Electricity of Vietnam

Environmental Impact Assessment on the Cambodian Side of the Srepok River due to Hydropower Development in Vietnam

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Prepared by SWECO Grøner
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Norwegian Institute for Water Research, EVIORO-DEV, ENS Consult

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EXECUTIVE SUMMARY

Objectives

The purpose of this Srepok EIA Study is to evaluate the potential impacts in Cambodia due to planned hydropower development in Vietnam. This study is part of the assessment of the Srepok River Basin in the Vietnam National Hydropower Plan Study (NHP 2005). The Srepok River basin has a moderate hydropower potential compared to other similar basins in the region and is so far undeveloped except for a small scale power station in Vietnam, Dray Linh Old (12 MW), which has not been in operation for the last few years. On the Vietnamese side there is currently four power plants under construction (Buon Koup, 280 MW, Ban Tou Srah, 86 MW, Dray Linh New, 16 MW, and Srepok 3, 220 MW), one plant is committed (Srepok 4, 65 MW), and another plant is under planning (Duc Xuyen main, 70 MW). This impact assessment is based on different operation scenarios of the power stations, superimposed by different hydrological situations, and experience from the development of hydropower in the Se San River in Vietnam. Srepok 4 is planned to be built and operated as a re-regulation reservoir, and this aspect is taken into consideration in this study.

The main objectives of this environmental study of Srepok River in Cambodia are:

1) To describe the present situation of (i) the river body (both physical and biological); (ii) the land use types and settlements and; (iii) possible cultural sites and relics.
2) To assess possible positive and negative impacts on the natural and social environment arising from different scenarios of operation of the hydropower plants in Vietnam.
3) To describe possible mitigation measures to reduce or avoid possible impacts from the operation of the Srepok power projects and release of flood flow from reservoirs.
4) To draft a ToR for further EIA studies in the Cambodian part of Srepok River.

Methodology

To assess the impacts along the Srepok River in Cambodia, a rapid field survey was carried out after the rainy season on aquatic, terrestrial and social environment themes. A review of available data from existing reports, published literature, maps, statistics, databases, ministries and non-government organizations (NGOs) provided an overview of the knowledge base and formed the basis for the field survey. Prior to the fieldwork the study themes were elaborated upon and structured in order to facilitate a rapid screening of key issues. These topics were organized into a survey questionnaire for information gathering in the villages. A limited number of PRA (Participatory Rural Appraisal) tools were selected and combined with the survey questionnaire, which was utilized as a checklist of issues to be covered. Rapid surveys of species in the agro-landscape (all gardening types), vegetation communities and markets were also conducted. Stakeholders consulted in this rapid study were defined into the following categories: (1) People to be affected by future HPP projects. These are the people living in the riverside villages being directly dependent on the river for their subsistence and culture; (2) Public sector agencies: Ministries, provincial and district authorities, and commune leaders; and (3) NGOs operating in the Study Area. The different stakeholders also contributed to an assessment of the potential and the threats for future development scenarios in local and regional level. This study began in November 2005 and a Draft Final report was ready in February 2006. Information on the decision to build and operate Srepok 4 as a re-regulation reservoir was provided in March 2006 and the report was adjusted accordingly.

The description of the baseline conditions is largely based on this field survey. Where information come from other sources, these sources are referred to in the text.

To describe the hydrology, a hydrodynamic modeling study for the Srepok River from the planned Srepok 3 Hydropower Station in Vietnam to the confluence with the Se Kong River, was carried out by PECC4 under the supervision of SWECO International. The results in the modeling study are presented for about 90 cross-sections along the river in Cambodia. High and low flow situations combined with different operation scenarios of the power station are explored.

Baseline

On the Vietnamese part of Srepok River there are several Hydropower Projects either in operation, under construction, projects that are committed or projects under planning.

Under operation	Under Construction	Committed	Under Planning
Dray Linh Old	Buon Koup	Srepok 4	Duc Xuyen Main
	Ban Tou Srah		
	Dray Linh New		
	Srepok 3		

The Srepok river water has low to moderate turbidity most of the year with values in the range of 1-10 FNU. This is relatively clear water and indicate low erosion activity. In the low flow season, particularly in May, it can be high amounts of algae in the water (mesotrophic-eutrophic levels), which indicate that the river is impacted by nutrients from human activities. The impact from human discharges is also indicated by a relatively high content of coliform bacteria. The impact from human discharges is mainly coming from Vietnam where the population density in the river catchment is rather high.

The aquatic life in Srepok River is rich, both with respect to species diversity and biomass. 120 fish species are recorded, but the number of species is most likely higher in the range from 200-300 species. Fish is a very important food source, and it constitutes approximately 90 % of the protein supply of the local people. A large number of the fish fauna are highly migratory, and we are told by Vietnamese fish researches that more than 50 species migrate all the way from the Mekong and far up into Vietnam. A large part of the migrations is for reaching spawning and nursery grounds. Most people said that the fish population had declined somewhat over the last 10-15 years, but in general they said that fishery was still good, and that there was no problem of getting sufficient fish for the daily food needs.

Agricultural activity is the main land use activity associated with villages. Home (all year round), backyard (all year round) and riverbank (only in the dry season) gardening is practiced and a high diversity of species are grown. Paddies are found usually away from the river but these do depend on early wet season full river flow. Water is channeled by various means into fields as rice seedlings are transplanted and establishment begins. This water also fills pools in the landscape. Orchards and paddies are usually started off in deforested areas, which may be illegally felled. There are several biodiversity rich areas which are protected in the Srepok River area, which are yet to be assessed for their diversity is detail, although key species and vegetative communities are known. Local people also rely on the use of non-timber forest products (NTFPs).

People residing along the downstream area of the Srepok River base their subsistence economy on available natural resources in the area. They rely on water, cultivation land and forest. In the current situation food security is good for most of the riverside population. People's nutritional status is satisfactory and no children are undernourished due to the abundant fish in the river, providing the main protein source. In most villages households have enough cultivation land and can even produce a rice surplus, which together with fish and animals can regenerate cash.

Impact Assessment

Hydropower development interrupts this normal hydrological cycle which both the aquatic life and humans are adapted to and dependent on. The dams, and any dry stretches, break the ecological continuum of the river and prevent fish (and other water associated animals) from reaching their spawning grounds and feeding grounds. Animals which have nesting sites by the river and on sand banks are highly depended on predictable water flow regimes. The deep pools in the Srepok River can accumulate sediments that can impact pool dependent aquatic life.

Changes in hydrology often result in increased erosion activity, which induces water quality, siltation, and sedimentation problems. Large fluctuations in water levels in the river will induce river bank land slips and weaken banks in general. Local people will not be able to practice riverbank gardening if river banks are weak and if there are unpredictable water level fluctuations. Paddy production can also be seriously impacted if early wet season water levels are low, and water cannot be channeled to areas away from the river.

The impacts from hydropower construction on people's lives in the downstream area depend on the measures taken firstly in the construction site and secondly along the river in order to reduce the anticipated negative effects from daily water fluctuations, erosion, water pollution, turbid water and reduced fish stocks. The migration barriers imposed by the many dams will result in considerably impacts on fish, both with respect to reduction in biomass production and species diversity.

Impacts with Srepok 4 as a re-regulation reservoir

The planned operation of Srepok 4 as a re-regulation reservoir will reduce the negative impacts. Such an operation mode will allow the river flow to be close to the "normal", the daily water level fluctuations will be marginal, and the impacts related to such water level fluctuations will consequently be marginal as well. These impacts include:

- Erosion due to daily peaking operation will be marginal and hence the direct and indirect impacts related to this little (for instance sedimentation of the deep pools).
- Turbidity will be reduced or in long term even improved.

- All riverbank activities (e.g. river bank agriculture, non-migratory aquatic life use, river and river bank related vegetables, river water use) will be little affected and the overall impact on social life and economy reduced accordingly.

The following impacts will remain the same:

- Impacts related to accidental flow releases.
- Impact on water quality related to establishment of the reservoir.

Impacts related to delaying the flood and reducing the flood peak.

Positive Impacts

Beyond the negative impacts related to hydropower development, there are also some positive impacts achieved, particularly in the operation phase.

The reservoirs can be operated in a way to reduce the flood peaks that may reduce flood damage downstream in Cambodia. The reservoirs will store water in the wet season to be released during the dry season that may increase the average river flow during the dry season. On a long term the reservoirs will contribute to reduce the content of coliform bacteria in the river water.

Mitigation

This report identifies the environmental mitigation measures intended to address the potential adverse impacts of hydropower projects, which involve changes to the baseline conditions.

The main measures to mitigate impacts from hydropower development in Srepok River are:

1) Using Srepok 4 as a deregulating reservoir for leveling out diurnal flow variations.
2) Prolong the wet season filling of the reservoirs
3) Reduce the nutrient inputs to the reservoirs
4) Consider building fish bypass systems
5) Consider establishing fish stocking program
6) Develop a program for aquaculture

The most efficient way of reducing these impacts is to use the Srepok 4 reservoir to level out the diurnal flow variations. The flow out of Srepok 4 should be as equal to the natural flow as possible.

Mitigation has also to include specific measures during construction of new projects among others, (1) against erosion (e.g., construction roads and permanent roads; erosion in the reservoir; sound re-vegetation techniques both at hydro power sites and on erosion prone banks), (2) runoff from tunnel blasting and drilling, (3) soil deposits and soil rock deposits, (4) sanitary effluents from the construction workers camps, (5) oil and chemical spill, and measures related to the operation of the power plants, such as; (6) accidental water releases, (7) dry-ups, (8) animal nesting areas and migration paths, (9) water and health changes related to changes in water quality, (10) to reduce property and agricultural loss due unexpected water level changes and related floods.

Planning for mitigation measures should always be made together with the different stakeholders involved in the project implementation. The stakeholder consultation process and mitigation planning should be started prior to project implementation in order to avoid much of the negative consequences. Following the procedures of the World Commission on Dams (WCD, 2000) of involvement of various stakeholder categories, in the Srepok downstream area at least the following groups should be involved in the stakeholder consultation process: (1) Directly affected people: People living in the riverside villages; (2) Indirectly affected people: (3) People utilizing the river for their life activities but not residing along the river; (3) Women in the directly affected villages; (4) People's organizations; (5) District health care staff and traditional health providers; (6) Village and commune chiefs of directly affected areas; (7) District administration representatives; (8) Provincial ministries representatives; and (9) NGOs working in the affected areas.

The stakeholder consultation process should be based on the risks and rights assessment (see WCD 2000) and lead to measures for mitigating the negative impacts along the Srepok River in Cambodia due to hydropower development in Vietnam. The institutional capacity in Lumphat, Kon Moum, Se San and Kaoh Nheaek districts and the affected communes and villages along the Srepok River for implementing the mitigation measures should be carefully evaluated in order to guarantee a sustainable development after the hydropower project operation. Both planning and implementation of mitigation measures should take place in cooperation with and supporting the existing institutional organizations like commune councils and district health centers. People's organizations and NGOs working in the area should be involved in the activities as well.

Environmental Monitoring

In line with international recommendations, an Environmental Monitoring Plan will be required which defines responsibilities for monitoring, the parameters that will be monitored, where the monitoring will take place, and how often it will be required.

Water related monitoring. The parameters should have indicative value for the anticipated impacts. Those are (1) erosion problems (described by turbidity, suspended sediments and water level fluctuations), (2) eutrophication problems (described by pH, oxygen, nutrients, chlorophyll and algae amount and species composition, and algal toxins (blue- greens)), (3) hygienic pollution (described by coliform bacteria), and (4) reduced fish stocks (described by fish yields by fishermen (catch per unit effort, CPUE)). Specific parameters include; water level fluctuation, temperature, pH, oxygen, turbidity, suspended sediments, total phosphorus, total nitrogen, *Escherichia coli* (or thermostabile coliform bacteria, 44^{o}C; total coliform bacteria, 37^{o}C), Chl-a, algal toxins using algae-filters, fish yield (CPUE), and large scale riverbank erosion.

Terrestrial/Land Use/Agricultural Monitoring. A monitoring program for physical, biological and agricultural components related to and dependent on the river will be required. Since the whole region is of high conservation value such a monitoring program will need to be developed with local environmental and forestry departments along with international NGOs, protected area managers and river users. Local communities can be involved in the monitoring. The monitoring program to be developed can consist of: (1) Riverbank stability, (2) Animal diversity and occurrence, nesting/breeding site presence, (3) Plant community type and habitat structure. In addition specific monitoring should be developed to include: (4) Migration routes, (5) Riverbank agriculture sites (and their use) and bare river banks, and (6) Flood water levels and flooding regimes. Typically some of the sites for monitoring should be designated by villages so that agricultural related activities can be monitored.

Social Monitoring. The proposed indicators listed below are based on the baseline study in the villages along the Srepok River in Cambodia. The number of indicators is reduced to the minimum and they focus on the obvious issues which potentially will be problematic and where vulnerability is likely to increase after the upstream hydropower implementation. Important indicators include (1) Water use and availability, (2) Health and water-related diseases, (3) Land access and food production, (4) Fishery and food security, and (5) Waterway/road transportation.

Conclusion

This study shows that there are water and land resources which are intact at present and that these form the nerve of the livelihoods of the local people, in addition to housing a high diversity of aquatic and terrestrial species. Changes in the hydrological flow from hydropower projects will have the largest impacts, particularly if appropriate mitigation measures are not taken. Constructing and operating Srepok 4 as a re-regulation reservoir will considerably reduce these impacts, and is seen as a positive mitigation measure and such an operation mode is a prerequisite for the pointed out reduced impacts. Salient elements that will need consideration when addressing impacts, mitigation and enhancement measures include the delineation of responsibility for implementation of mitigation measures and monitoring activities, participatory involvement of public and stakeholders in decision making, establishment of a Vietnam/Cambodian Agreement for the Srepok River, and compliance with the Mekong River Commission (MRC) Agreement. Detailed EIAs for each hydropower plant will be necessary to point out the specific impacts and related mitigation needed. It is important to note that there is a general lack of baseline data for the region and these may be need to build up such a base.

1. INTRODUCTION AND METHODOLOGY

1.1 Objectives of the Project

The hydropower potential in Vietnam has been evaluated under the National Hydropower Plan Study (NHP 2005). Assessment of the Srepok River Basin is part of the NHP study. The Srepok River is a trans-boundary river originating in Vietnam and running through North-Eastern Cambodia where it ends up in the Mekong River. The purpose of this Srepok EIA Study is to evaluate the potential impacts in Cambodia due to planned hydropower development in Vietnam. The impact assessment is based on different operation scenarios of the power stations, superimposed by different hydrological situations.

The Srepok River basin has a moderate hydropower potential compared to other similar basins in the region and is so far undeveloped except for a small scale power station in Vietnam, Dray Linh Old (12 MW). This power plant has not been in operation for the last few years. On the Vietnamese side there is currently one power plant under construction (Buon Koup, 280 MW) and another 5 plants under planning (NHP).

This report also draws on the experience from the development of hydropower in the Se San River.

The main objectives of the Environmental Study of Srepok River are:

1) To describe the present situation of:
   - the river body (physical and biological) of the relevant reaches of Srepok River in Cambodia,
   - the land use types and settlements affected by the estimated fluctuation in water level along the same river,
   - possible cultural sites and relics along the same reach of Srepok River and in the area affected by the operation of hydropower plants in Vietnam.

2) To assess possible positive and negative impacts on natural and especially social environment arising from different scenarios of operation of the hydropower plants in Vietnam.

3) To describe possible mitigation measures to minimize or avoid possible impacts from operation of the Srepok power projects and from possible release of flood flow from the reservoirs.

4) To draft a ToR for further EIA studies in the Cambodian part of Srepok River as part of Feasibility Studies related to development of Hydropower projects on the Vietnamese side.

The Study also provides relevant information on environmental and socio-economic issues to facilitate the decision on final design of the projects. In addition, the study recommends methods for monitoring relevant environmental and social indicators.

1.2 Scope of Work and Limitations

The study is based on the following material and methods:

1) Existing data and reports from former and ongoing studies and on earlier environmental measurements and field investigations in the Srepok River both in Vietnam and Cambodia.
2) A rapid field survey on relevant issues along the Srepok River to supplement possible existing information and to collect new data of importance to the rapid assessment of impacts on the natural and social environment and on possible cultural sites. Data on river ecology and aquatic life is based on existing information.
3) Hydrological time series from relevant hydrological stations will be used to assess the flow regime of Srepok River before and under operation of the hydropower stations.
4) The results from the technical study of NHP will be of major importance to the environmental study, both in relation to the geographical extent of the study and to the magnitude of possible impacts. There is a close connection between the two study endeavors to ensure that both subjects are taken into account in the assessment.

To assess the impacts along the Srepok River in Cambodia, a rapid field survey has been carried out. Both the International and Cambodian team members have taken part in this work. The basis for the rapid field assessment has been to present the baseline conditions of the river and the land affected by the expected changes in the river conditions (flow/water level) and water quality resulting from different operational scenarios of the different Hydropower Projects. These have included the use of the river (water supply, wastewater outflow and navigation etc.) by downstream villagers. The condition and use of terrestrial, aquatic and riverine habitats, fish migrations, socio-economic conditions and the villagers' potential for adaptation to the possible change in river conditions have been evaluated. The impact evaluation is based on one rapid field survey, just after the rainy season.

The description of the baseline conditions is largely based on this field survey. Where other information come from other sources, these sources are referred to in the text.

In addition, a hydrodynamic modeling study has been carried out for the Srepok River from the planned Srepok 3 Hydropower Station in Vietnam to the confluence with the Se Kong River. The results (water level) are presented for about 90 cross-sections along the river in Cambodia. High and low flow situations combined with different operation scenarios of the power station are studied.

The work on this study commenced November 2006 taking into consideration the planned hydropower projects on the Srepok River in Vietnam. After the Draft Final Report was delivered in February 2006, the study team was informed by EVN that it had been decided to construct Srepok 4 and operate it as a re-regulation plant. This presumption has been incorporated into this report.

Even if there might appear limitations in some of the findings, it is the consultant's opinion that the present study is sufficient to meet the objectives described above.

1.3 Study Area

The Srepok River is one of the main tributaries to the Mekong River. It originates in the Southern Highlands in Vietnam and flows into Cambodia. It joins the Mekong River by Stung Treng 45 km south of the border between Cambodia and Laos. The total basin area is about 30,000 km^2 of which 18,000 km^2 lie in Vietnam. The length of the Srepok River on the Cambodian side from the Vietnamese border to the confluence with Se San River is about 245 km. More than one million people live in the whole river basin. Most of the population resides in Vietnam while the Cambodian side is sparsely populated.

The climate is monsoon type with a dry and a wet season. The wet season starts in August and lasts through November. Usually the minimum flow occurs in April and the maximum in October. Deforestation and erosion are reported as the main environmental problems in many parts of the river basin.

