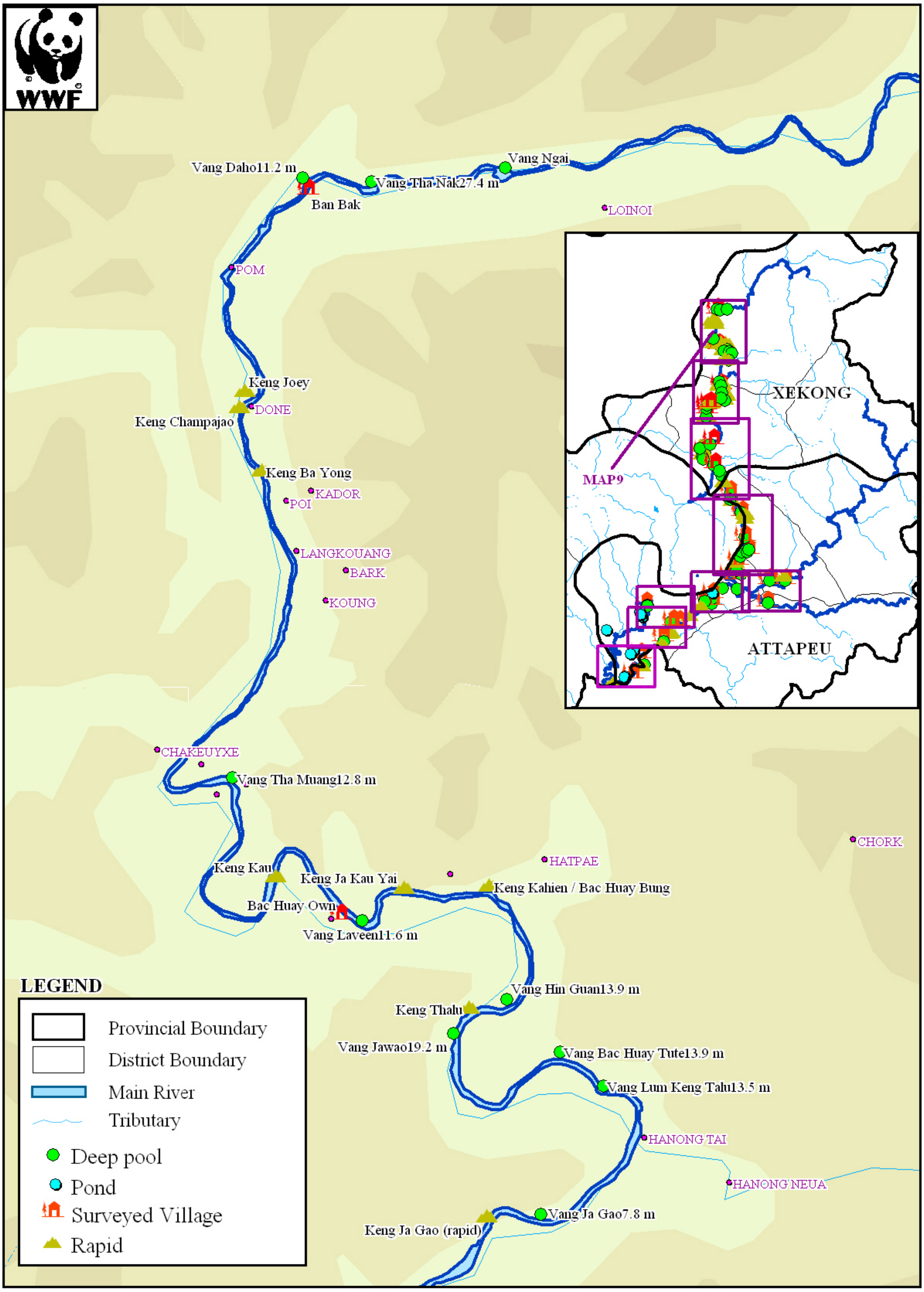

WWF
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid
LAYAO MAI
LAYAO KAO
LAYAO KANG
LAYAO TAI
CHAMPAO
KHAEMXANG
NONG LOM
TAMMALEUY
Ban Sisomphonh
Vang Khankinok7.9 m
KHANG
Vung Ong11.0 m
Ban Khang Loum
Ban Teo
Vang Teo11.4 m
CHORMPHONG
POUNG
rapid (Keng Khuii)
rapid
Vang Hat Done9.8 m
Ban Don Thom
THAHIN
XEYAI
SIVILAY
LAKSAM
SAMAKKHI
XEKONG
SAPHAO
XEKAMAAN TAI
Vang Deng7.3 m
Vang PaKawLoon5.8 m
XEKONG
MAP4
ATTAPEU


WWF
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid
Keng Bak Ba (rapid)
Vang Vern Haa (Vang Tha Ban)
KAENGYAI
Ban Cheng Nua
Ban Touay
Vang Touay
XAI
PHOXAI
PHANGDAENG
KHANMAKHONG
VATTHAT
SAISI
DONSIM
NAXEUAK
Ban Donngiou
Vang Tha Ban Donngiou
MAAKKHEUA
XEKONG
MAP5
ATTAPEU


Vung (FCZ signs)10.4 m
Vung PakPatou6.2 m
Vung (below PakPatou)11.1 m
rapid
Ban Sapoualın
Vung ?6.4 m
SAPUAN TAI
rapid (mouth of H'Souat)
rapid (bottom end of above)
SOK
rapid
KAENGXAI
Vung Tam Keh7.2 m
Ban Keng Xai
KASOM
Vung ?6.1 m
Ban XaKhe
Vung ? Vung Koom Wa?2.0 m
Veun ?8.9 m
Vung (Koom Wa?)13.8 m
Vung ?4.0 m
Ban Hat XaThi
rapid (Keng Khehb)
KAYI
Vang Hin La5.0 m
rapid