The study area is the area along the Srepok River from the border between Cambodia and Vietnam to the confluence of the river with the Se San River and further to the Se Kong River. In addition to the river body itself, the study area comprises adjacent terrestrial areas expected to be affected due to hydropower development on the Vietnamese side of the border. The social study encompasses the riverside villages dependent on the Srepok River as a socio-economic and cultural resource.

1.3.1 Landscape and Ecology

The landscape comprises mostly of open canopy forest dominated by deciduous forest types with largely grassy understory. There are also areas with rubber, fruit orchards and some sugar cane plantations. Near inhabitations agriculture comes into the picture with areas of rice paddies, permanent crops (cashew), secondary crop plants, home gardens, backyard secondary crops, and riverbank crops. As forest dominates the land type in the Srepok basin and particular by the rivers, wildlife is still abundant, unlike along the Se San River. People rely on and use both wild animal and plant resources. Several areas are designated as conservation havens and thus protected. These protected areas (PAs) abound with wildlife. The forested areas thus serve as valuable habitats for wild biological species and provide non-timber forest products for subsistence. Shifting agriculture is generally practiced by tribal/ethnic groups relying on forest areas. Restrictions to obtaining land for agriculture are substantial and enforced where possible. Most often extra land (> 5ha) is obtained by clearing land, often for permanent rice fields or permanent crops like cashew.

1.3.2 Aquatic Ecology

Srepok River is part of the Mekong – Tonle Sap River system that is known to be among the most species rich and fish productive rivers in the world. A large proportion of the fish populations is migrative in nature, and several species undergo migration starting from the Mekong Delta and going, possibly, as far up as in Vietnam. The fish contributes to about 90 % of the protein supply for the population along the river. The river has a gentle slope, and has a large number of deep pools, which makes it possible for large fish specimens to survive during the dry season. The river is the main mode of transportation for the population along the river. The river is not only used for fishing and transport, but also serves as drinking water supply for people and animals, for irrigation, for washing and bathing. The river is clearly the life nerve of the people living in the area.

Fig. 1.1 Srepok River at Krabei Chrum Village, Stung Treng Province

1.3.3 Administrative Areas and Population

The Srepok River in the Cambodian territory runs from the Vietnamese border through areas belonging to the three Northeastern provinces of Mondulkiri, Ratanakiri and Stung Treng. Prior to merging into the Mekong River, the Srepok River first confluences with the Se San River, which also runs from Vietnam through Ratanakiri Province into Stung Treng Province, and then further downstream with the Se Kong River running from Laos. The upstream area closest to the national border is a practically uninhabited wildlife sanctuary in Mondulkiri Province, and only a few villages are located along the river stretch, which forms the border between Mondulkiri and Ratanakiri provinces.

In Mondulkiri Province four villages in Kaoh Nheaek District, Nang Khi Loek Commune are located along the southern bank of the Srepok River. These are Kaoh Moueleu, Koh Meul Krom, Nang Buo and Peam Chi Miet villages.

Across the river a few kilometers downstream on the northern bank lies Kaeng San Village of Seda Commune in Lumphat District, Ratanakiri Province. Further downstream six villages in Chey Otdam Commune in the same district are located along the river: Thmey (=Ban Mai), Dei Lou, Lumphat, Ou Kan, Srae Chhuk and Sam Kha. The next downstream district is Kon Moum where three communes with totally seven villages are located by the Srepok River: Serei Mongkol Commune with Neang Dei, Srae Pok Touch and Srae Pok Thom villages; Trapeang Chres Commune with Sangkum Village; and Srae Ankrong Commune with Phum Muoy, Phum Pir and Phum Bei villages.

Srae Ankrong Commune borders to Se San District in Stung Treng Province where three villages in Kbal Romeas Commune locate along the Srepok River: Krabei Chrum, Kbal Romeas and Srae Sranok. Within the next downstream commune of Phluk the river merges together with the Se San River running northeast of the Srepok River. The river then continues into Samkhuoy Commune and confluences with the Se Kong River.

The areas mostly affected by potential hydropower development in Vietnam are located along the Srepok River down to its confluence with the Se San River. The villages along this river stretch constitute the study area for assessing the likely socio-economic impacts.

The villages in order from up- to downstream are listed in Table 1.1 below and shown in Figure 1.2. It should be noted that:

1) The information on the location of villages along the Srepok River is mainly acquired from respective district authorities and District Health Centers as well as from Commune Chiefs.

2) The administrative borders and names of villages are frequently changed in the study areas, and several of the names appear different on various maps and other sources.
3) The names of villages, communes, districts and provinces and their English transcriptions are taken from SEILA data for the year 2004.
4) Data on the numbers of families and inhabitants is according to the data from SEILA database for the same year.

The North-Eastern Provinces, like the whole country, have been under great recent migrations due to war, calamities and insecurity, Khmer Rouge population politics, repatriation, people seeking land and working opportunities, etc. In Ratanakiri Province more than 20% of the population are migrants, and almost half the migrants originate in other provinces or abroad. In Mondulkiri as much as 46% of the total population are migrants, and over 50% of them come from outside the province. Proportion of the population born in the area, but out-migrated due historical reasons and returned later is likewise rather large, but no figures are available.

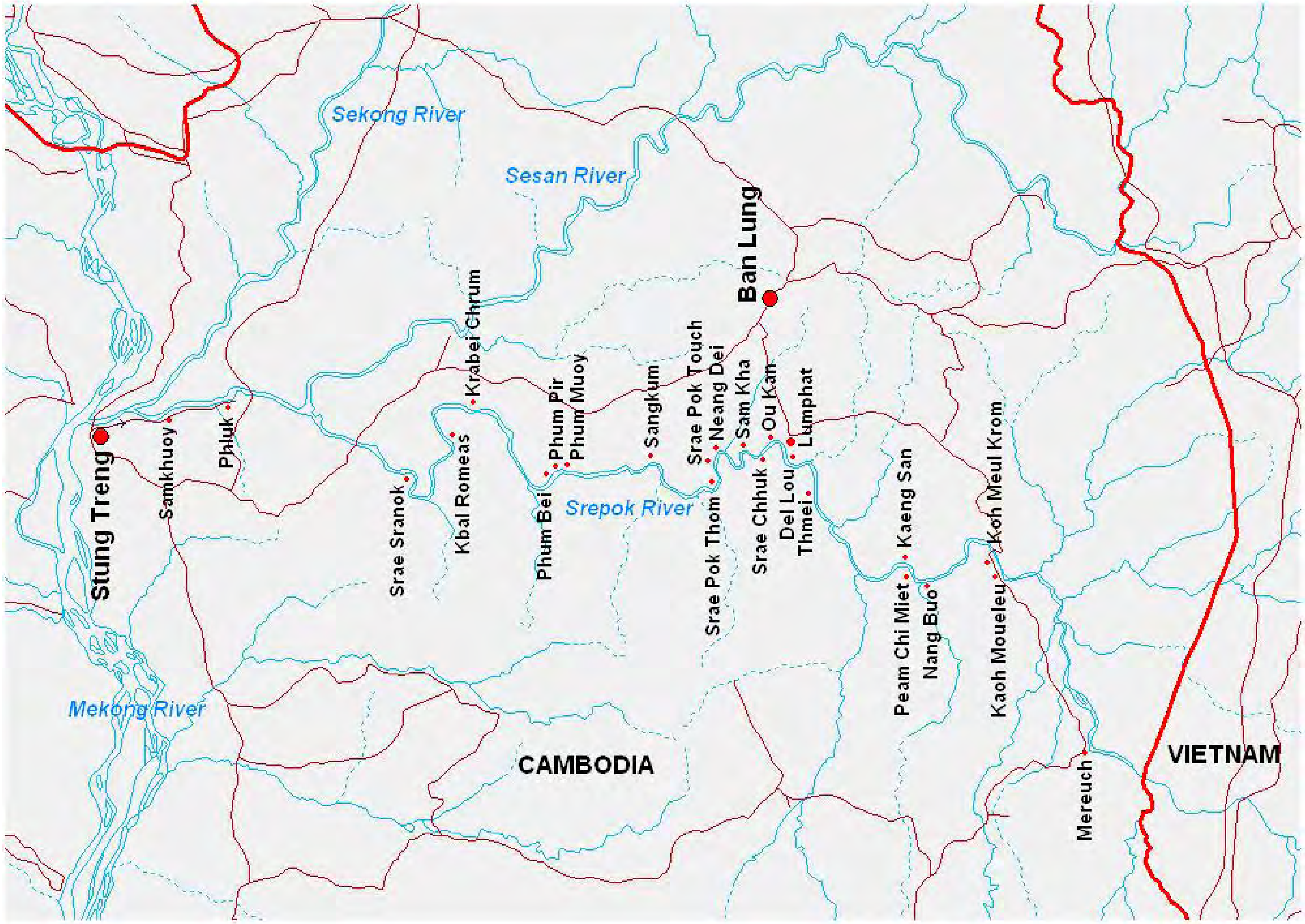

Fig. 1.2 Villages along the Srepok River

Table 1.1 Administrative areas located along the Srepok River from up- to downstream.

Province	District	Commune	Village	No. of families	No. of people
Mondulkiri	Kaoh Nheaek	Nang Khi Loek	Kaoh Moueleu	56	345
			Koh Meul Krom	86	440
			Nang Buo	221	1208
			Peam Chi Miet	96	490
	Total Kaoh Nheaek			459	2,483
Ratanakiri	Lumphat	Seda	Kaeng San	77	432
		Chey Otdam	Thmei	156	715
			Dei Lou	113	520
			Lumphat	159	838
			Ou Kan	70	399
			Srae Chhuk	98	526
			Sam Kha	63	329
	Total Lumphat			736	3,759
	Kon Moum	Serei Mongkol	Neang Dei	31	128
			Srae Pok Touch	121	479
			Srae Pok Thom	148	893
		Trapeang Chres	Sangkum	51	273
		Srae Ankrong	Phum Muoy	71	346
			Phum Pir	101	543
			Phum Bei	111	567
	Total Kon Moum			634	3,229
Stung Treng	Se San	Kbal Romeas	Krabei Chrum	146	696
			Kbal Romeas	97	432
			Srae Sranok	91	426
	Total Se San			334	1,554
TOTAL	4	7	21	2,163	11,025

1.3.4 Ethnicity

Ratanakiri, Mondulkiri and Strung Treng Provinces are traditional areas for Cambodia’s ethnic minority populations, the so-called hill tribes, or indigenous people. A majority of the country’s approx. 101,000 ethnic minority people reside in Ratanakiri (64,000 persons) and Mondulkiri (19,230 persons). The largest ethnic minority groups in these areas are the Tampuon (more than 22,000 in Ratanakiri), the Phnong (18,000 in Mondulkiri), the Jarai (15,670 in Ratanakiri), the Kreung (almost 15,000 in Ratanakiri), the Brao (7,130 in Ratanakiri) and the Kravet (almost 4,000 in Ratanakiri and Stung Treng together) (Data from ADB 2002).

The villages of ethnic minority people are typically located in highland forest areas close to mountain lakes and streams. Along the Srepok River, most of the villages from Lumphat downstream are populated by ethnic Lao people and by majority Khmer, mixed at least to some extent with Phnong, Tampouen, Jarai and Kreung ethnic minority people. Exception to the Lao and Khmer dominance in this area is found in Kbal Romeas commune with Phnong ethnic minority people in Srae Sranok Village. Upstream from Lumphat, Kaeng San Village is more or less inhabited by Tampuon ethnic minority people. An ethnic mix of people with Tampuon, Phnong, Jarai, Lao and Khmer origin lives across the river on the southern bank in the Mondulkiri villages of Nang Buo and Peam Chi Miet. Predominantly Phnong inhabits the two upstream villages of Kaoh Moueleu and Koh Meul Krom. (NGO Forum 2005b, and field data).

1.3.5 Socio-Economic Setting

The Srepok River from the Vietnamese border into Cambodia runs through Mondulkiri Protected Forest Area and continues into Lumphat Wildlife Sanctuary in Ratanakiri Province. This area is characterized by large forests and many different kinds of wildlife, and the riverside is consequently very sparsely populated by humans from the national border down to Lumphat District center. In general, population density in the entire Ratanakiri and Mondulkiri provinces is extremely low, 9, respective 2 persons/km^2, and even lower along the upstream areas of the Srepok River. Both provinces are rural, and the provincial towns comprise the whole urban population.

Villages

The villages along the river are typically located in clusters of a few villages, followed by a long uninhabited stretch of the river down to the next cluster of villages. Houses are located along the riverside, in between the home gardens closest to the river and the paddy fields further up. Subsistence economy is based on rain-fed paddy cultivation and on fishery. Forests bordering to the rice fields provide both firewood and construction material, vegetables, fruit, roots, mushrooms, leaves and other plant items for food and medicine, as well as wild animals for hunting.

Fig. 1.3 Chi Meat Village, Mondulkiri Province

Infrastructure

The basic infrastructure in the Study area is very poor, and many villages are rather inaccessible during the rainy season. The Srepok River is frequently used for travel and transportation wherever road network is poor, like in the upstream villages of Seda and Nang Khi Loek communes. Where road access to villages is more convenient, motorbikes and bicycles have replaced boat transportation to a great extent. Access to electricity is poor. At nighttime, more than 50% of the rural population in Ratanakiri uses resins and firewood for lighting, and 44% have kerosene lamps. For cooking, 98% of the rural population use firewood. (CIPS 2004).

Literacy and Education

Living standards and education levels in the North-Eastern Provinces are the lowest in the whole Cambodia. Ratanakiri Province alone shows the lowest literacy rate in the country. The general literacy rate in Cambodia is 72.8%; but 66.2% for women and 64.2% for rural women (CIPS 2004, for population over 6 years). Education level is rising slowly, but still in 2004, 54% of the literate population (and 63.6% of the literate female population) 25 years and over had not even completed primary level education. The education level and literacy rates among women are in the whole country very much lower than those among men. Likewise, differences between urban and rural areas are significant. Of the total rural population, according to the 1998 population census, the literacy rate of rural women in Ratanakiri Province was 8.5% (47.6% among urban women at the same time) and of rural men 23.4%. In Mondulkiri Province, the literacy rate among rural women was 16.4%, and in Stung Treng Province 31.2%.

The total literacy rate (2004) in Ratanakiri Province is 42.7%, but 38.3% among women. In the riverside villages with ethnic minority populations literacy is significantly lower; in the upstream villages of Mondulkiri Province 30.8% (22.9% among women) and 26.5% (4.6% among women) in Kaeng San village of Ratanakiri Province. In the villages with Lao and Khmer population majority, literacy figures are slightly higher: 47.3% (36.2% among women) in Lumphat District villages; 85.6% (women 80.7%) in Srae Ankrong Commune villages in Kon Moum District; 46% (women 60%) in Kbal Romeas Commune except in Srae Sranok Village with Phnong ethnic minority population where the general literacy rate is 39.4% (37.9% among women).

Lack of teachers, long distances to school, poor infrastructure and poverty all contribute to the remaining low level of education in the Northeastern areas of Cambodia. In the Srepok riverside villages quite generally around 30% of the children in school age do not attend school, slightly higher percentage of girls than boys. However, comparing different villages it is clear that ethnicity and road infrastructure as well as nearness to school play a decisive role for school attendance.

1.3.6 Living and Health Standards

In Ratanakiri a large majority of the population consists of rural ethnic minority people with remote and isolated habitation patterns, poor road- and other infrastructure, and widespread poverty. Especially many ethnic minority women and children in the highland areas do not know the Khmer language, which isolates them from education and communications outside their own group. Among the Khmer, Lao and Vietnamese populations in district centres and in the riverside villages in Kon Moum and Se San Districts where infrastructure is more developed, living standards are better, and so are access to education and health care as well.

The living and health standards in the villages along the Srepok River are in general better compared to those in the highland villages of Ratanakiri Province. Cultivation land is generally sufficient and fishing in the river provides an adequate diet in combination with rice, vegetables and fruit. Less children are undernourished than in the highland villages, according to the district health centers. In most clusters of villages there is a primary school, but usually with only grades 1–2, primarily due to a lack of teachers. A secondary school is available in each district town, but upper secondary school only in the Provincial capital.

In the riverside villages the Srepok River is the main source of water for household use, animals and irrigation. Wells are not common and latrines are rare. According to the district health centers diarrhea and malaria appear during the rainy season and respiratory infections and skin diseases during the dry season in the riverside population. Death cases in these diseases have been reduced considerably, but no figures are available. In every district there is a District Health Center. There is counseling staff and midwives but no doctors working in these centers. Doctors are available only at the provincial hospital.

Currently a structure of Health Posts in commune level is under construction in order to bring the basic health care closer to villages. In Ratanakiri many NGOs like Health

International and Health Unlimited are cooperating with health authorities at province and district level in order to support and develop health services.

Comparison between the different villages along the Srepok River makes it rather evident that the downstream villagers of Lao and Khmer origin are more well-off than the upstream villagers from different ethnic minority groups. Data on e.g. literacy, distance to roads, access to market, ownership of boats and motorbikes shows that the downstream villagers are more privileged than the upstream villagers. The villages upstream from Lumphat district center are more remote and difficult to access than the downstream villagers. Habitation patterns partly follow the ethnic affiliation as well. Development options are therefore slightly varying along the Srepok River, which is further reflected in Chapter 4 below.

1.4 Study Methods

The study has followed internationally recognized methods and guidelines related to the level of evaluation both as to data collection, study subjects of importance, assessment methods and reporting. Mekong River Commission guidelines have been considered.

The environmental impacts from developing the planned Hydropower Projects have been considered by superimposing the proposed project operations onto the existing environmental, social and cultural conditions along the affected Srepok River in Cambodia.

It should be noted that the current study is a rapid assessment of the expected downstream impacts in Cambodia from future hydropower plants along the Srepok River in Vietnam. Detailed EIAs for each hydropower plant will be necessary to point out the specific impacts and related mitigation needed. It is important to note that there is a general lack of baseline data for the region and these may be need to build up such a base.

1.4.1 Study Process

The Study process is described in short in Figure 1.4.

Fig. 1.4 The Study Process

PROJECT DESCRIPTION
↓
BASELINE INFORMATION
↓
FIELD STUDIES
↓
RAPID IMPACT ASSESSMENT
↓
MITIGATION MEASURES
↓
ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

The first step describes the project layout with the project components that are superimposed on the natural conditions in the project area.

Baseline information consists of the existing information on relevant topics – environmental, social and cultural. Based on this data, and parallel with the impact evaluation, the need for further field studies is evaluated in relation to the selected topics and their extent. Information has been derived both from written sources and databases and through consultations with government authorities and NGOs in Phnom Penh and in Ratanakiri and Stung Treng provinces.