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid
XEKONG
MAP6
ATTAPEU


WWF
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid
XEKONG
MAP7
ATTAPEU
HUAYKHYOW
TAATNOI
DAAKCHOUN
NAVAKANG KAO
NAVAKANGN MAI
NAVASAEN TAI
HONGLAI
DONMI
VATLUANG
Ban NaVa San
PHIA MAI
Huay Pa Duk Yai
Vang Sang Thoke9.3 m
Bac Huay Tone
Vang Khe6.4 m
Vang Kammagang
Ban Bak Tone Thai
PENGYA
Vang Bak Huay Luke6.1 m
Keng Muang
Vang Wern Thaa5.5 m
PARK-AR
DONGMOUANG
Vang Bak Huay Lamphan9.6 m
LAVINOI
DONCHAN
Ban Thuay Don
TOUYDAAN
Van Khum Buay7.7 m
Vang Hoo11.7 m
XENOI
Vung (Pak Xe Nam Noy)8.3 m
rapid (seasonal fish camp)
MUENHUAMOUANG
KHOUMKHAM
Ban Nam Hiang
Vung (FCZ signs)10.4 m
Vung PakPatou6.2 m


WWF
XEKONG
MAP8
ATTAPEU
Vang Lum Keng Talu13.5 m
HANONG TAI
HANONG NEUA
Vang Ja Gao7.8 m
Keng Ja Gao (rapid)
HATVI
Vang Bac Huay Meu12.5 m
Ban Huang Khang
Keng Beup
Keng Mo
Vang Tha Ban Huang Khang11.3 m
Keng Khai
Vang Huang Thai9.9 m
Keng Satu
TAVUE
Vang Keng Chang15.6 m
Keng Satua Thai
Keng Song Khon
Vang Satua27.1
Ban Bac Gayong
Keng Yang
Vang Bak Beu12.2 m
Ban Bak Boon
Vang Bak Kok10.6 m
Ban Nang Yong
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid



WWF
Vang Daho11.2 m
Vang Tha Nak27.4 m
Vang Ngai
Ban Bak
LOINOI
POM
Keng Joey
DONE
Keng Champajao
Keng Ba Yong
KADOR
POI
LANGKOUANG
BARK
KOUNG
CHAKEUYXE
Vang Tha Muang12.8 m
Keng Kau
Keng Ja Kau Yai
Bac Huay Own
Vang Laveen11.6 m
HATPAE
Keng Kahien / Bac Huay Bung
CHORK
Vang Hin Guan13.9 m
Keng Thalu
Vang Jawao19.2 m
Vang Bac Huay Tute13.9 m
Vang Lum Keng Talu13.5 m
HANONG TAI
HANONG NEUA
Vang Ja Gao7.8 m
Keng Ja Gao (rapid)
XEKONG
MAP9
ATTAPEU
LEGEND
Provincial Boundary
District Boundary
Main River
Tributary
Deep pool
Pond
Surveyed Village
Rapid

Annex 4: Google Earth images for every 10 km reach of Sekong and Se Kamman


20 km
Phumi Khsach Nòn
10 km
© 2013 Google
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
Google earth


30 km
20 km
© 2013 Google
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
Google earth

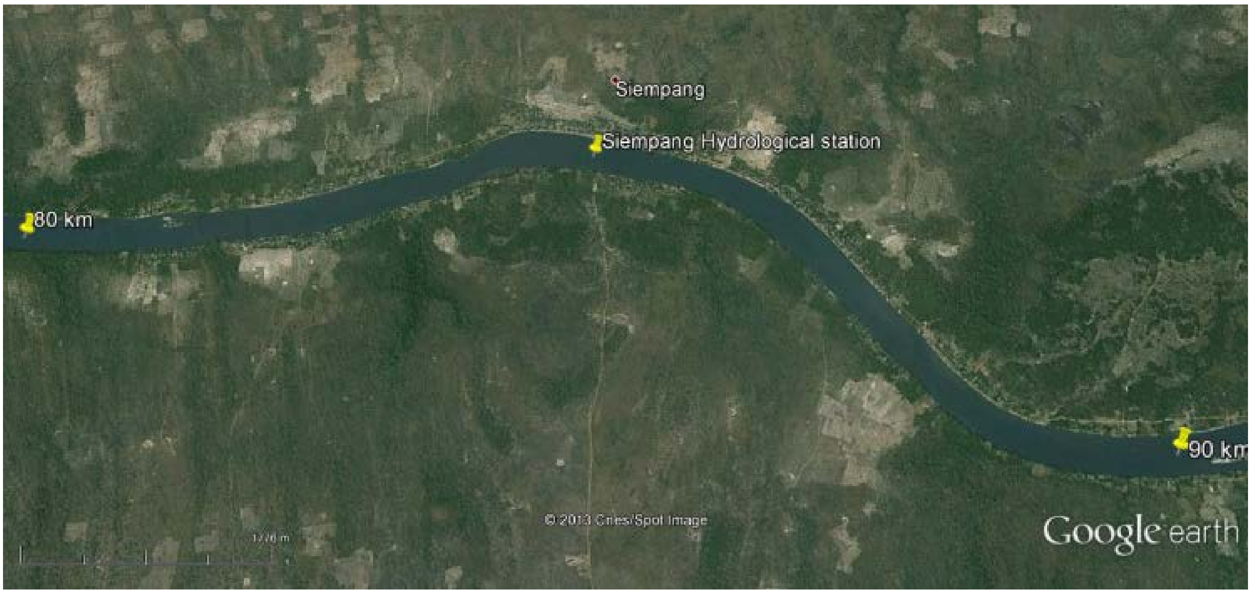

30 km
40 km
Nhoun
1778 m
© 2013 Google
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
Google earth


Sekong HPP
Ban Done Thben
50 km
40 km
© 2013 Google
© 2013 Cnes/Spot Image
Google earth