Fieldwork was conducted in the study area. In addition to village studies, consultation with provincial, district and commune authorities as well as NGO representatives in Ratanakiri, Stung Treng and Mondulkiri was an integral part of the field study. After the field studies, the data were compiled and analyzed. The impacts were quantified wherever possible. Impacts that could not be quantified are described qualitatively. Evaluation of the significance of the different impacts was done in parallel, leading to consideration of mitigation needs and measures.

Mitigation measures for the potential project impacts identified for both the construction and operation phases are evaluated and described in general. The mitigation measures are at this stage only outlined, and have to be further elaborated on in additional studies, during the future planning of the potential hydropower projects.

Finally, a framework for environmental management and monitoring is suggested.

1.4.2 Study Topics

According to the ToR, the questions of relevance for the Study are related to the aquatic, terrestrial and social environment, and give attention to the topics listed below. Most of these issues are closely interconnected and have therefore been further elaborated and studied in an integrated manner. The methodological approach is both to focus on issues from a specific perspective (aquatic, terrestrial and social) and to consider the issues from an interconnected perspective. This combined approach of an integrated and a specific focus leads to an analysis of interrelated issues in a holistic manner - such as they appear in real life.

Topics Based on the ToR:

Aquatic-related issues

Physical Environment

- Hydrology
- Water Quality
- Erosion, Sediment Transport and Sedimentation
- Water Supply
- Waste Water/Recipient
- Irrigation
- Navigation
- Fishing practices
- Other in stream and riverbank activities (gravel taking, gold panning, clothes washing, recreation activities etc.)

Biological Environment

- Aquatic Life and Fish
- Riverine Flora and Fauna

Terrestrial-related Issues

Physical Environment

- Land use, with special focus on cultivated land
- Riparian and Terrestrial Flora and Fauna
- Settlement overview for the same affected area along the river
- Infrastructure overview for the same area

Social Environment

- Families and people affected
- Impacts on the families food supply, economy and daily life
- Income activities related to the river
- Cultural sites and relics affected

1.4.3 Methodology for an Integrated Field Survey

Integration of Study Issues

Prior to the field study the above study topics were elaborated and structured in order to facilitate a rapid screening of key issues. Available data from existing reports, published literature, maps, statistics, databases, ministries and NGOs formed the basis for the field survey.

These topics related to the aquatic, terrestrial and social environment were then brought into an integrated framework for fieldwork data collection. The issues were rearranged into the following overall topics, referring to the respective three areas of the study:

- People (population, households, ethnicity) – social
- Domestic animals (type, number, breeding, watering, animal health, food) – social, terrestrial and aquatic
- Domestic water (household water, water adequacy/shortage, quality) – aquatic and social
- Land use types, cover, acquisition/access (see also cultivation and forest below) – terrestrial and social
- Cultivation (fields and their locations, crops and their importance, land and food adequacy, irrigation, different types of cultivation lands) – terrestrial and social
- Forest (location, utilization, ownership, hunting, NTFPs) – terrestrial and social
- Plants (different locations in/near river, food, utilization, gathering, food sufficiency/insufficiency, additional income generation) – terrestrial, social and aquatic
- Wildlife (type, frequency, hunting) – terrestrial and social
- Fishing (kind of fish, frequency, methods, food habits, cultural traditions and meanings, development) – aquatic and social
- Other water life (type of animals, utilization, food) – aquatic and social
- Health (waste, diseases, water-related diseases, treatments, health care) – social and aquatic

- Boats and Communications (social networks, traveling, no. of boats, electricity, road traveling) – social and aquatic
- Additional income generating activities (selling of products, trade) – social

These topics were organized into a survey questionnaire for information gathering in the villages, enclosed in Appendix 4. The team selected a limited number of PRA (Participatory Rural Appraisal) tools (see e.g. Calub 2003) and combined them with the survey questionnaire, which was utilized as a checklist of issues to be covered.

Field Team
The field team consisted of four International Consultants (Team Leader, Aquatic Ecologist, Terrestrial Ecologist and Socio-economist) and four Cambodian Consultants (Aquatic Ecologist, Terrestrial Ecologist and two Socio-economists) Representatives for the Ministry of Water resources and Meteorology from Phnom Penh and Ratanakiri facilitated the team with logistics and contacts on province and district levels.

Field Work
The field work was covered by three visits to Cambodia:

1) The Team leader visited Phnom Penh for one week in July 2005 for planning of the main field trip. He visited concerned ministries/directorates and some NGOs, as well as had contacts with Cambodian consultants to participate in the study.
2) The International Aquatic Ecologist visited Phnom Penh for one week in October 2005 and had discussions with concerned ministries/directorates, NGOs and international organizations.
3) The whole field team visited Cambodia for 2.5 weeks in November/December 2005. The team visited concerned ministries/directorates and some central NGOs in Phnom Penh, and provincial, district and commune authorities, as well as affected villages in Ratanakiri, Stung Treng and Mondulkiri Provinces. The field team was based in Ban Lung town in Ratanakiri Province and made daily trips to different districts, communes and villages in the study area. The aim was to collect data on all the districts and communes located along the river and to visit at least two villages in each district.

Field Methodology
The field data collection consisted of semi-structured interviews, observations, village mapping, village walks and photographing. In each studied district area the team first had a meeting with a district administration representative (in most cases the District Chief or his Deputy) and according to the advise from him riverside villages were selected for village visits. District Health Center staff contributed to important district level information as well.

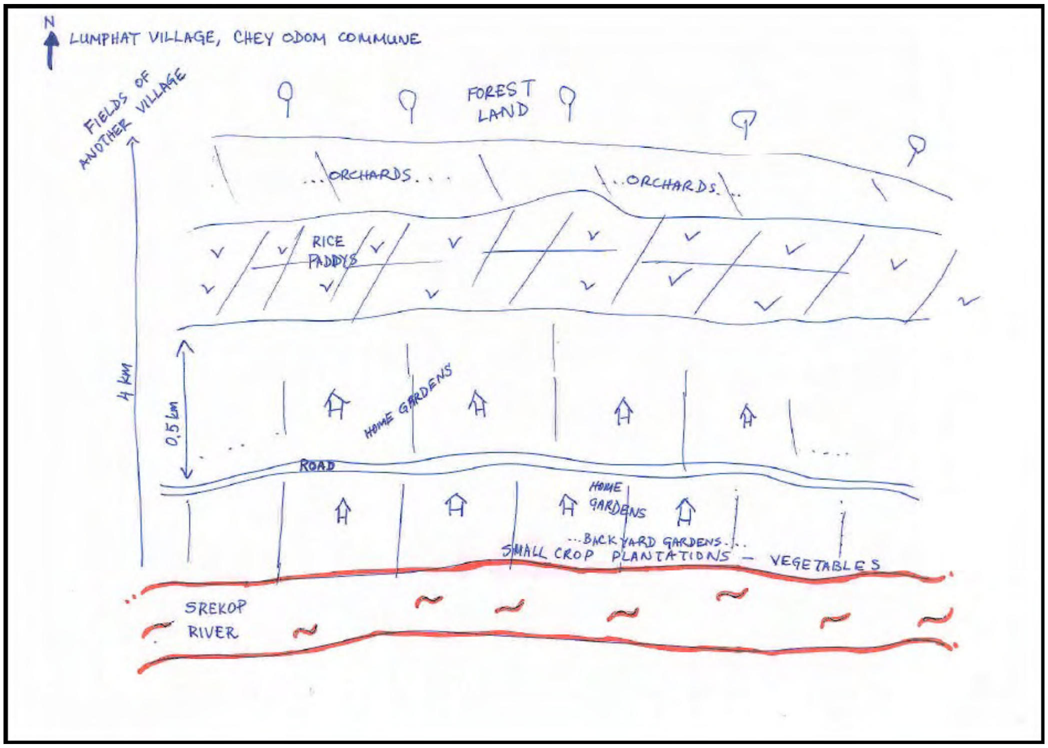

Fig. 1.5 Example of village map (Lumphat Village)

For the village studies the team was divided into smaller groups visiting different villages in order to optimize the time allocated for these visits. The survey questionnaire covering the study topics appeared to be a valuable structured checklist for information gathering. In villages the team was focused on meeting both the village chief and village inhabitants. However, in some visited villages the village chief was not available and instead the team met with another elder person as well as villagers. In some villages the team also had an opportunity to meet the Commune Chief and at one time acquire data for all the villages in the commune in concern. The list of persons met and districts, communes and villages visited is enclosed in Appendix 2.

Vegetation types based on existing classifications and land cover were confirmed. The riverbank vegetation and cultivation types were mapped and surveyed. Riverbank gardens (where started) and home gardens were surveyed in detail to obtain a good understanding of the diversity of food plants and their local importance. Distribution of land use types in relation to homesteads and the Srepok River were also mapped to confirm the configuration provided in the village maps.
Official land use maps were used to delineate the Srepok Riverbank vegetation to estimate the type of vegetation impacted and dependent on the river. Interviews and literature were used to gather information on terrestrial animals. The assistant from MoE covering terrestrial biodiversity had significant local experience (i.e., had published books and papers on local biodiversity) and was thus able to provide vital information on the flora and fauna. The use of the forest, riverbank and hunting (NTFP in general) were issues discussed at length with officials, rangers, villagers (men and women), and national and international NGOs. Understanding the relationship of local people with land (agricultural and forest related) was also a core subject that shed light on dependency, availability, and productivity.

Existing water quality data were collected and evaluated. The river was surveyed and erosion activity and impact were evaluated visually. The risk of eutrophication in the reservoirs, including downstream algal problems, was evaluated by use of predictive models, and pollution loading estimates. Information on fishery and water use were collected by visiting responsible officials at state level, provincial levels, district level, commune levels as well as village levels. In addition the most important NGOs were met with and their experience and opinions were included in the analyses. A study of the fish market in Ban Lung gave valuable information about the fishery. The work was greatly facilitated by participation of an expert from the Department of Fisheries in Phnom Penh, who had great knowledge about the fish species present as well as the fisheries along the river. The collected material was compared with earlier data, and the present river status was described. The likely development and impacts of the planned regulations on the Vietnamese side of the border were evaluated, as well as the need and descriptions for appropriate mitigation measures.

Stakeholder Consultation

Stakeholders consulted in this rapid study were defined into the following categories:

1) People to be affected by future HPP projects. These are the people living in the riverside villages being directly dependent on the river for their subsistence and culture.
2) Public sector agencies: Ministries, provincial and district authorities, and commune leaders.
3) NGOs operating in the Study Area.

These groups were consulted in order to access information and also in order to achieve an insight picture of the current situation in the Study Area from different actors' viewpoint and experience. Different stakeholders also contributed to an assessment of the potential and the threats for future development scenarios in local and regional level.

It should be noted that the current study is a rapid assessment of the expected downstream impacts in Cambodia from future hydropower plants along the Srepok River in Vietnam. Neither all categories of stakeholders like the indirectly affected people nor the specifically vulnerable stakeholder groups like fishermen and women have been possible to arrange consultations with within the allocated time frame. However, the basic needs satisfaction and the rights and risks approach as recommended in both the MRC Hydropower Development Strategy (2001) and in the WCD Report (2000) have been considered in the impact and mitigation assessments in Chapters 5 and 6. The recommendations for future studies and monitoring programs given in Chapter 7 are further based on these international guidelines.

1.4.4 Integration of Data into Impact Assessment

The information collected through the field study was combined and compared with the one acquired from previous studies, reports and statistics. The method to evaluate the liability of different kind of information departed from focusing on one topic at a time, comparing all the available data from different sources. This review was made by each of the International Consultants in respective issues. The evaluation of the specific topics was then integrated into a baseline study.

An assessment of the potential impacts of future hydropower development in Vietnam on the Study Area in Cambodia is based on this study of the present situation. Evaluation of possible positive and negative impacts leads into recommendations of viable mitigation measures to reduce the negative ones for the aquatic, terrestrial and social environment. A further step is to suggest a management and monitoring plan for future hydropower development in the area in order to reduce the negative environmental and social impacts to the least possible. Formulation of a viable management and monitoring plan, however, requires further extensive and detailed feasibility studies, different from the rapid assessment made in the current study. The concluding task of this study is accordingly to propose an agenda for such substantial future studies.

The output from the Study is accordingly:

1) Baseline description;
2) Assessment of the impacts on the Study Area of different scenarios of hydropower development in Vietnam;
3) Recommendations on mitigation measures to reduce the expected negative impacts in the Study Area to a minimum possible;
4) Drafting a management and monitoring plan for future hydropower development;
5) Drafting a Terms of Reference for further detailed feasibility studies in the Study Area.

2. HYDROPOWER PROJECTS ON THE VIETNAMESE PART OF SREPOK RIVER

2.1 General

On the Vietnamese part of Srepok River there are several Hydropower Projects either in operation, under construction, projects that are committed or projects under planning. Projects in the different categories are as follows;

1) Under operation
   - Dray Linh Old
2) Under Construction
   - Buon Koup
   - Ban Tou Srah
   - Dray Linh New
   - Srepok 3
3) Committed
   - Srepok 4 (Construction planned to start 2006)
4) Under Planning
   - Duc Xuyen Main

The different hydropower projects in Srepok River Basin are closer described below.

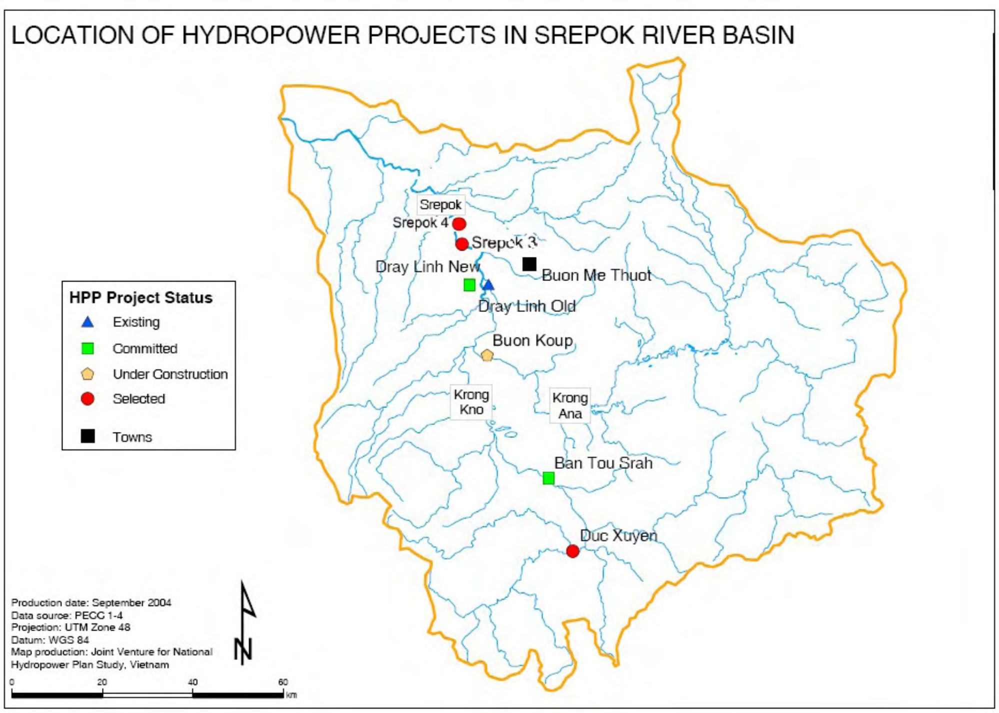

Fig. 2.1 Hydropower Projects in Srepok River, Vietnam (NHP 2005)

2.2 Description of the Hydropower Projects

Main project parameters are taken from the National Hydropower Plan Study for Vietnam (NHP) – Draft Final Report. Some changes may have occurred during detail design.

2.2.1 Projects in Operation

Dray Linh Old Hydropower Project

The Dray Linh Old Hydropower Project is located in Dak Lak Province some 15 km west of Buon Me Thuot Town. The Project comprises an existing embankment dam with an old 12 MW power plant that has not been in operation for some time. The dam requires rehabilitation and the old power station, located on the right side of the river, is also foreseen to be rehabilitated. The Project has a small reservoir with an active storage of 1.5 Mm^3.

The main project parameters for Dray Linh Old Hydropower Project are shown in Table 2.1:

Table 2.1 Project parameters for Dray Linh Old HPP

Item	Unit	Dray Linh Old
Catchment Area	km^2	8,880
Mean Annual Flow	m^3/s	241
Full Supply Level, FSL	m.a.s.l	302
Reservoir Area at FSL	km^2	NA
Minimum Operating Level, MOL	m.a.s.l	299
Reservoir Total Storage	Mm^3	2.9
Reservoir Active Storage	Mm^3	1.5
Maximum Tail Water Level	m.a.s.l	291.2
Minimum Tail Water Level	m.a.s.l	280.8
Maximum Head	m	21.1
Design Head	m	18.5
Minimum Head	m	14.5
Turbine Design Discharge	m^3/s	90
Installed Capacity	MW	12
Annual Average Energy Potential	GWh	100

2.2.2 Projects under Construction

Buon Koup Hydropower Project

Construction of Buon Koup Hydropower Project started in 2003 and commissioning is expected in 2008. The Project is located where Ea Krong Kno and Ea Krong Ana rivers meet, some 30 km southeast of Buon Me Thuot Town in Dak Lak Province. The main features of the Project are a 37 m high homogeneous fill dam and a spillway on the right bank. The power intake has been located in a separate structure on the right bank, about one kilometer upstream from the dam. Two concrete lined tunnels of 4,7 km length and two 250 m long embedded penstocks would convey the flow through a right bend of the river to the two Francis turbines located in an open-air powerhouse. The Project has a small reservoir with a size of 5.6 km^2 at FSL, and an active storage of 14.7 Mm^3, corresponding to less than 1% of the average annual runoff.

According to the Feasibility Study prepared by PECC2, the main project parameters for Buon Koup Hydropower Project would be as shown in Table 2.2:

Table 2.2 Project parameters for Buon Koup HPP

Item	Unit	Buon Koup
Catchment Area	km^2	7,980
Mean Annual Flow	m^3/s	217.0
Full Supply Level, FSL	m.a.s.l	412
Reservoir Area at FSL	km^2	5.6
Minimum Operating Level, MOL	m.a.s.l	409
Reservoir Total Storage	Mm^3	63.2
Reservoir Active Storage	Mm^3	14.7
Spillway Design Flood	m^3/s	11,190
Maximum Tail Water Level	m.a.s.l	318.5
Normal Tail Water Level	m.a.s.l	304.2
Maximum Head	m	109
Design Head	m	94.9
Minimum Head	m	90.5
Turbine Design Discharge	m^3/s	316
Installed Capacity	MW	280
Annual Average Energy Potential	GWh	1,459

Ban Tou Srah Hydropower Project

The Ban Tou Srah Hydropower Project is situated about 14 km downstream of the confluence of Da R'Mang and Ea Krong Kno rivers some 45 km south of Buon Ma Thuot Town in Dak Lak Province.