50 km
60 km
© 2013 Google
© 2013 Cnes/Spot Image
1773 m
Google earth


60 km
70 km
© 2013 Google
© 2013 Cnes/Spot Image
1774 m
Google earth


70 km
Ban Hui
80 km
© 2013 Google
© 2013 Cnes/Spot Image
1762 m
Google earth


Siempang
Siempang Hydrological station
80 km
90 km
© 2013 Cnes/Spot Image
Google earth


100 km
90 km
© 2013 Google
© 2013 Cnes/Spot Image
Google earth


Khan Mak Hoean
100 km
110 km
© 2013 Google
© 2013 Cnes/Spot Image
1783 m
Google earth


120 km
110 km
© 2013 Cnes/Spot Image
1774 m
Google earth

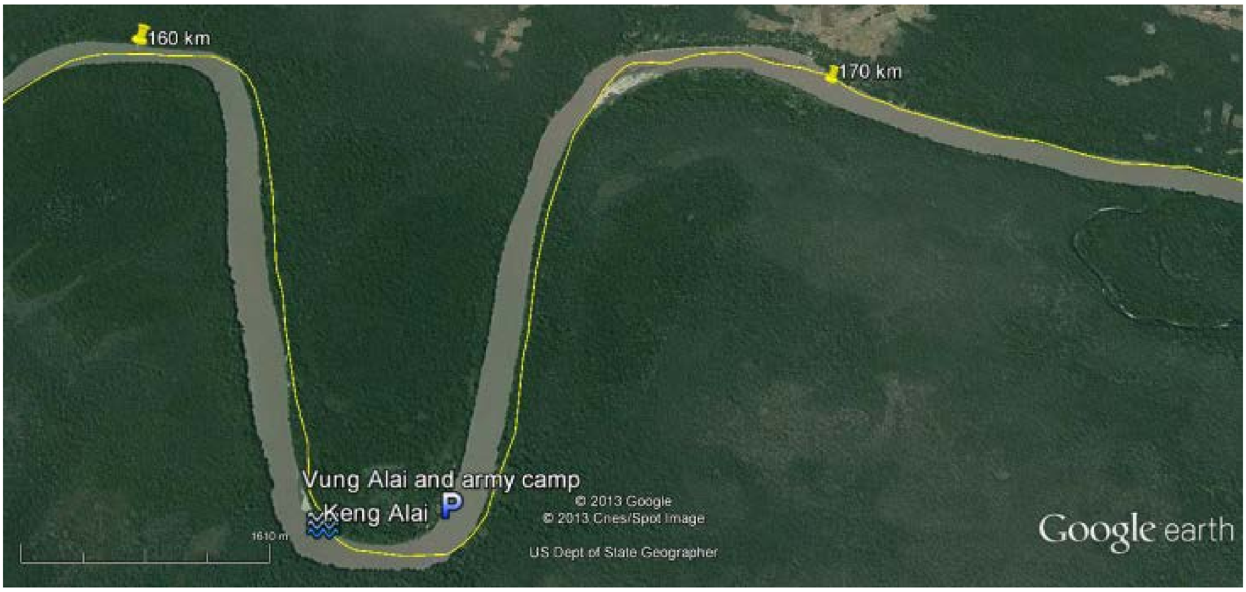

120 km
130 km
© 2013 Cnes/Spot Image
1774 m
Google earth


140 km
130 km
US Dept of State Geographer
© 2013 Cnes/Spot Image
1784 m
Google earth


MWBP FCZ
140 km
150 km
© 2013 Cnes/Spot Image
US Dept of State Geographer
1772 m
Ban Hai
Google earth


160 km
150 km
© 2013 Cnes/Spot Image
US Dept of State Geographer
Google earth


160 km
150 km
© 2013 Cnes/Spot Image
US Dept of State Geographer
Google earth


160 km
170 km
Vung Alai and army camp
Keng Alai
© 2013 Google
© 2013 Cnes/Spot Image
US Dept of State Geographer
Google earth


170 km
180 km
Hua Ke
© 2013 Google
© 2013 Cnes/Spot Image
US Dept of State Geographer
Google earth


Veun Nyang
180 km
Hua Keng Katohm
Keng Meh Maw
190 km
Keng Nam Khong
© 2013 Google
© 2013 Cnes/Spot Image
US Dept of State Geographer
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Sanamxai
Veun Khan Tchan
200 km
190 km
eng Meh Maw
Keng Nam Khong
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200 km
Keng Oop
210 km
© 2013 Google
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Keng Khuii
210 km
Khang Loum
Vung Ong
Teo
220 km
Vung Khankhinok
Vung Teo
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220 km
Vung Khankhinok
Vung Deng
230 km
© 2013 Google
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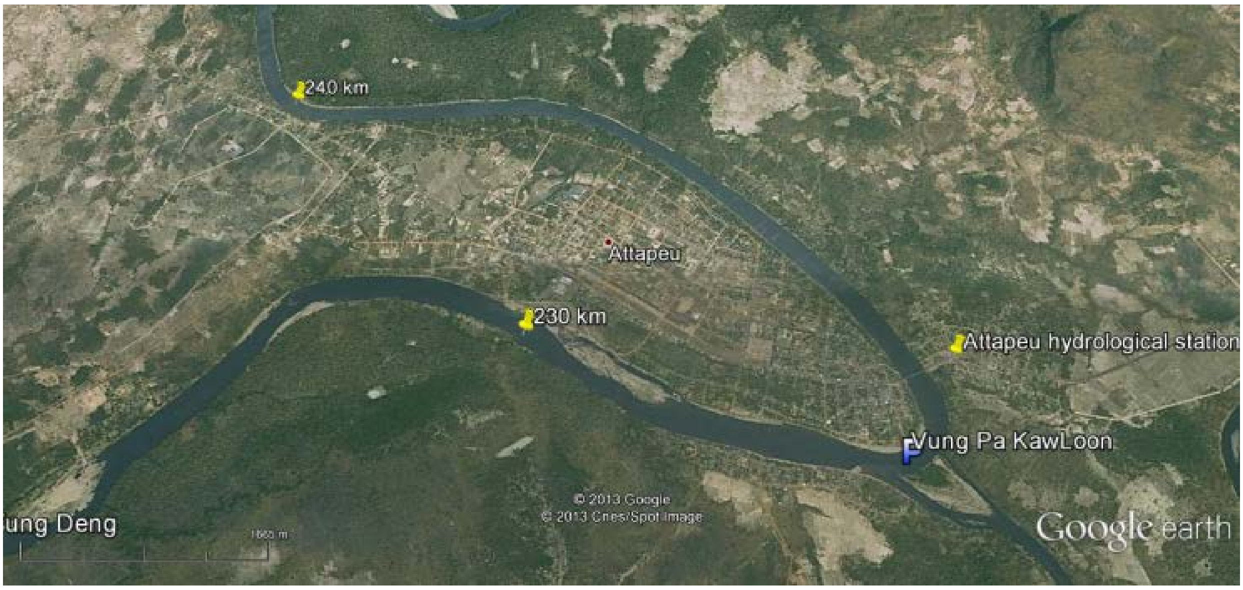
240 km
Attapeu
230 km
Attapeu hydrological station
Vung Pa KawLoon
ung Deng
© 2013 Google
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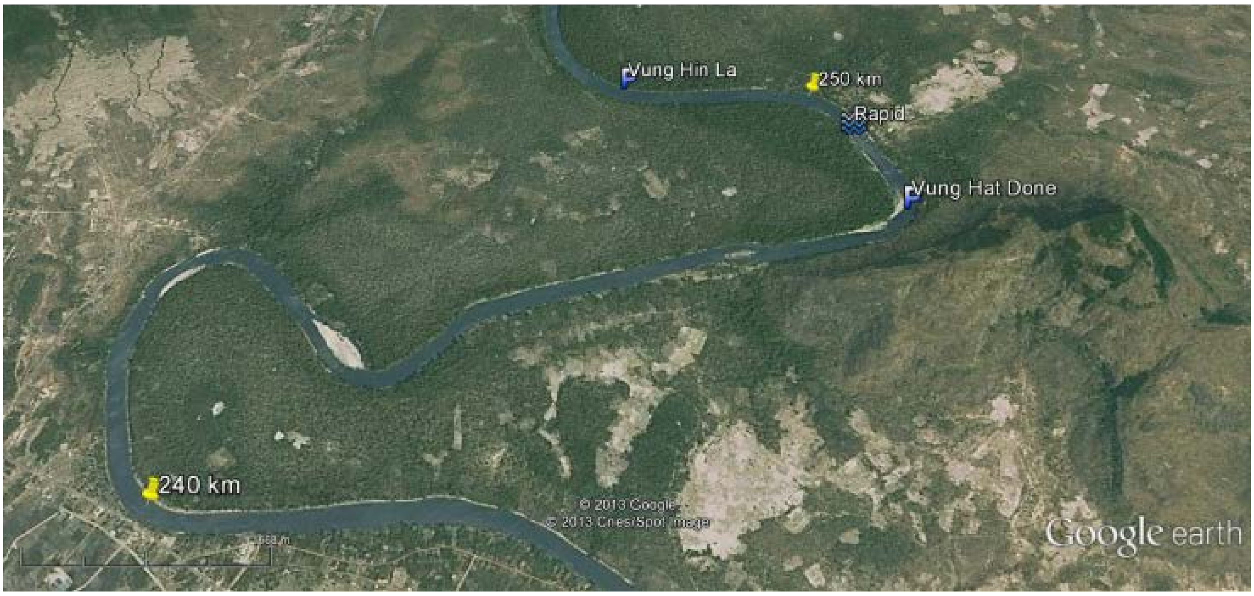
Google earth