The Ban Tou Srah Hydropower Project comprises of an embankment dam of 83 m height and a spillway on the right side of the river. The waterway will comprise a 220 m long pressure tunnel of which the last 36 m will be a penstock of steel. The surface powerhouse, with two Francis turbines and a total installed capacity of 86 MW, is located on the left abutment of the dam with the power intake just upstream of a sharp left bend in the river. The Project has a fairly large reservoir with a size of 37,1 km^2 at FSL, and an active storage of 483 Mm^3, corresponding to some 15% of the average annual runoff.

According to the feasibility study by PECC4, the main project parameters for Ban Tou Srah Hydropower Project would be as shown in Table 2.3:

Table 2.3 Project parameters for Ban Tou Srah HPP

Item	Unit	Ban Tou Srah
Catchment Area	km^2	2,930
Mean Annual Flow	m^3/s	99.5
Full Supply Level, FSL	m.a.s.l	487.5
Reservoir Area at FSL	km^2	37.1

Minimum Operating Level, MOL	m.a.s.l	467.5
Reservoir Total Storage	Mm^3	787
Reservoir Active Storage	Mm^3	483
Spillway Design Flood	m^3/s	4,449
Maximum Tail Water Level	m.a.s.l	441.8
Normal Tail Water Level	m.a.s.l	430.5
Maximum Head	m	58.1
Design Head	m	47
Minimum Head	m	36.1
Turbine Design Discharge	m^3/s	204.9
Installed Capacity	MW	86
Annual Average Energy Potential	GWh	358.4

Dray Linh New Hydropower Project

The Dray Linh New Hydropower Project is located in Dak Lak Province some 15 km west of Buon Me Thuot Town. The Project comprises an existing embankment dam, which requires rehabilitation, a 250 m long canal to the intake structure and four 35 m long concrete penstocks. The new power plant, equipped with two Kaplan turbines, is proposed to be built on the left side of the river. The Project has a small reservoir with an active storage of only 1.5 Mm^3.

According to the River Basin Planning Report prepared by PECC2, the main project parameters for Dray Linh New (Extension) Hydropower Project would be as shown in Table 2.4:

Table 2.4 Project parameters for Dray Linh New HPP

Item	Unit	Dray Linh New
Catchment Area	km^2	8,880
Mean Annual Flow	m^3/s	241
Full Supply Level, FSL	m.a.s.l	302
Reservoir Area at FSL	km^2	NA
Minimum Operating Level, MOL	m.a.s.l	299
Reservoir Total Storage	Mm^3	2.9
Reservoir Active Storage	Mm^3	1.5
Maximum Tail Water Level	m.a.s.l	291.2
Normal Tail Water Level	m.a.s.l	280.8
Maximum Head	m	21.1
Design Head	m	18.5
Minimum Head	m	14.5
Turbine Design Discharge	m^3/s	101
Installed Capacity	MW	16
Annual Average Energy Potential	GWh	94

Srepok 3 Hydropower Project

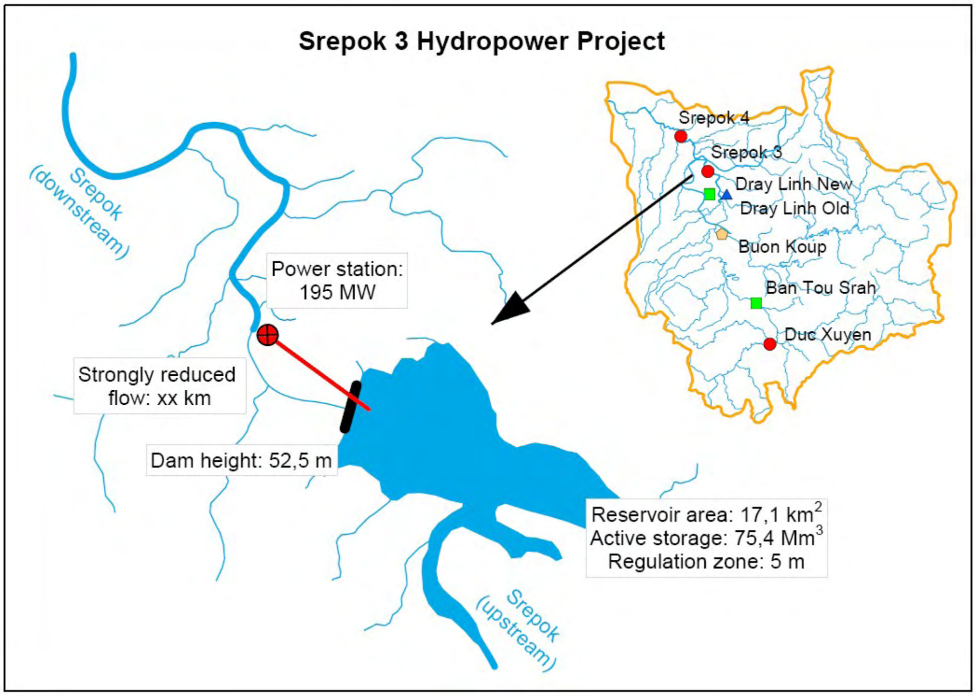

Fig. 2.2 Map of Srepok 3 project area.

Fig. 2.3 Srepok 3 dam site viewed from downstream right side

The Srepok 3 Hydropower Project would be located on Srepok River, some 5 km west of the Tan Hoa village on Highway No. 681 between Buon Me Thuot and Ban Don.

The salient features of the recommended development of Srepok 3 Hydropower Project are given in the table below:

Table 2.5 Project parameters for Srepok 3 HPP

Item	Unit	Srepok 3
Catchment Area	km^2	9,410
Mean Annual Flow	m^3/s	251
Full Supply Level, FSL	m.a.s.l.	272.0
Reservoir Area at FSL	km^2	17.1
Minimum Operating Level, MOL	m.a.s.l.	267.0
Reservoir Regulation	m	5
Reservoir Total Storage	Mm^3	223
Reservoir Active Storage	Mm^3	75
Maximum Tail Water Level	m.a.s.l.	221.2
Normal Tail Water Level	m.a.s.l.	207,5

Design Head	m	62.5
Turbine Design Discharge	m^3/s	396.6
Installed Capacity	MW	220
Average Annual Energy Production	GWh	1,002

Hydrology

The inflow series for Srepok 3 Hydropower Project have been derived from the monthly flow series from the Cau 14 gauging station. The derived natural monthly inflow series for Srepok 3 Hydropower Project for the period 1977 to 2002 are given in Table 2.12 indicating a mean annual discharge of 250 m^3/s.

Discharges at various durations, based on monthly data, is given in the table below:

Table 2.6 Natural discharges at various durations at Srepok 3 dam site

Duration, %	Discharge, m^3/s
5	613
10	541
90	58.1
95	46.6

The basic statistics of the derived natural mean annual inflow series at Srepok 3 dam site is presented in the table below:

Table 2.7 Statistical parameters of the natural mean annual inflow series at Srepok 3 dam site

Dam Site	Basin Area (km^2)	Mean Annual Flow (m^3/s)	Mean Annual Flow (Mm^3)	Mean Annual Flow (l/skm^2)	Minimum Annual Flow (m^3/s)	Maximum Annual Flow (m^3/s)
Srepok 3	9,410	250.6	7,894	26.6	137	423

The natural average monthly inflows at Srepok 3 dam site is summarized in the table 2.8:

Table 2.8 Natural average monthly inflow at Srepok 3 dam site (m^3/s)

Dam Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Srepok 3	152	90	66	68	116	192	236	351	440	538	436	321

The following design floods were estimated by PECC2 in the Pre-feasibility Study on Srepok 3 Hydropower Project:

Table 2.9 Flood peak values for different return periods at Srepok 3 dam site (m^3/s)

Dam Site	Return Period, Years	
	100	1,000
Srepok 3	7,440	12,320

2.2.3 Committed Projects

Srepok 4 Hydropower Project

The site of Srepok 4 Hydropower Project would be situated just downstream of Srepok 3 Power Station some 12 km southeast of Ban Don village.

The rational of Srepok 4 Hydropower Project, being the most downstream project in a cascade development of Srepok River, is to provide re-regulation of the intermittent outflow from Srepok 3 Hydropower Project and thus provide a steady flow without daily variations into Cambodia. According to EVN the project is committed and construction will start 2006.

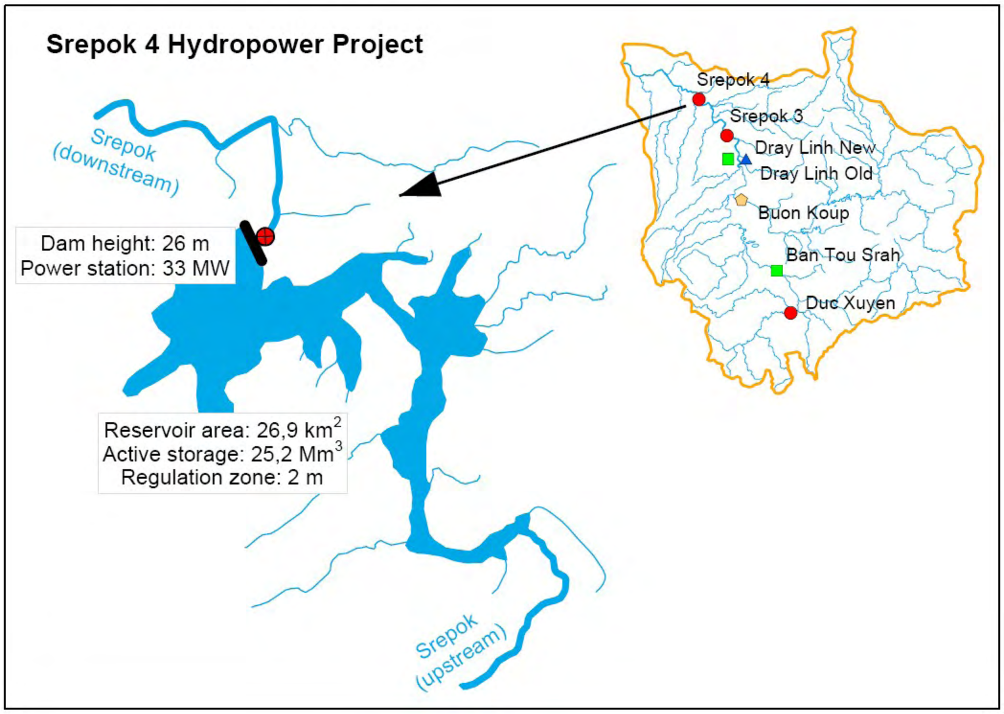

Fig. 2.4 Map of Srepok 4 project area

Fig. 2.5 Srepok 4 new dam site viewed from upstream right side

The salient features of the recommended development of Srepok 4 and Srepok 3 and 4 combined are given in the table below:

Table 2.10 Project parameters for Srepok 3 and 4

Item	Unit	Srepok 3	Srepok 4	Srepok 3 and 4
Catchment Area	km^2	9,410	9,523	9,523
Mean Annual Flow	m^3/s	250	253	
Full Supply Level, FSL	m.a.s.l.	272.0	206	
Reservoir Area at FSL	km^2	17.1	3,4	20.5
Minimum Operating Level, MOL	m.a.s.l.	267.0	202.5	
Reservoir Regulation	m	5	3.5	
Reservoir Total Storage	Mm^3	222	27	249
Reservoir Active Storage	Mm^3	77	11.5	88.5

Maximum Tail Water Level	m.a.s.l.	221.2	190	
Normal Tail Water Level	m.a.s.l.	208.0	185	
Design Head	m	62.5	20	
Turbine Design Discharge	m^3/s	408.6	383	
Installed Capacity	MW	220	65	285
Average Annual Energy Production	GWh	1,002	299	1,301

Hydrology

The inflow series for Srepok 4 Hydropower Project have been derived from the monthly flow series from the Ban Don gauging station.

Discharges at various durations, based on monthly data, is given in the table below:

Table 2.11 Natural discharges at various durations at Srepok 4 dam site

Duration, %	Discharge, m^3/s
5	619
10	550
90	62.8
95	49.7

The basic statistics of the derived natural mean annual inflow series at Srepok 4 dam site is as shown in Table 2.17:

Table 2.12 Statistical parameters of the natural mean annual inflow series at Srepok 4 dam site

Dam Site	Basin Area (km^2)	Mean Annual Flow (m^3/s)	Mean Annual Flow (Mm^3)	Mean Annual Flow (l/skm^2)	Minimum Annual Flow (m^3/s)	Maximum Annual Flow (m^3/s)
Srepok 4	9,523	252.9	7,966	26.6	139	423

The natural average monthly inflows at Srepok 4 dam site is summarized in the table below:

Table 2.13 Natural average monthly inflow at Srepok 4 dam site (m^3/s)

Dam Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Srepok 4	153	91	67	69	118	195	238	355	445	543	439	322

The following design floods were estimated for Srepok 4 Hydropower Project in the River Basin Planning Report by PECC2:

Table 2.14 Flood peak values for different return periods at Srepok 4 dam site (m^3/s)

Dam Site	Return Period, Years	
	100	1,000
Srepok 4	7,840	12,700

2.2.4 Hydropower Projects under Planning

Duc Xuyen Main Hydropower Project

The Duc Xuyen main Hydropower Project would be the most upstream project in the cascade of Srepok River, and with the main dam situated some 5 km west of Don Du village on Highway No. 27 between Da Lat and Buon Me Thuot. The Project would be located partly in Dak Lak Province and partly in Lam Dong Province.

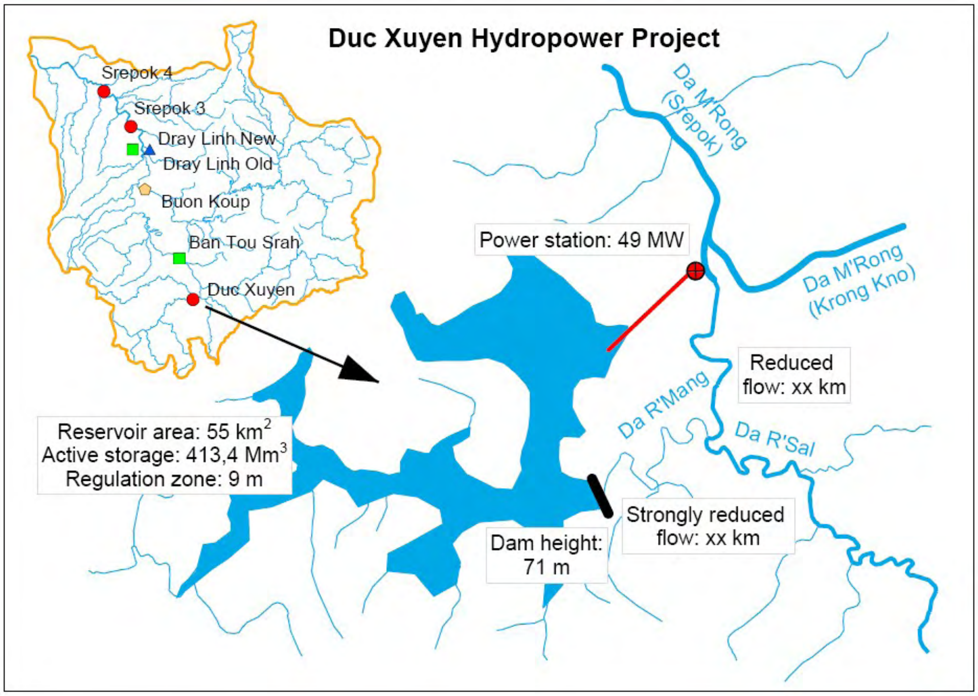

Fig 2.6 Map of Duc Xuyen project area

Fig 2.7 Dam site of Duc Xuyen Main Hydropower Project

The salient features of the recommended development of Duc Xuyen Main Hydropower Project are given in the table below:

Table 2.15 Project parameters for Duc Xuyen Main HPP

Item	Unit	Duc Xuyen Main
Catchment Area	km^2	1,100
Mean Annual Flow	m^3/s	42
Full Supply Level, FSL	m.a.s.l.	560
Reservoir Area at FSL	km^2	55.6
Minimum Operating Level, MOL	m.a.s.l.	551
Reservoir Regulation	m	9
Reservoir Total Storage	Mm^3	1,088
Reservoir Active Storage	Mm^3	413.5
Maximum Tail Water Level	m.a.s.l.	497.5
Normal Tail Water Level	m.a.s.l.	486.0
Design Head	m	71

Turbine Design Discharge	m^3/s	111,7
Installed Capacity	MW	70
Average Annual Energy Production	GWh	255

Hydrology

The inflow series for Duc Xuyen Main Hydropower Project have been derived from the monthly flow series from the Duc Xuyen gauging station. The derived natural monthly inflow series for Duc Xuyen Main Hydropower Project for the period 1977 to 2002 are indicating a mean annual discharge of 42 m^3/s.

Discharges at various durations, based on monthly data, is given in the table below:

Table 2.16 Natural discharges at various durations at Duc Xuyen Main dam site.

Duration, %	Discharge, m^3/s
5	113
10	94.2
90	10.3
95	8.7

The basic statistics of the derived natural mean annual inflow series at Duc Xuyen Main dam site is presented in the table below:

Table 2.17 Statistical parameters of the natural mean annual inflow series at Duc Xuyen Main dam site.

Dam Site	Basin Area (km^2)	Mean Annual Flow (m^3/s)	Mean Annual Flow (Mm^3)	Mean Annual Flow (l/skm^2)	Minimum Annual Flow (m^3/s)	Maximum Annual Flow (m^3/s)
Duc Xuyen Main	1,100	42.2	1,329	38.4	21.7	73.6

The natural average monthly inflows at Duc Xuyen Main dam site is summarized in the table below:

Table 2.18 Natural average monthly inflow at Duc Xuyen Main dam site (m^3/s)

Dam Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Duc Xuyen Main	22.7	14.8	11.7	11.9	18.1	32.6	41.8	73.1	82.1	94.3	62.1	41.6

Flood Flows

The following design floods were estimated by PECC2 in the Pre-feasibility Study on Duc Xuyen Hydropower Project:

Table 2.19 Flood peak values for different return periods at Duc Xuyen Main dam site (m^3/s)

Dam Site	Return Period, Years	
	100	1,000
Duc Xuyen Main	2,620-2,650	4,420-4,520

2.3 Hydropower Projects on Cambodian Side of Srepok River

On the Cambodian side of Srepok River one project, Lower Srepok 2 Hydropower Project, was recommended as one of six projects in a study by Halcrow in 1999 (Se Kong-Se San and Nam Thuen River Basins Hydropower Study) financed by ADB.

The Project is located just upstream of the confluence with Se San River and would involve a 25 m high fill dam creating a reservoir with an area of 120 km^2 and a total storage of 420 Mm^3 at a FSL of +70 m. No active storage was proposed, i.e. run-of-river, and the Project would therefore benefit from upstream storage developments in Srepok River on the Vietnamese side. Installed capacity was estimated to 222 MW generating 1,174 GWh/year on average.