Vung Hin La
250 km
Rapid
Vung Hat Done
240 km
© 2013 Google
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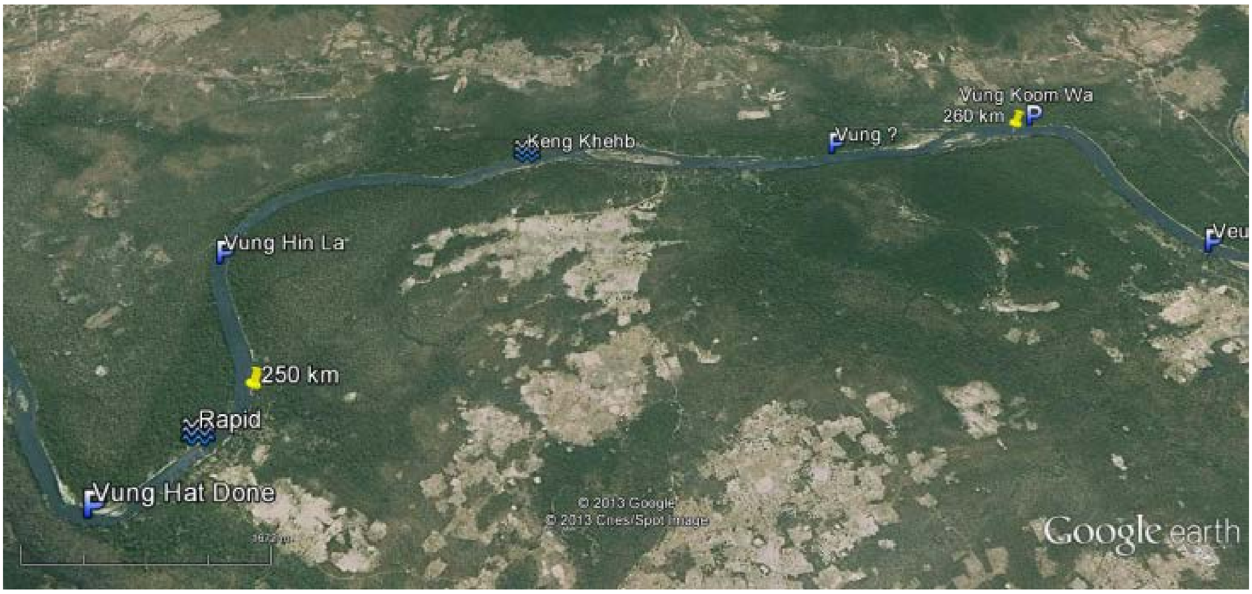
Google earth