A Japanese investor (Chugoku Electric Power Co., Inc) has carried out a pre-feasibility study on the Project (2004) and suggested to lower the FSL to +67.8 m, to avoid resettlement of people, thereby reducing the installed capacity to 195 MW and the annual average generation to 1,034 GWh.

According to unconfirmed information to the team, the Asian Development Bank has recently engaged a Japanese company to conduct an EIA study for this project that is located near the confluence between the Srepok and the Se San Rivers.

3. HYDROLOGY AND FLOW CHARACTERISTICS

The river flow in the Srepok is the basis for the aquatic life, the terrestrial ecology near the river and hence the livelihood for people living adjacent to the river. The baseline conditions in and along the Srepok River are based on the natural hydrological situation as described below.

Hydropower development in Vietnam will cause impacts downstream the power plants. One of the reasons for these impacts is the change in the hydrology due to the operation modes of the power stations. To illustrate the change in the hydrology, hydrodynamic modeling (Srepok River – Hydrodynamic Modeling - PECC4, 2005) has been carried out for 3 example scenarios of operation. The report is attached as Appendix 7 (separate volume) to this report and some of the main conclusions are presented below in this chapter.

There are four discharge gauging station in operation within Srepok River Basin on the Vietnamese side. The Giang Son station is located in the lower reaches of the Krong Ana River and Duc Xuyen discharge stations on Krong Kno River. Two other stations i.e. Cau 14 and Ban Don are located on Srepok River below the confluence of Krong Ana and Krong Kno rivers.

The available hydrological information constitutes a relatively good basis for the estimation of inflow series for the selected hydropower projects within Srepok River Basin, and for other characteristic locations The selected Srepok 3 and Srepok 4 Hydropower Projects, located on the main stream of Srepok River, provide high quality inflow series.

The inflow series for the selected hydropower projects have been derived using simple area scaling to transpose the monthly series of discharge from the base stations to the different dam sites and other locations of interest.

Table 3.1 show mean monthly flow values at the Srepok 4 dam site, at the border between Vietnam and Cambodia, at Lumphat and at the confluence between Srepok and Se San rivers. The monthly values are calculated using simple area scaling with the inflow values at Srepok 4 as bases (NHP-Hydrological Report).

In the same table are also given flow values representing the undeveloped catchment downstream Srepok 4 (no hydropower projects). For instance there will still be natural runoff from a catchment of 8.477 km2 at the border, 17.270 km2 at Lumphat and 20.477 km2 at the confluence with Se San. In addition to the flow from the undeveloped downstream catchment comes the regulated flow passing Srepok 4 HPP.

Fig.3.1 Map of the Srepok River with hydrological measuring stations indicated as red spots

		January	February	March	April	May	June	July	August	Sept	October	Nov	Dec	Year
Before HPP in Vietnam	Total Catchment Area (km2)													
Srepok IV Dam Site (9.523 k	9523	153	91	67	69	118	195	238	355	445	543	439	322	253
Border (18.000 km2)	18000	289	172	127	130	223	369	450	671	841	1026	830	609	478
Lom Phat 26.793 km3)	26793	430	256	189	194	332	549	670	999	1252	1528	1235	906	712
Se San confluence (30.000k	30000	482	287	211	217	372	614	750	1118	1402	1711	1383	1014	797
After HPP Development in Vietnam*	Catchment Area undeveloped (km2)													
Border	8477	136	81	60	61	105	174	212	316	396	483	391	287	225
Lom Phat	17270	277	165	122	125	214	354	432	644	807	985	796	584	459
Se San confluence	20477	329	196	144	148	254	419	512	763	957	1168	944	692	544

*natural hydrological runoff from catchment downstream Srepok IV, regulated flow from Srepok IV comes in addition

Table 3.1 Mean Monthly and Yearly Flow Values at selected Locations on Srepok River

3.1 Hydropower Operation Scenarios

The Hydrodynamic Modeling Study has studied five different flow scenarios. For each scenario a low and high flow is considered. The scenarios and the main results are described below.

3.1.1 Scenario 1 – Baseline

Due to lack of historical data the baseline scenario is based on daily discharge mean values from Ban Don hydrometeorological station. Since the lowest flow generally occurs in April and the highest in October, the mean values for these months (1977-2002) have been selected as baseline scenario. Thus, the discharge representing the low flow season is 72 m^3/s (April mean flow at Ban Don 1977-2002) and the high season is represented by 595 m^3/s (October mean flow at Ban Don 1977-2002).

The relation between the flow at Ban Don and further down in the system can not be clearly defined from the available data, but in order to obtain a synthetic baseline scenario, the flow at Ban Don (upstream area 10700 km^2) has been scaled to the other tributaries and catchments, see Table 3.2.

Table 3.2. Scaling of discharge recordings from Ban Don to other inflows to the model.

Inflow	Area (km^2)	Low flow (m3/s)	High flow (m3/s)
Ea Hleo (river)	5200	34	292
Ea Drang (river)	2400	16	135
Ban Don – Lom Phat (catchment)	9670	63	542
Lom Phat – Se San (catchment)	2990	20	168
Se San (river)	18820	133	2120

*Se San discharges are not scaled since results from a hydraulic model is used (mean values for discharge during April and October).

3.1.2 Scenario 2 – Srepok 3 turbine design discharge

Srepok 3 is planned for a turbine design discharge of 420 m^3/s. The spillway rules are not defined, but three hydrographs has been tested (rectangular shaped hydrographs with 1, 3 and 6 hour duration). The base flow for these simulations are taken from computer runs for different production strategies of the hydropower stations (SWECO, 2005). The lowest starting level during the optimizing period (discharge 50 m^3/s) is selected in order to evaluate the largest water level change due to the operation of Srepok 3. For other tributaries and catchments, Table 3.2. is used.

3.1.3 Scenario 3 – Srepok 3 flood storage

This scenario evaluates the capacity of the reservoir to dampen high flows. The flow peak (3220 m^3/s) from October 2000 is used as input data. At the start of the simulation, the water level in the reservoir is at full supply level (+272 m). As the peak enters the water level is allowed to rise to full capacity level (+275 m).
By using the storage capacity of the reservoir between these levels the peak from October 2000 can be reduced by 230 m^3/s to 2990 m^3/s, see Figure 3.2. Note that the duration of the flood peak is somewhat longer due to the fact that the same volume of water has to be released.

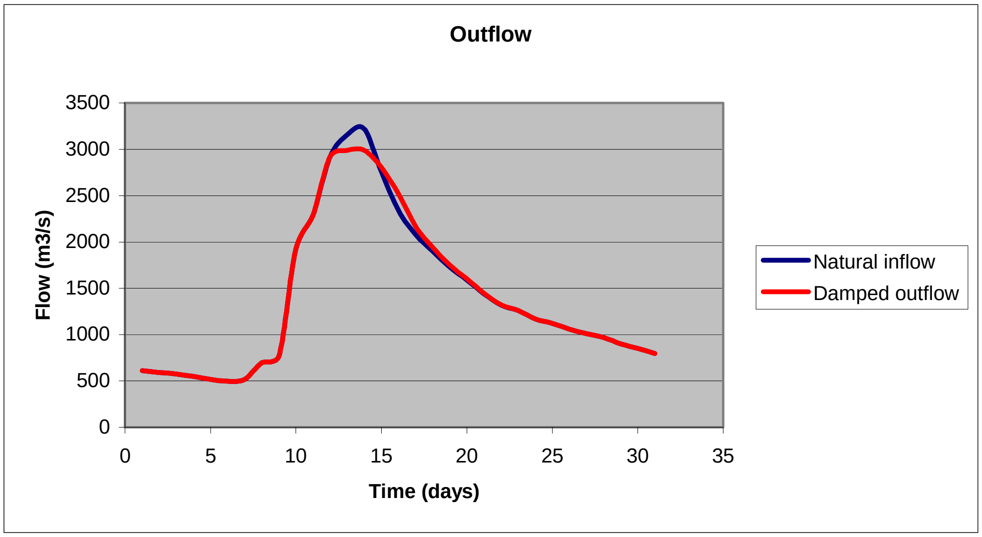

Figure 3.2. The reduction of peak flow October 2000 due to storing in Srepok 3 reservoir.

3.1.4 Scenario 4 – Srepok 4 high operational discharge

Srepok 4 high operational discharge is evaluated with respect to the largest difference between two subsequent weekly values in the optimizing simulations (SWECO, 2005). The selected sequence is when the flow increases from 195 to 418 m^3/s, a sudden increase in river flow of 223 m^3/s. The simulation is run for a two week period, i.e. on day 7, the flow rises instantly from the lower to the higher figure.

3.1.5 Scenario 5 – Srepok 4 mean operational discharge (Re-regulation Reservoir)

Srepok 4 mean operational discharge is evaluated with respect to the mean difference between two subsequent weekly values in the optimizing simulations (SWECO, 2005). The selected sequence is when the flow increases from 125 to 138 m^3/s, a sudden increase in river flow of 13 m^3/s. The selection of new discharges is based on mean flow (125 m^3/s) and mean increase of flow between two subsequent weeks (13 m^3/s). The corresponding water level change is 6-8 cm along the river. The simulation is run for a two week period, i.e. on day 7, the flow rises instantly from the lower to the higher figure.

3.2 Main Results from the Hydrodynamic Modeling Study

3.2.1 Scenario 1 - Baseline

By analyzing water level recordings from Ban Don (1995-2003), Lumphat (2000-04) and Stung Treng (1998-2004) a general pattern of the water level fluctuation can be seen. A comparison of normal water level fluctuations is presented in Table 3.2.

Table 3.3. Normal water level change in meters in Srepok River at two locations as defined by 50% occurrence, i.e. 50 % of the days in one year, these water level changes can be expected

Water level change (m)	Lumphat		Stung Treng	
	Low flow (April)	High flow (October)	Low flow (April)	High flow (October)
50% occurrence	0.02	0.31	0.02	0.09

From Table 3.3 the conclusion is that during 50% of the time in the dry seasons no sudden changes in water level is expected. In the wet season water level changes of 0.1-0.3 m can be expected along the river during 50% of the time.

It is also of interest to see how often larger changes in water level occur. Three levels have been selected for the analysis; 0.3, 0.5 and 1.0 m. The selection of levels is based on the Downstream Hazard Classification Guidelines (U.S. Department of Interior, 1988) developed to evaluate downstream effects of flood waves due to dam breaks. The two higher levels represents the level at which children and adults respectively are in danger (valid for slow moving water). For velocities of 0.5-1.0 m/s, (a velocity span that characterizes Srepok river) 0.3 and 0.5 m/s are more accurate levels for potential danger for children and adults, respectively. The occurrence of these fluctuations is presented in Table 3.4.

Table 3.4. Water level change (0.3, 0.5 and 1.0 m) in Srepok River (without regulation) at two locations and their occurrence, presented as percentage of time

Water level change (m)	Lumphat		Stung Treng	
	Low flow (April)	High flow (October)	Low flow (April)	High flow (October)
0.3 m	2%	52%	1%	7%
0.5 m	2%	31%	1%	2%
1.0 m	1%	15%	0%	1%

Concluding remarks regarding Table 3.3 and 3.4 is that there exist water level fluctuations in Srepok River under natural conditions, but not during all seasons of the year, except for rare occasions, which may occur all times of the year. In the low flow season water level changes exceeding 0.3 m (daily values) are very rare. Expected fluctuation is less than 0.1 m. In the high flow season water level changes (daily values) up to 0.3 m are relatively frequent and water level changes exceeding 0.5 and 1.0 m occurs a few times every year.

3.2.2 Scenario 2 – Srepok 3 Turbine Design Discharge

The downstream effects when running the turbines at full capacity during 1, 3, and 6 hours per day is presented in Fig. 3.3–3.6 below. Two scenarios have been studied, low and high flow season.

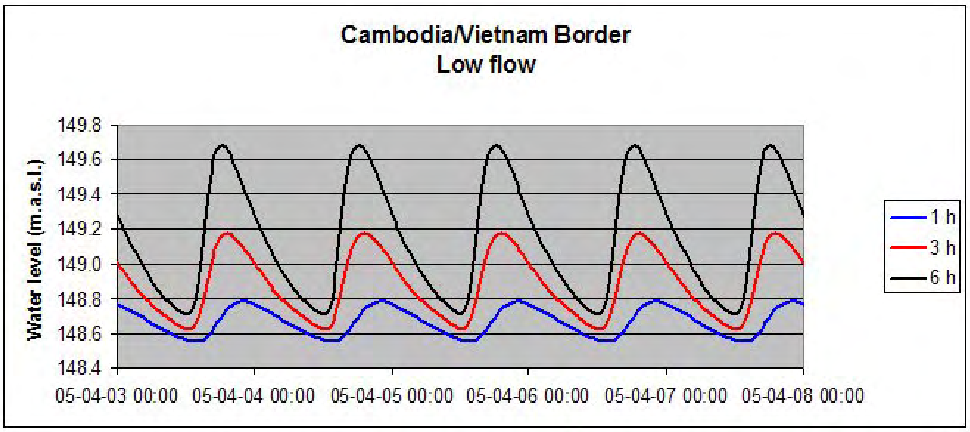

Fig. 3.3 Water level fluctuation during low flow at the border between Vietnam and Cambodia when Srepok 3 is running at full capacity for 1, 3 and 6 hours in 24 hour periods, respectively

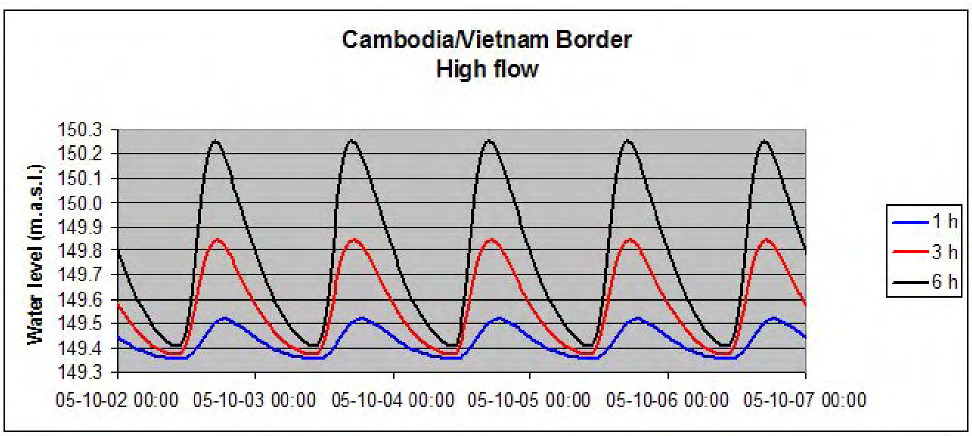

Fig 3.4 Water level fluctuation during high flow at the border between Vietnam and Cambodia when Srepok 3 is running at full capacity for 1, 3 and 6 hours in 24 hour periods, respectively

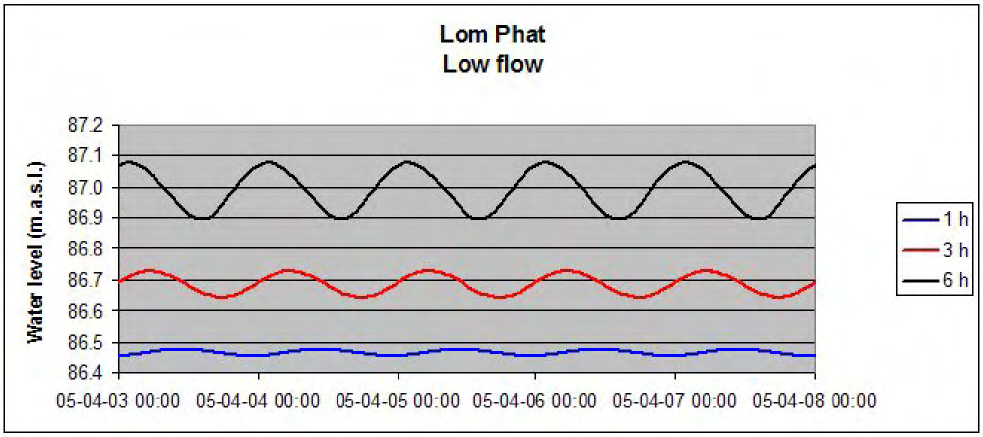

Fig 3.5 Water level fluctuation during low flow at Lumphat when Srepok 3 is running at full capacity for 1, 3 and 6 hours in 24 hour periods, respectively

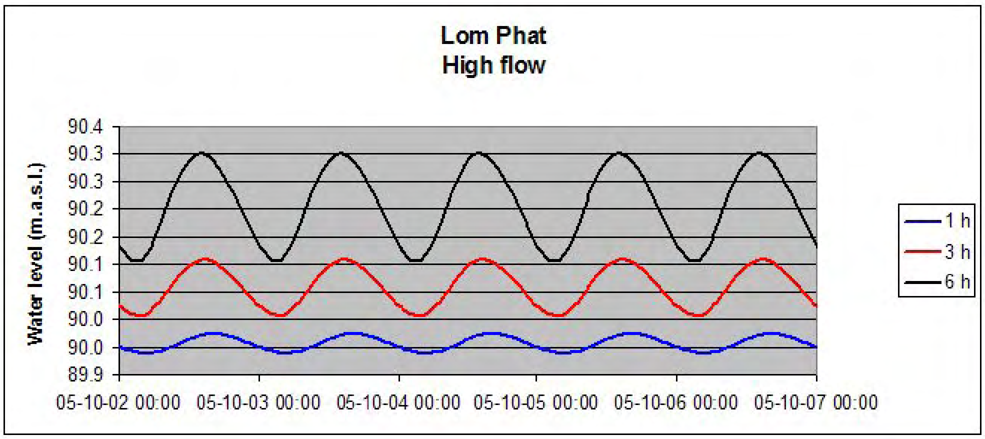

Fig. 3.6 Water level fluctuation during high flow at Lumphat when Srepok 3 is running at full capacity for 1, 3 and 6 hours in 24 hour periods, respectively

At the Cambodian border (80 km downstream Srepok 3), running Srepok 3 at full capacity 1, 3 and 6 hours yields water level changes up to 0.1, 0.4 and 1.0 m respectively. These figures are slightly lower in the high flow season. These fluctuations are expected to decrease further down the river, for instance 0.05, 0.1 and 0.2 m respectively at Lumphat.

There is some difference between the water level changes in low and high flow season. Generally in the high flow season the change in water level is smaller than during the low flow season due to the fact that the river cross-sections are wider in the upper part banks. The difference ranges from 0.05 up to 0.2 m.

3.2.3 Scenario 3 – Srepok 3 Flood Storage

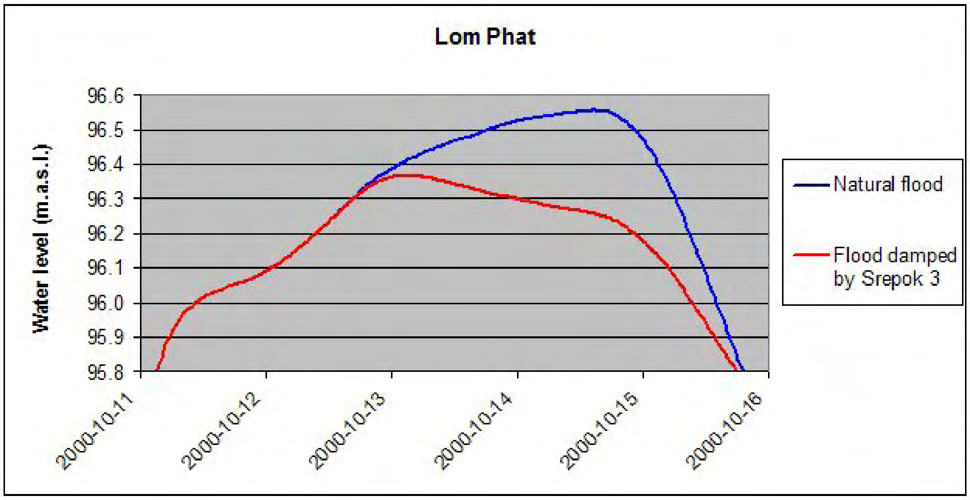

Fig. 3.7 Reduction of the peak flood at Lumphat due to the Srepok 3 reservoir

The volume of Srepok 3 reservoir is not designed to manage extreme floods. A small reduction of the peak flow (from 3220 to 2990 m^3/s) result in the reduction of water level as presented in Figure 3.7. In general, a water level reduction of 0.2 to 0.4 m can be expected along Srepok River as a result of the Srepok 3 reservoir.

3.2.4 Scenario 4 - Srepok 4 High Operational Discharge

Water level changes due to sudden operational discharges from Srepok 4 are expected to 0.8-1.0 m along Srepok River in Cambodia (Srepok 4 **not** operated as a re-regulation reservoir). See Figures 3.8 – 3.10.

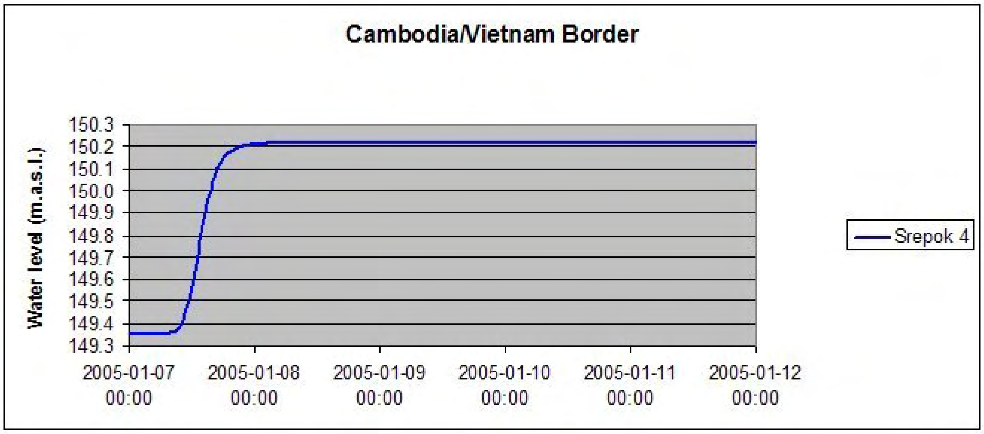

Fig. 3.8. Delay in water level fluctuation at the border between Vietnam and Cambodia due to sudden release from the Srepok 3 reservoir

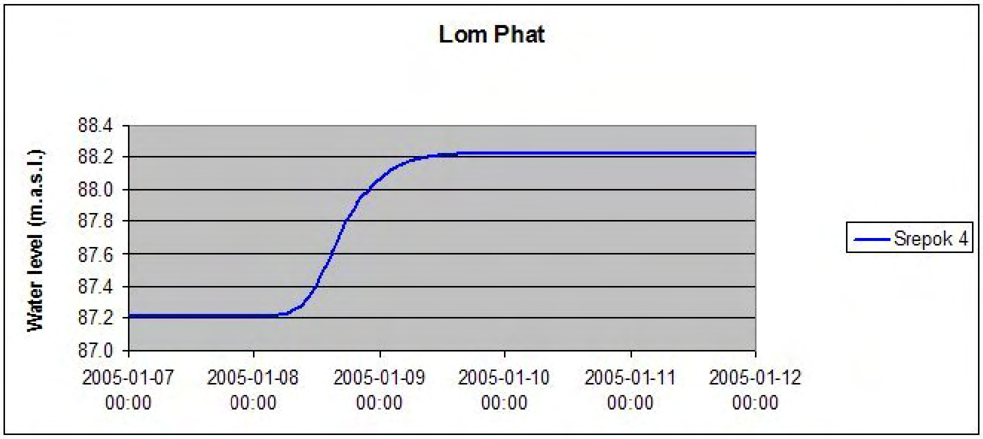

Fig. 3.9. Delay in water level fluctuation at Lumphat due to sudden release from the Srepok 3 reservoir

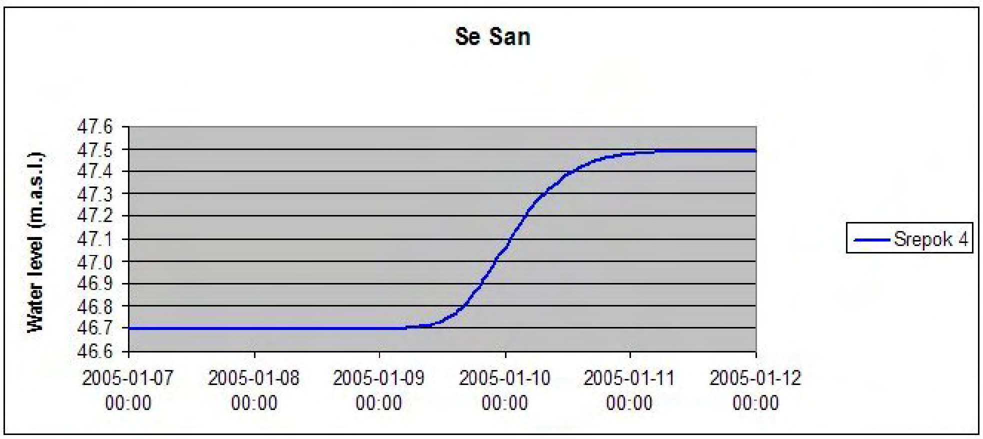

Fig. 3.10. Delay in water level fluctuation at the confluence between the Srepok and the Se San Rivers due to sudden release from the Srepok 3 reservoir

3.2.5 Scenario 5 – Srepok 4 Mean Operational Discharge (Re-regulation Reservoir)

Water level changes due to operational discharges from the re-regulating reservoir Srepok 4 is expected to increase the water level less than 0.1 m along Srepok river in Cambodia during normal operation, as shown in Fig. 3.11 – 3.13.

From the simulations shown in Figures 3.08 – 3.13, the flow time from Srepok 4 to the border between Vietnam and Cambodia, to Lumphat and to the confluence between Srepok and Se San rivers can be calculated. To the three locations the flow time will be about 7, 30 and 57 hours respectively. At the border it will take about 15 hours for the flow wave to reach its maximum. The raising time at Lumphat and Se San confluence are about 33 and 46 hours.

As seen from Scenario 5, using Srepok 4 as a re-regulation reservoir will under normal operation minimize daily water level variations to a very low level.

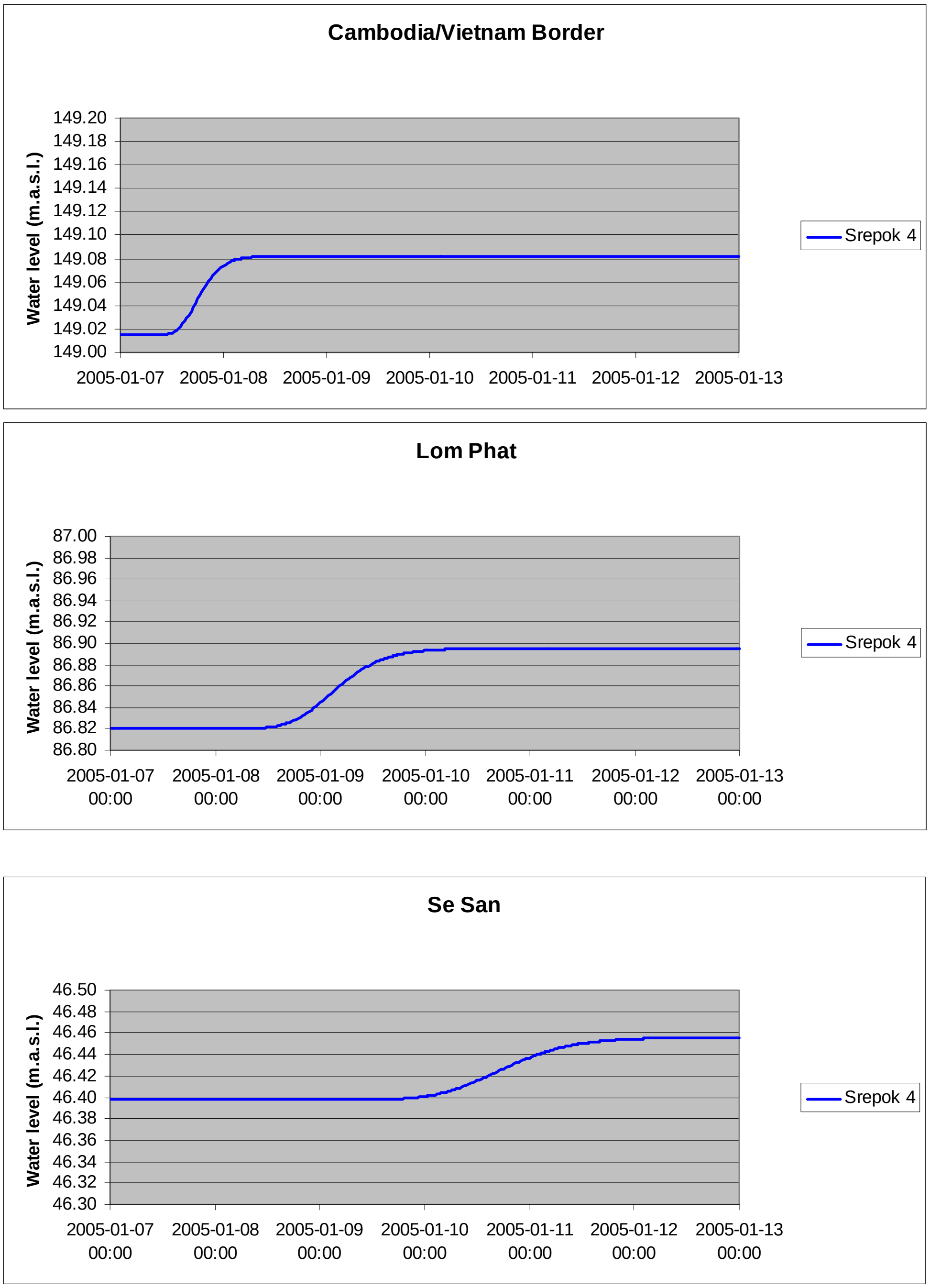

Fig. 3.11.- 3.13. Maximum water level increase expected due to operation of Srepok 4 at mean operational discharge.

4. BASELINE CONDITIONS

The environmental evaluation along Srepok River in Cambodia due to hydropower development in Vietnam has been achieved considering the existing information with regard to the natural resources, field surveys, specific researches, new field studies, public consultation and the project outlines and operation. The description of the baseline conditions is largely based on the rapid field survey conducted by the team in November/December 2005. Where other information come from other sources, these sources are referred to in the text.

The present environmental characteristics described in this chapter; are taking into consideration the physical, biological and socio-economic components.

4.1 Water Quality and Aquatic Life

4.1.1 Water Quality

MOWRAM has monitored the water quality in Srepok at Lumphat the last year. The data are given in Table 4.1 There exists also a few analysis from the Vietnamese side of the border collected in connection with the National Hydropower Plan.

Table 4.1 Water quality data from Srepok River at Lumphat analyzed by MOWRAM

Date	Side of river	Sampling time	T^{o}C	pH	EC mS/m	Turbidity NTU	DO mg/L	Coliform 37^{o}C
26.May.04	L	14:25	31.2	7.62	5.64		6.3	4300
26.May.04	M	14:15	31.3	7.65	5.64		6.4	1500
26.May.04	R	14:35	31.3	7.71	5.62		6.5	740
22.Jul.04	L	14:15	27.8	6.99	5.4		6.9	9400
22.Jul.04	M	14:24	27.5	7.01	5.2		8.4	6100
22.Jul.04	R	14:28	28.0	6.95	5.2		8.2	2700
23.Sep.04	L	14:09	28.6	7.1	5.86		7.7	400
23.Sep.04	M	14:15	28.6	6.79	5.88		7.7	200
23.Sep.04	R	14:22	28.6	6.8	5.86		7.7	300
22.Nov.04	L	16:21	27.2	6.99	5.36		7.2	60.0
22.Nov.04	M	16:29	27.2	7.08	5.34		6.8	80.0
22.Nov.04	R	16:23	27.4	7.11	5.35		7.1	100.0
26.Dec.05	L	17:10	24.2	7.48	4.98	8.92	8.05	42.5
26.Dec.05	M	13:28	24.2	7.8	5	9.11	8.05	37.5
26.Dec.05	R	13:34	24.6	8.2	4.94	8.81	8.13	50.0
28.Jan.05	L	13:24	27.0	7.55	5.8	2.62	7.52	1 900
28.Jan.05	M	13:28	27.0	7.72	6.1	3.05	7.31	2 400
28.Jan.05	R	13:34	28.0	7.71	5.9	2.31	7.41	2 700
23.Feb.05	L	12:59	30.0	7.91	6.4	1.14	8.43	750
23.Feb.05	M	13:07	29.6	7.96	6.3	1.41	8.63	2 500
23.Feb.05	R	13:14	31.0	7.9	6.1	1.08	8.73	3 000
30.Mar.05	L	13:54	34.0	8.1	7.0	2.9	5.9	1 000
30.Mar.05	M	13:59	34.0	8.3	6.7	1.9		100
30.Mar.05	R	14:02	34.0	8.3	6.9	1.13		260
25.Apr.05	L	01:30	32.3	7.13	7.3	3.1	7.13	1 100
25.Apr.05	M	01:40	32.3	7.9	7.3	3.5	6.41	500
25.Apr.05	R	01:47	32.2	6.45	7.4	3.2	7.93	900
16.May.05	L	01:18	32.4	8.59	6.6	1.34	9.07	150
16.May.05	M	01:25	31.0	8.63	6.8	2.34	9.03	400
16.May.05	R	01:37	34.0	8.89	6.5	0.88	9.01	50
Average			29.6	7.6	6.0	3.3	7.6	1457

Parameters Indicating Erosion Activity

The turbidity is low during the dry season from January to May with values ranging from 0.8-3.5 NTU. This is characterized as relatively clear water. The values (8 NTU) from December indicated a more turbid river, but still within natural ranges in these types of soils. The relatively low turbidity indicates that there is low erosion activity in the catchment in the sampling period. There are, however, no turbidity data from the rainy season.

It is not measured suspended sediments in the monitoring of Srepok River. This can, however, be estimated, as there exist a relatively good correlation between turbidity and relationship in river water. Results from a study made in Nam Theun River in Laos are presented in Figure 4.1. If this correlation also applies for Srepok River, calculations show that the concentration of suspended sediments varies from 1-10 mg/l. These are fairly low values and indicate that there is not much erosion taking place in Srepok River during the period of sampling. No data is, however, available from the rainy season, where it is likely that the concentration of suspended sediments can approach 100 mg/l in periods of heavy rain.

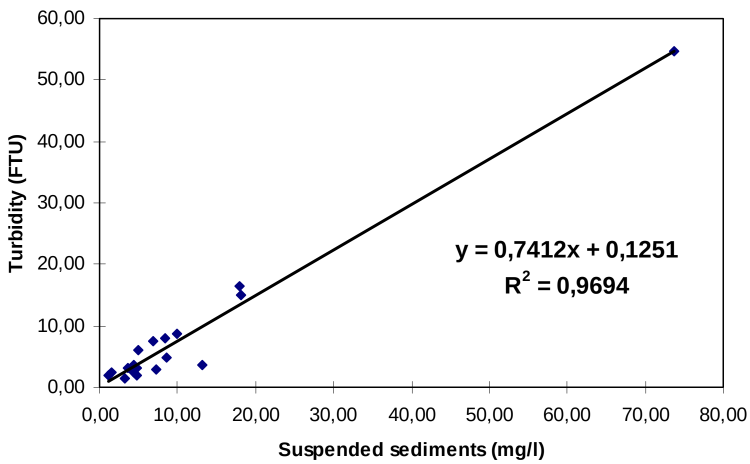

Figure 4.1 Relationship between turbidity measurements and the concentration of suspended sediments. (from Nam Theun River in Laos, Berge et al 1995)

Different fish species have different tolerance towards suspended sediments, and few standards exist. However, the European Commission for Inland Fisheries (EIFAC) has developed water quality criteria for fish in rivers. They state that no direct damage to fish is likely to occur below 35 mg/l, whereas above 100 mg/l it is impossible to keep up a good fish production (Alabaster and Lloyd 1983). The erosion activity taking place in Srepok River to day creates little or no problems for the fish life of the river.

Oxygen and pH

The oxygen concentration is high all around the year. In May 2005 there was a super-saturation of oxygen of 120%. At the same time the pH of the water is close to 9. This condition indicates high concentration of algae in the water. The algae produce oxygen when they are growing, at the same time they use CO_2, making the water more alkaline. The interviewed people in the villages reported that the water was very green during this period. There was no monitoring observation of algae May 2005, see Figure 4.2, but in 2004 the highest concentrations of algae was measured in May, with Chlorophyll values around 7 µg/l, which is in the mesotrophic level of algal biomass. There was no super-saturation of oxygen in May 2004. This indicates that in May 2005 there have been much higher algal biomasses, most likely in the eutrophic level.

Concentration of Algae

The monitoring program of MOWRAM observed algal biomasses from May 2004-March 2005, the results is given in Figure 4.2 See also Table 4.1 The measurements are performed by use of a fluoroprobe, which can distinguish the different algal groups from each other by their content of different pigments. Green algae constituted the main share of the algae, blue-green algae also made up a significant part of the biomass. Most of the year, the amount of algae was within the oligotrophic level. However, in May 2004 the values were in the mesotrophic level, and as indicated above, in May 2005 (when no flouroprobe measurements unfortunately were made) the chemical monitoring showed O_2 super saturation and high pH-values, which indicated algal biomass in the eutrophic level.