Vung Koom Wa
260 km
Keng Khehb
Vung ?
Veu
Vung Hin La
250 km
Rapid
Vung Hat Done
© 2013 Google
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Vung ?
Vung Koom Wa
260 km
Vung Tam Keh
270 km
Veun ?
Vung ?
Xakhe
© 2013 Google
© 2013 Cnes/Spot Image


Houay Ho
Donchan
Kengsai
Vung ?
Rapid H.
Rapid
Rapid
280 km
Ban Kenaxai
m Keh
270 km
© 2013 Google
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Houay Ho
Donchan
Kengsai
Vung (below PakPatou)
Xe Kong 3 d
290 km
Rapid
Kagnak
Vung PakPato
Vung ?
Rapid
Rapid
Rapid H. Souat
280 km
© 2013 Google
© 2013 Cnes/Spot Image


Vung (below PakPatou)
3 d
290 km
Rapid
Kagnak
Vung PakPatou
Vung FCZ
Rapid
Rapid - fish camp
300 km
© 2013 Google
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Mun-Houamuang
310 km
Van Khum Buay
Vang Hoo
Rapid
Rapid - fish camp
300 km
Vung (Pak Xe Nam Noy)
Pakphong
© 2013 Google
© 2013 Cnes/Spot Image
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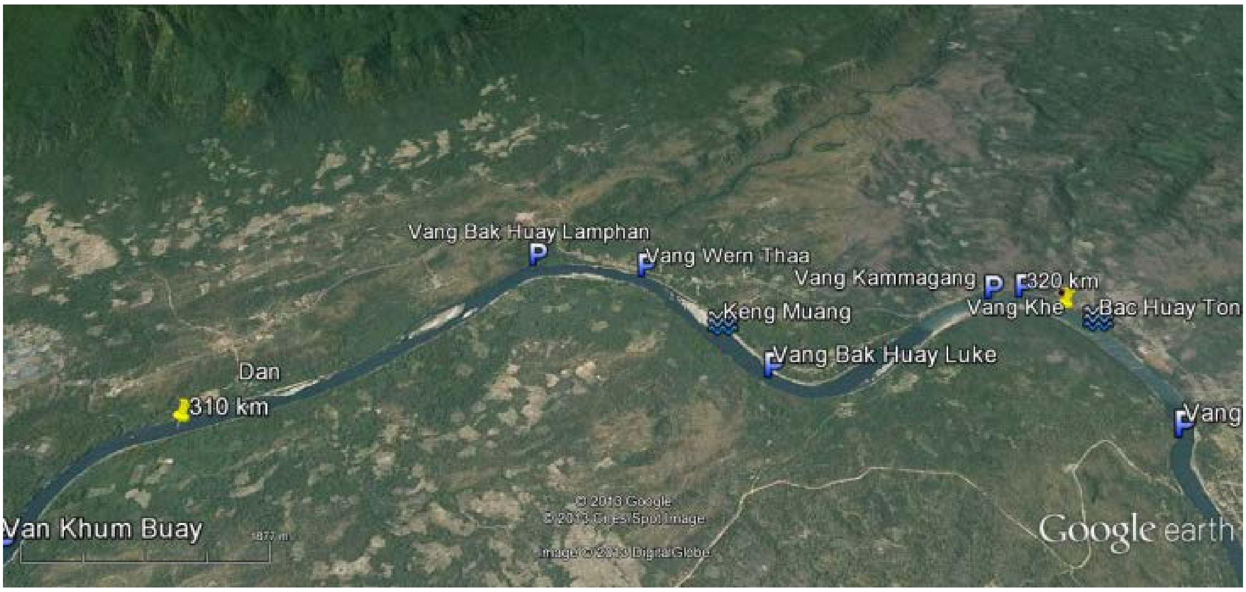
Vang Bak Huay Lamphan
Vang Wern Thaa
Vang Kammagang
320 km
Vang Khe
Bac Huay Ton
Keng Muang
Vang Bak Huay Luke
Dan
310 km
Vang
Van Khum Buay
© 2013 Google
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Image © 2013 DigitalGlobe
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Nava Nua
Hongla
320 km
Bac Huay Tone
Vang Khe
Pakthon
Vang Sang Thoke
Sekong
Vang Kammagang
Nava
Xe Kon
Vang Bak Huay Yang
330 km
uay Luke
© 2013 Google
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
Google earth