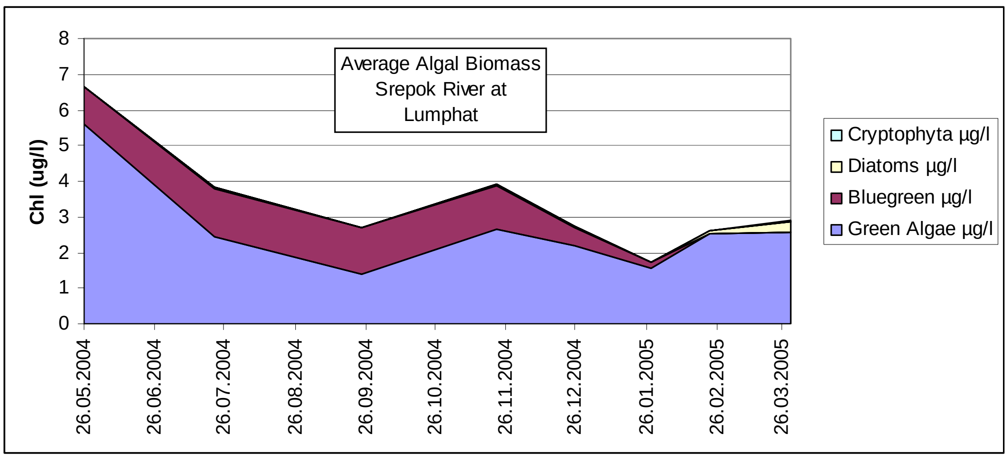

Fig 4.2 Average biomass of planktonic algae in the water of Srepok River at Lumphat

On the Vietnamese side of the border the population density is much higher than on the Cambodian side. In Dak Lak Province, which for a large part drains to Srepok River, the population density is 91 people per km^2 according to data given in Vietnam Adm. Atlas (2003). The population density of Ratanakiri Province in Cambodia is 9 persons per km^2. In Mondulkiri province the population density is around 2 persons per square kilometer. The population of the town of Buon Ma Thuot in the upper part of Srepok is 250 000 persons, and reaches 500 000 if the surrounding area is included. In this area there is a lot of human activity. Much of Dak Lak province, with a total population of 1.8 million people, drains towards Srepok River. In addition there are large agricultural activities on the Vietnamese side. This means that eutrophication may be a problem in the hydropower reservoirs, with considerable algal growth. This will be further analyzed in Chapter 5 (Impacts).

The content of coliform bacteria is relatively high, and indicates that the river is contaminated by faecal pollution, likely originating both from livestock animals and from humans. The river water should not be used as drinking water without pre-boiling.

Periphyton and Bottom Dwelling Animals
There is not available any data on this important organism groups from the Cambodian part of Srepok River. These organism groups are the most important fish food in the river. They are both very susceptible to increase in erosion material in the water quality, and are easily affected negatively by hydropower regulations. Proper abatement measures can reduce the negative impact considerably.

4.1.2 Fish

Srepok, Se Kong and Se San rivers constitute the largest tributary system to the Mekong River. At the outlet in Mekong at Stung Treng, they contribute with 20 % of the water flow in Mekong. These 3 rivers, together with the Mekong mainstream, the large lake Tonle Sap, as well as the Mekong delta, make up one inter connected fish habitat system (Rainboth 1996, Baird 1995, Fisheries Office 2000). Many species are found to perform large annual migrations within this large area as part of their life cycle. Surprisingly many species migrate up these 3 rivers in the wet season to spawn in tributaries, in inundated wetland areas, or in the rapids in the main river. Others are performing feeding migrations into the same areas.

Fish Diversity.
There is not carried out any fish diversity study in Srepok River. In the Mekong river system between 500 and 600 species of fish are described scientifically. However, mainly the fishes used for food are described. Among the small bottom living fishes a large amount of species are still unknown. It is statistically estimated that the real number of species are about 1200 (Rainboth 1996).

Ian Baird (1995) made a list of fish species in Se San River based on the catch by fishermen, and registered 120 distinct species. In addition, he had a long list of un-confirmed species, not included in the list of 120. He anticipated that the real number of fishes in Se San River in Ratanakiri is 200 - 300 species. Baird is currently working with a new assessment of fish stock and species diversity in Se San River that will be finished early 2006. This report includes the species list made by Baird (1995) from Se San, anticipating that the three rivers, Se Kong, Se San and Srepok had the same species composition prior to the regulation of Se San River (Table 4.2).

It is believed (Rainboth 1996, Fisheries Office 2000) that the three rivers Se Kong, Se San and Srepok have more or less the same species of fishes, and contains almost the same species as the main stream Mekong. It seems that Srepok has higher diversity, and contain larger specimen of the different species than the Se San River (Baird 1995). This may be because Srepok generally is deeper, have more deep pools (summer refuges), and fewer migration barriers than the 2 other rivers. Fish from Mekong can migrate far up in Vietnam in the Srepok River, a distance of more 300 km. According to a recent Vietnamese fish study in Srepok, more than 50 species of fish migrate from Mekong into Vietnam (Dr. Ho Thanh Hai, Inst. Ecol. Bio-Res. – personal Comment). There are also more flooded wetland areas (spawning and nursery grounds) along the Srepok River than along the Se San River (Baird 1995), particularly on the Vietnamese side, see Fig. 4.3.

In several villages along the Srepok River, the villagers said that new species have entered the river the last years. The number of new species varies from 2 to 4, depending on the source. According to information from the fishermen one of the new fishes is Thilapia, the others are looking like marine fish.

Fig. 4.3 The upper parts of Srepok River has several wetlands that are believed to be spawning areas for several species of migratory fish (Satellite image from south east of Buon Ma Tout)

Table 4.2 List of fish species in Se San River given by Baird 1995. It is anticipated that the Srepok River contains much of the same species

Family: Dasyatidae	Family: Notopteridae
Dasyatis laonsensis	*Chitala blanci*
Family: Clupeidae	*Chitala ornate*
Tenualosa thibaudeaui	*Notopterus notopterus*
Family: Cyprinidae	*Labiobarbus leptocheilus*
Amblyrhynchichthys truncatus	*Labio pierrei*
Bangana behri	*Leptocheilus hoeveni*
Barbichtys nitidus	*Lobocheilus melanotaenia*
Barbodes altus	*Lusiosoma sp.*
B. schwanefeldi	*Macrochiricthys macrochirus*
Catlocarpio siamensis	*Mekongina erythrospila*
Chela laubuca	*Morulius sp.*
Cirrhinus jullieni	*Mystacoleucus sp.*
Cirrhinus leneatus	*Osparius pulchellus*
Cirrhinus lobatus	*Osteochilus hasselthi*
Cirrhinus microlepis	*O. melanopleura*
Cirrhinus molitorella	*O. microcephalus*
Cirrhinus siamensis	*O. waandersi*
Cosmochilus harmandi	*Paralaubuca typus*
Crossocheilus reticulates Cyclocheilichtys	*Probarbus jullieni*
apogon	*P. labeamajor*
C. enoplos	*Puntioplites proctozysron*
C. repasson	*Poropuntius deauratus*
Discerodontus asmeadi	*Raiamas guttatus*
Epalzeorhynchus siamensis	*Rasbora borapetensis*
Epalzeorhynchus sp.	*Rasbora trilineata*
Esomus metalicus	*Rasbora spp.*
Garra sp	*Scaphognathops sp.*
Hampala dispar	*Systomus orphoides*
H. macrolepidota	*Thynnichthys thynnoides*
Hypsibarbus sp.	*Tor tambroides*
Family: Cobitidae	*B. modesta*
Acantopsis sp.	*B. morleti*
Acantopsoides sp.	*B. splendia*
Botia eos	*Nemacheilus spp.*
B. helodes	*Pangio spp.*
B. lecontei	
Family: Gyrinocheilidae	Family: Siluridae
Gyrinocheilus sp.	*Belodontichthys sp.*
Family: Bagridae	*Kryptopterus sp.*
Bagrichthys spp.	*Micronema apogon*
Heterobagrus bocourti	*M. bleekeri*
Leiocassis siamensis	*Ompok bimaculatus*
Mystus nemurus	*Wallago attu*
M. singaringan	*W. leeri*
M. wicki	Family: Schilbeidae

Mystus spp.	*Laides hexanema*
Family: Pangasiidae *Helicophagus waandersi* *Pangasianodon hypopthalamus* *Pangasius bocourti* *P. conchophilus* *P. krempfi* *P. larnaudiei* *P. macronema* *P. pleurotaenia* *P. polyuranodon*	Family: Akysidae *Akysis spp.* Family: Sisoridae *Bagarius sp* *Glyptothorax sp.* Family: Clariidae *Clarius batrachus* *Clarius spp* Family: Hemirhamphidae *Dermogenys sp* *Hemirhamphodon sp*
Family: Belonidae *Xenentodon sp* Family: Synbranchidae *Monopterus albus* Family: Mastecembelidae *Macrognathus siamensis* *Mastacemblus armatus*	Family: Syngnathidae *Micophis brachyurus* Family: Ambassidae *Parambassios sp.* Family: Coiidae *Coius sp.* Family: Sciaenidae *Boesemania microlepis*
Family: Toxotidae *Toxotes sp.* Family: Nanidae *Pristolepis fasciatus* Family: Gobidae *Several undetermined genuses* Family: Anabantidae *Anabas testudineus* Family: Belontiidae *Trochogaster trichopterus* *Trichopsis vittatus* Family: Osphronemidae *Osphronemus exodon*	Family: Channidae *Channa lucius* *C. marulia* *C. micropeltes* *C. orientalis* *C. striata* Family: Soleidae *Achiroides sp.* Family: Tetrodontidae *Tetrodon bayleyi* *T. leirius*

Fig. 4.4 Different species of fish, frog and snake available at the fish market in Ban Lung

Fish Migrations

It is not performed any fish migration studies in Srepok River, all data is based on information from fishermen. This means it is not exactly known how far up in Vietnam fish from Mekong migrate. According to a recent Vietnamese fish study in Srepok, more than 50 species of fish migrate from Mekong into Vietnam (Dr. Ho Thanh Hai, Inst. Ecol. Bio-Res. – personal Comment). Baird (1995) gives a description of the fish migrations in the 3 rivers, which are shortly summarized below:

The three rivers support many populations of strongly migratory fish species. Several species conduct seasonal migrations between the 3 rivers and the Mekong mainstream, and several species are believed to migrate from as far away as the Mekong Delta in Vietnam, the great Tonle Sap Lake in Cambodia, and the Mekong central basin in Thailand and Laos.

May-July
Every year between May and July, when the monsoon rains start and the flood season starts, a number of species of fish migrate up the rivers from Mekong. Some apparently travel down the Mekong from Laos before entering the three rivers.

These include the Cyprinids; Scaphognathops spp., Mekongina erythrospila, Labeo pierrei, Bangana behri, Hypsibarbus spp., and Cyclocheilichthys spp. (hereafter referred to as the group A fishes). These cyprinids migrate up the three rivers before entering smaller tributaries, where they spawn during the rainy season.

At about the same time of the year, a number of species of the so-called “black fishes”, including Channa striata, Clarias spp., Systomusophroides, Trichogaster spp., Rasbora spp., and others (hereafter referred to as group B fishes) also enter streams and wetlands, including rice field paddies, where they reproduce.

In addition a number of pangasid catfishes enter the rivers when the river flow rises. One species (hereafter referred to as group C) is Pangasius krempfi, which reach 20 kg in weight, arrives in large numbers at the beginning of the rainy season. Other pangasid catfishes (herafter referred to as group D) include Pangasius larnaudiei, P. hypopthalamus, P. bocourti, and P. macronema and they also migrate up the three rivers from Mekong in the rainy season. Although the big catfish Pangasius saintwongsei, P. pleurotaenia, and Laides hexanema also occur, their migratory habits are not well known.

Several of the pangasid catfishes are believed to spawn in the free water of the upper reaches close to or beyond the Vietnamese border, and the eggs are drifting in the surface and hatch to larvae on the way down. In Stung Treng the small drifting pangasid fingerlings are caught and sold for stocking in fish ponds (Chann Soupheap, Dept. of Fishery).

Another group of large catfishes, including Mystus spp., Wallago leeri and Wallago attu (group E) also migrate into tributaries of the three rivers for spawning.

August - December
At the top of the rainy season, mature Labeo pierrei and Bangana behri (group F) migrate and spawn along the three rivers.

As the monsoon ends, and water levels begin to drop, many species of fish begin to return from the streams and wetlands to larger perennial water bodies.

The whole population of Pangasius krempfi (group C) descends the three rivers and migrates down to the South China Sea.

Most of the pangasid catfishes (group D) also return to the Mekong mainstream, but some also remains in the deep pools in the three rivers.

Group E also withdraw from the streams back to the three rivers.

Group A, the cyprinids also leave the streams and enters the three rivers. They begin a long migration that takes them to the Mekong River and further upstream to Laos and Thailand where they feed until the monsoon begins again. Then they migrate back to the three rivers for spawning. As the streams and wetlands begin to dry out, the group B, black fishes, also returns to larger water bodies such as the three rivers and the Mekong.

December – January
During this season, large Probarbus jullieni and P. labemajor (hereafter called group G) migrate unknown distances up the three rivers before spawning.

February – March
As the water levels drop further, large numbers of small cyprinoids, including Cirrhinus lobatus, C. siamensis, C. lineatus, C. julienne, C. microlepis, Labiobarbus leptocheilus, Crossocheilus reticulates, Lobocheilus melanotaenia, Barbodes altus, Paralaubuca typus, Cyclocheilichtys enoples, Botia, spp., and others (group H) migrate up the three rivers from Mekong and the great Tonle Sap Lake. These species migrate back to the Mekong when the waters rise in May – June, although some may remain in the three rivers all the year around.

All the species listed above are species used for subsistence food by the local people living along the rivers. There is a lot of small species which migratory behavior are not known, because the fishermen do not catch them frequently enough.

It is quite clear that a large number of species are migrating up these rivers both for spawning and feeding, and they are caught and are an important food supply for the local people when they are passing their fishing grounds. The local people say that there are more fish migrations in Srepok and Se Kong than in Se San, which is mainly due to the fact that the Srepok and Se Kong are deeper than Se San, and because they also have more adjacent wetlands that are flooded during the wet season.

Fishing Activity and Most Common Methods Used
Almost all families living along the river fish for daily food, and those who are not fishing buy fish from the fishermen. Fish is the main protein source for the residents in all areas along the rivers.

The fishing methods used in Srepok River are mainly:
- Gillnet
- Castnet
- Baited long-line
- Cylinder trap

The 3 first methods are dominating. The most typical mesh sizes for the gillnets was from 20-50 mm. Most fishing included the use of boat. Also the cast net was mostly used from boat, but also from land. Most fishing takes place during the night. They deploy the equipment at 10-11 pm and take it up again at 04-05 am. They claimed that the fish is only moving when the moon is up. A normal catch per boat per night was typically 2 –5 kg, but some days the catch could be as high as 10 kg.

Only a few persons in each village are professional fishermen. They sell their catch to those who do not fish in the village and to other people living near by. Some of the fish are sold to traders bringing the fish to the fish markets in Ban Lung or Stung Treng. The fish market in Ban Lung is growing and is also supplied with fish from Kratie (at the Mekong River), which is brought in by car every morning. It is a problem for the professional fishermen that the traders do not come to their village as often as before. A visit to the fish market in Ban Lung (December 2005) more than 90 % of the fish was from Kratie.

4.1.3 Fish Management

In all the three rivers the fish stocks have declined the last 10-20 years, particularly in Se San River where all claimed that the fish was more or less gone. Even in Srepok River most of the villagers said that there has been a decline in the fish stock in the river, while others said that there still is a good fishery.

Both at the district level and at the commune level they have recognized that the fishery was threatened by over-fishing, and that fishery management has to be implemented. Units called Community Fisheries are organized in some of the villages along Srepok. These units gave fishing quotas to fishermen, as well as created fish sanctuaries where it is not allowed to fish in certain periods. Some of the deep areas are protected during the dry season. It is generally accepted that the fish need protection to survive the increasing fishing pressure. However, the protection rules have made it more difficult to get fish during the dry season. See Baird et al (2002) for more information concerning the community fisheries.

It was discussed with several village chiefs, fishermen, head of commune fisheries, what is the reason for the decline in fish yield in Srepok. Some claimed that illegal fishing methods by explosives and electro-fishing are the reason. On the other side they said that there are so few people using these forbidden methods that it cannot account for the decline. Most local people agree that most likely the main reason is increase and widespread use of highly efficient machine made monofil gillnets. The gillnets have become much cheaper over the years, and every family have gillnets of varying mesh sizes. Previously they made gillnets themselves by hand knitting. Particularly in the deep pools during the dry season, gillnets can take out much of the important brood stock population.

Every village has also a few (2-3) professional fishermen. They fish for sale to other villagers and sometimes to the fish traders who buy fish for sale in the fish market in Ban Lung. These professional fishermen have to get a license from the district administration, and this “fishing quota” contains information about where to fish and regulations on how much fish of each species that can be taken out.

4.2 Land Use and Terrestrial Biodiversity

4.2.1 Land: Use, Cover and Resources

A large part (>80%) of the Srepok Basin in Cambodia comprises of areas not under permanent agriculture, where forest vegetation[1] (including forest-grassland communities) cover dominates. This is the case for both the Cambodian and Vietnamese sections of the basin. In Vietnam the forest (and associated vegetation communities) cover about 55% of the basin area (NHP 2005). The forest area in Vietnam represents various stages – both primary, secondary and some abandoned plantation forests. In contrast to the forest area in Vietnam there are large areas of pristine forest communities in Cambodia. The sparsely population in Cambodia may partly be the reason for the fairly good condition of the area. The nature of the area with its prime vegetation and wildlife (for details see sections below on biodiversity) has been and is subject to illegal exploitation and is thus vulnerable (interviews with provincial officials of the MoE; Lumphat Wildlife Sanctuary officials and rangers; WWF-Cambodia reports and interviews; NGO Forum 2005).

Fig. 4.5 Rice Fields at Seuv Ka Village, Ratanakiri Province

Agriculture

Along the Srepok River, where this study is concentrated, villagers utilize land for a range of agricultural activities, namely; rice paddies, fruit orchards, secondary crops (seasonal mostly), home gardens and riverbank gardens. Village maps and field observations showed some general but clear distribution of crops across the landscape in relation to the Srepok River. Paddies and fruit orchards were furthest from the river while homesteads surrounded by home gardens and secondary crops were closest. However, small patches of fruit trees (similar species) were also some places located behind houses (backyards) – between houses and the river covering spans of up to 50 meters at times. The darker soils, more fertile than red soils, occurring further away from the river, most likely once covered by forest, are better for rice paddies and fruit orchards. Some secondary crops are also planted in the vicinity of paddy fields.