Vang Kammagang
Bac Huay Tone
Vang Sang Thoke
Sekong
Honglai
Phon
Vang Bak Huay Yang
Keng Luang
Khoueng
340 km
Nava Nua
330 km
Xe Kong 3 up
Nava Kang
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Image © 2013 DigitalGlobe
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Phon
Vang Hua Keng Luang
Keng Luang
Khoueng
Vang Bak Kok
Vang Bak Beu
340 km
Nava Nua
Keng Yang
350 km
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Image © 2013 DigitalGlobe
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Vang Bac Huay Meu
Hung Nua
Keng Mo
Keng Beup
Vang Tha Ban Huang Khang
Vang Bak Beu
350 km
Keng Yang
Keng Song Khon
Vang Lek
Keng Khai
360 km
Vang Keng Chang
Xe Kong 4
Keng Satua Thai
Keng Satu
Vang Satua
Pakkayong
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Image © 2013 DigitalGlobe
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Vang Bac Huay Meu
Hung Nua
370
Keng Mo
Vang Tha Ban Huang Khang
Vang Lek
Keng Khai
Keng Beup
360 km
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Google earth


370
Thatvi
Keng Ja Gao
Vang Ja Gao
380 km
© 2013 Google
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
Google earth


Thatvi
Keng Ja Gao
Vang Ja Gao
380 km
Vang Lum Keng Talu
Vang Bac Huay Tute
Vang Jawao
Keng Thalu
Vang Hin Guan
390 km
Hatpe
Keng Kahien / Bac Huay
Keng Ja Kau Yai
Vang Laveen
Keng Kau
400 km
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Vang Ja Gao
Vang Jawao
Keng Thalu
Vang Hin Guan
390 km
Keng Kahien / Bac Huay Bung
Hatpe
Keng Ja Kau Yai
Vang Laveen
Keng Kau
400 km
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Xathang
400 km
Vang Tha Muang
Keng Ba Yong
410 km
Boung-Nom
© 2013 Google
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Keng Champajao
Keng Joey
Chakeuy Nua
Ba Yong
410 km
Salou
Vang Daho
Bak
Vang Tha Nak
Keng Thagang
420 km
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Tha Nak
420 km
eng Thagang
Vang Ngai
430 km
© 2013 Google
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Google earth


430 km
Paliang
440 km
© 2013 Google
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Xe Kong 5
450 km
440 km
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Image © 2013 DigitalGlobe
© 2013 Google
Google earth


Xe Kong 5
450 km
Ban Talouy Gnai
460 km
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
© 2013 Google
Google earth


460 km
A Loi
470 km
Amoi Nua
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
© 2013 Google
Google earth


A Loi
470 km
480 km
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
© 2013 Google
Google earth


480 km
490 km
© 2013 Cnes/Spot Image
© 2013 Google
Google earth


An Rum
500 km
490 km
Google earth


Nhâm
510 km
A Luoi HPP
500 km
US Dept of State Geographer
1359 m
© 2013 Google
© 2013 Cnes/Spot Image
Google earth


Hồng Quang
Phú Vinh
520 km
510 km
© 2013 Cnes/Spot Image
Image © 2013 DigitalGlobe
© 2013 Google
US Dept of State Geographer
1306 m
Google earth


520 km
Hương Phong
530 km
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1326 m
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