Fruit orchards are not as common as among villagers near the Se San River, but are on the increase as these provide a secure source of income. The most lucrative orchards were said to be those of cashew. Rice paddies harvested for one crop per year are by far the most common and important source of starch. Most of the riverside villagers met during the field study said their paddy land was enough to provide them with adequate food in ordinary years. For many people excess rice also provides cash income, for example in Sam Kha Village a villager (with a household of two adults and 2 young) relied on selling about 1 ton of rice per year. Land area for rice per household varies from 0.5 ha to 5 ha. The poorest and the young families generally have the smallest paddies, and thus do not have enough land to generate ample income. Thus among the young there is pressure to claim land from the forest (interviews with villagers in Sam Kha Village in Lumphat District) to start permanent paddy fields or cashew orchards. Rainfed paddy is grown furthest from the river. The

[1] When referring to forest areas it is recognized that the forest can be called primary or pristine and still include human use for subsistence, i.e., collection non-timber forest products, including hunting animals, and timber for local use. Such subsistence activities are not regarded as degrading forest quality and hindering ecosystem functioning, where otherwise this is stated explicitly in the text.

riverside is used for other crops- secondary, cash and also those which fetch more income. Dry rice or upland rice is not grown by villagers along the Srepok River.

Homesteads are surrounded by a range of agricultural activities. In order to provide a clear spatial picture of the homestead area related the agricultural activities, the area is divided into three zones in relation to the position of the house and the river:

- *home gardens (around and closest to the house);*
- *backyard gardens/crop fields; and*
- *riverbank gardens*.

Fig. 4.6 Backyard garden of a house surrounded by a species rich home garden in Sam Kha Village (The first view is seen from the river towards the house, the second is seen towards the river)

Home gardens are found associated with all homes and are the most diverse of agricultural land use types. These usually consist of perennial plants yielding fruits, spices, tubers and vegetables (Table 4.4). Annual plants commonly comprise spice plants (e.g. coriander, spring onions, Chinese chives), vegetables (e.g., long beans, greens of Brassicaceae plant family, gourds) and ornamental plants (Table 4.4). Nurturing these gardens is an essential part of the daily household activities and these provide invaluable plant components of the daily meals – thus serving as important nutritional resources. The Backyard gardens or crops are those areas where many households have larger areas allocated for crops like beans, cassava, sweet potatoes, tobacco, sugar cane and, in some cases, also cashew both for their own use and for sale (Table 4.4). Note that all homes utilized the backyards in this way and thus had shrubs and grasses dominating, among which cows were tied and grazed. Chickens and ducks roamed freely around the homesteads, just as pigs and goats (when present, as goats were not common). Domestic dogs were also common.

Riverbank gardening is practiced by most homes during the dry season, low flow period of the river, where drawing water from the river is near and easy. The sand banks and slopes of the riverbank are used. The rich and fertile riverbanks are cleared and terraced for planting of seasonal vegetables (Table 4.4). This is usually done just as harvesting of rice is coming to an end and as the dry season begins. The planted riverbank plants serve as significant contributions to daily meals. The availability and accessibility to use the riverbank is vital for most families especially the poorest households and those with small areas of land (paddy). The water from the river serves in most cases as the only source of water for watering the plants/gardens and domestic needs.

Fig. 4.7 Backyard garden with bananas and beans at Lumphat Village, Ratanakiri Province

In some areas land along the rivers (areas beyond the riverbanks, where backyard gardens are situated) are used for crops like sugar cane (which can bring in significant income), cassava, and bananas. These were strips of land along the river, usually about 50-100 meters long and 20-30 meters wide (approximate values from interviews and field observations). The owner usually lives in the vicinity.

Riverbanks are also used for the collection of wild vegetables (leafy plants) and some flower buds (e.g., *Truoy Raing (Baringtonia sp.) and Ph´ka Andaeng (Sapotaceae*) (Table 4.4; see also NGO Forum 2005a, 2005b; Dy Phon 2000). Many of these species are rich in minerals and iron, and are preferred by the villagers due to their 'delicious' taste.

Fig.4.8 Riverbank garden at Kaeng San Village. Note the fragile terraces

Animals in the Agricultural Landscape

The area (land) mentioned in the sections above are also used for domestic animals. Buffalos, cows, pigs and chickens are the most common animals. It was not common to see ducks and chickens by the water. Many villagers mentioned that cows and buffalo use the river for water.

Crabs, frogs, snails, insects, lizards, and earthworms (for fishing) are collected from and by the river for food. From the paddy field areas and fruit orchards, wild boar and deer are, occasionally, killed for food and sale in the market (see later sections for wildlife hunting). Both these animals fetch good prices in the market.

Table 4.4 List of Food and Crop Plants in Srepok River homesteads. (source: interviews and field observations)

Food and Crop plants					
Plants grown in the home gardens		**Crop/food plants in the backyards of homes**		**Plants cultivated along riverbank slopes**	
Local Name	*Name*	*Local Name*	*Name*	*Local Name*	*Name*
Chi Angvong	Mint	Chek	Banana	Uv Loek**	Water melon
Sloek Krey	Lemon grass	Spey	Lettuce	Spey**	Lettuce
Chi Vansuy	Coriander	L'hong	Papaya	Thnaim Chok**	Tobacco
Spey	Lettuce	Ampuv	Sugar cane	Ampuv**	Sugar cane
Mtesh*	Chili (hot pepper)	Damlong Ch'vea	Cassava	Pot**	Corn
Sandaek Kuo*	Long bean	Sloek Krey	Lemon grass	Kh'toem Sor**	Spring onion
Chek	Banana	Chi Angvong	Mint	L'ngo**	Sesame
L'hong	Papaya	Kh'nhei	Ginger	Trav	Taro
Kroch Chhma	Lemon (lime)	Sandaek Bay	Mung bean	Trakuon+	Morning glory
Trob	Species of Solaneaceae	Damlong Ch'ea	Sweet potatoes	Lpuv**	Pumpkin
Trasak*	Cucumber	Trav*	Taro	Thnaim Chok*	Tobacco
Tralach*	Long gourd - 1 (hairy)	L'ngo*	Sesam	Mnaos	Pineapple
Nonong*	Long gourd - 2 (smooth surface)	Thnaim Chok*	Tobacco		
Kh'toem	Spring onion				
Chi Kraham	Basil				
Chi	Chinese				

Krahorm	Chives				
Trab Kdako	Aubergine				
Rumchek	Pandan				
Kh'toem Sor*	Garlic			Plant collected by the riverbank (non-cultivated-vegetables)	
Roum Denh	Galanga			*Local name*	*Name*
Ampov*	Sugar cane			Rey Toek**	Barringtonia
M'lou	Peper betel			Ph'ka Andaeng**	Sapotaceae
Damlong Ch'vea*	Cassava	Damlong Ch'ea	Sweet potatoes	Pak Khai+ (Lao name)	
Mnaos	Pineapple	Mnaos	Pine apple	Pak Sukun+ (Lao name)	
Dong	Coconut tree	Dong	Coconut tree	Pak paui+ (Lao name)	
Ampel	Tamarind	Ampel	Tamarind		
Sla	Betel nut	Sla	Betel nut		
Seda*	Sapota	Seda*	Pomelo		
Svay	Mango	Svay	Mango		
Speu	Corambole	Speu	Corambole		
Kroch Pursat	Orange	Kroch Pursat	Orange		
Trabaek	Guava		Guava		
Kh'nol	Jackfruit	Kh'nol	Jackfruit		
Deum Toekdoh Ko	Milk fruit	Deum Toekdoh Ko	Milk fruit		
Deum Ko	Bombax	Deum Ko	Bombax		
Mean	Longan	Mean	Longan		
L'mut*	Species of Sapotaceae	L'mut*	Species of Sapotaceae		
Svay Chanti	Cashew	Svay Chanti	Cashew		
Kroch Th'ong	Pomelo				
	Flower (ornamental plant)				

** = uncommon: ** = reported by villages and recorded during the field visits : + = reported by villagers: other species listed were all recorded during field visits*

Reliance on Water for Agriculture

Paddy fields are flooded with water during the onset of the wet season when the river gets full and water is channeled into the fields, through dikes and in some areas also pumps. The water level when the river is full, not necessarily always overflowing the banks, has to be adequate for the water to stream into the landscape to flood the paddies at the right time so that the young rice plants start to grow efficiently. If this does not occur during the appropriate period the rice seedlings dry and have retarded growth, increasing death of plants and lowering productivity substantially. Some of the filling occurs through dikes or with pumps but also via tributaries and flooded swamp areas. The flooding also fills pools of water in the landscape, some of which provide essential sources of water for secondary crops near paddy fields.

Rain and river water is used for watering the home gardens, backyard gardens and riverbank gardens. During the dry season the river is the only reliable source for water and most of the plants (especially seasonal greens) require water on a daily basis. All home garden and backyard gardens rely on water from the river, particularly during the dry season. The domestic animals also use the river for drinking water.

Forest

The most common forest type in the Srepok Basin and its tributaries in Cambodia is the deciduous forest type, largely characteristic of dry seasonal deciduous forest dominated by, e.g. *Diptherocarp* spp. and *Lagerstroema* spp. (details of vegetation communities are given in the biodiversity section). An estimation of vegetation in a 100 m belt along the north and south riverbanks of Srepok River in Cambodia to the confluence with Se San River revealed the following land use types and cover (Table 4.5). Along the river the dominant vegetation is riparian followed by deciduous forest characteristic of the region (see also Hourt 2005; WWF 2001). In addition land use along the river beyond the Srepok River and Se San River confluence to Strung Treng comprises of predominantly paddy fields, and home and backyard gardens (Landuse Map of Cambodia. 2003). Riverbank agriculture and cropped areas may be underestimated due to the seasonality and the resolution of the maps used.

Naturally Bare Slopes

Although not listed as a category on the map there were several riverbank areas which are bare due to natural reasons, and are thus prone to erosion. The magnitude of such natural bare slopes is not expected to be significant.

Fig. 4.9 Mixed Deciduous Forest at Seuv Ka Village, Ratanakiri Province

Forest Use

Villages by the Srepok River have contiguous areas with forests, and local people have traditional associations with the forest. In this section the focus is the use of the forested areas for NTFPs. The Srepok River runs through the protected area of Lumphat Wildlife Sanctuary and the Mondulkiri Protected Forest, which are home to several known valued species (see biodiversity section for more details). The forests although once easily accessible and cleared for use by villagers are thus now largely protected by strict regulations and guarded by rangers and forest officers. There are, however, forest areas that villagers occasionally go hunting in (many mentioned hunting at least once a month). Local people enjoy eating wild boar, and barking and sambar deers, and these are the most commonly hunted and not restricted for hunting. Meats of these were also sold in open markets (observed during field visit). Apart from these civets, rabbit, monitor lizards and turtles are also killed for eating.

Table 4.5 Proportion (%, numbers rounded) of land use or vegetation type along the north and south Srepok riverbanks. Measured along the Srepok riverbank in Cambodia until its confluence with the Se San River. Note that the value are approximates measured using the Land use Map of Cambodia. 2003 (scale 1:100,000)

Land use/Vegetation Type	North Bank of Srepok River (Estimated Percentage of length)	Land use/Vegetation Type	South Bank of Srepok River (Estimated Percentage of length)
Paddy Fields	0.5	Paddy Fields	0.4
Village Garden Crops	0.5	Village Garden Crops	2
Deciduous forest	29	Deciduous forest	21
Evergreen Broadleafed forest	4	Evergreen Broadleafed forest	2
Riparian Forest	51	Riparian Forest	67
Bamboo and Secondary forest	13	Bamboo and Secondary forest	5
Mixed forest of evergreen and deciduous species	1.5	Mixed forest of evergreen and deciduous species	1.5
Dry Deciduous Forest (open)	0.8	Sand Bar	0.03

The forested areas are also an important source of plant based non-timber forest products (Table 4.6). Resin collection is the most important source, used to generate income. Medicinal plants, mushrooms, wild fruits and rattan are other important products which locals rely on. Fixed wood/timber allocations for building houses are granted by the provincial forestry department without any problem. Small scale illegal logging is also common, although this is being kept checked. Illegal loggers usually make planks. Illegal forest clearing for setting up permanent paddies or orchards is also a problem. In comparison to areas along the Se San River the problems mentioned above are less severe along the Srepok River. This is partly due to the sparse population and protected areas. There also appears to be a good level of awareness among some villagers of the value of the forest. Community forest groups and forest co-management initiatives are also being experimented with (SEILA program, NTFP program, Provincial departments of Environment and Forestry, WWF-Cambodia). There is no specific legislation dealing with Community Forests and Management but there are Articles in the Law on Forestry (decree approved in 2002, see Articles 40-47[2]) which recognize customary property of ethnic groups. The communities have to establish that they qualify, through historical accounts, their ethnic status (indigenous) to be able to claim rights over forests[3]. Therefore

[2] Law of Forestry (2002). Chapter 9. Article 40 – '*For local communities living within or near the Permanent Forest Reserves, the state shall recognize and ensure their traditional user rights for the purpose of traditional customs, beliefs, religions and living as defined in this article. The traditional user rights of a local community for forest products and by-products shall not require the permit.*' By-product here implies NTFPs like honey and resin.

[3] See on-going activities and plans of NTFP Project (NGO) in Bang Lung, Ratanakiri province.

community management of forests is still in its infancy, although some villagers and provincial officials mentioned its potential.

Table 4.6 List of forest products collected or hunted inside and outside protected area reported by villagers living along the Srepok River. Several of the animals reported have their habitat in the Srepok River and other waterways, most running through forested areas. (Source: interviews and field observations)

Plants inside and outside protected area			**Animals inside and outside protected area**		
Local name	*Name-description*	*Parts used*	*Local name*	*Name-description*	*Parts used*
Raing Phnom	Tree (*Dipterocarpus* spp.) and Fungus	Resin, bracket fungi, timber	Chrouk Prey	Wild boar	Whole
Sokram	Tree (*Dipterocarpus* spp.) and Fungus	Bracket fungi, timber	Chhlosh	Barking deer	Whole
Ph'choek	Tree (*Dipterocarpus* spp.) and Fungus	Resin, bracket fungi, timber	Preus	Sambar deer	Whole
Ph'set	Mushroom	The whole fungus	Andeuk	Turtle	Body without shell
Th'naim Boran	Medicinal plant	Various parts	Trakuot	Monitor lizard	Whole
	Fir wood	Various species	Sampoch	Civet	Whole
Tumpaing	Bamboo shoot	Young stem	Tonsay	Rabbit	Whole
Banlae Prey	Wild vegetable	Leaves		Wild Chicken	Whole
Meum Damlong	Wild root	Tuber	Kangkaeb	Frog	Whole
Ph'lae Chheu Prey	Wild plant	Fruit	Kh'chang	Snail	Body without shell
Ph'dao	Rattan	Stem	Trey (not from main river)	Fishes	Whole
Reussey	Bamboo	Stem	Chunlen	Earthworm	Whole
Troat	Palm	leaves			

Acquisition of Land for Agriculture
(based on interviews with villagers (land owners))

Land clearing is at present restricted due to the control of forested areas and land planning regulations being tested out and implemented. According to province and district officials every household is guaranteed to allocate 5 ha of cultivation land, and getting a permit to clear land within this limit should normally meet no problems. A household just has to send a claim to the district administration through the village and commune chiefs. The administration then points out the location of the land plot allowed to be cleared for cultivation. However, according to the village interviews, the land acquisition process is long from the village chief through the central government approval. Several young villagers who required extra land for paddy or orchards expressed dismay and frustration. Part of this difficulty is due to the protected nature of the forest near villages. In comparison to the conditions by the Se San River the situation by the Srepok River appeared to get difficult and was highly

restrictive due to many villages bordering to the protected areas. Potential new cultivation land is sometimes located far away, and therefore not attractive to the people in need of additional land. In some villages people also expressed bureaucratic and economic obstacles in achieving a permission to clear land from the authorities; in some cases they said they were expected to pay the authorities and could not afford the required sum. Consequently, illegal forest clearing is taking place, creating a potential conflict between the villagers and the authorities (according to interviews with villagers, district, and provincial officials).
It appears that the customary rights (especially to land use and forest ownership) are to some degree treated differently by the government regulations.

4.2.2 Biodiversity Status and Protected Areas (PA)

The biodiversity status of Cambodia is poorly known mainly due its historical past of civil war which did not allow for the development of a knowledge base in this area, and thus natural resource management and wildlife conservation are in their infancy (e.g., Baltzer et al. 2001; Birdlife International 2005; WWF-Cambodia interviews). Nevertheless the recent years have seen the formal set-up of PA management plans, growing concern for enforcing regulations related to natural resource use and conservation, clearer definitions for land planning in rural and natural areas, more biodiversity documentation, and general awareness of biodiversity related issues. Institutional concerns include an insufficient legal structure, a lack of technical capacity (few national taxonomists and in-field rangers), a lack of financial resources, a lack of coherent and complete data to make informed management decisions, and conflicts of priorities and responsibilities between Ministries and Departments (particularly MoE and MAFF).

Cambodia ratified the Convention on Biodiversity[4] in February 1995 (www.biodiv.org/conv/RATIFY_date.htm). Cambodia has just recently begun to address the obligations of the Convention through the approval of a National Biodiversity Strategy and Action Plan (NBSAP) in May 2002 and the enactment and drafting of biodiversity related laws. In October 1999, Cambodia joined the RAMSAR convention and nominated three RAMSAR sites. In addition Tonle Sap Lake was designated as a Biosphere Reserve by Royal Decree in February 2001. The current draft of the Wildlife law put forth by Department of Forestry and Wildlife (DFW) is under consideration by MAFF. The only existing law that provides a legal framework for wildlife conservation is the Law of Forestry approved by Royal Decree in 2002[5], under the jurisdiction of MAFF. The NBSAP (2002) clearly acknowledges that 'the full extent of Cambodia's biodiversity is far from known, but is expected to have rich in species diversity and may be considered a biodiversity hotspot' given its location. Compared to its neighboring countries Cambodia is sparsely populated and still has vast tracts of intact natural areas. Some of the best areas are associated with

[4] The objectives of Convention on Biodiversity (CBD) are spelled out in Article 1: The objective to the Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of the relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding.

[5] Law of Forestry, 2002. Chapter 10, Conservation of Wildlife. The main Article 48 (page 31) states: All kinds of wildlife species in the Kingdom of Cambodia are State property and the component of forest resources, including all species of mammals, birds, reptiles, amphibians, insects, other invertegbrates, and their eggs or offspring. Such wildlife is under the management, research and conservation of the Forest Administration, except for fish and animals in water.

the Srepok River (Lumphat Wildlife Sanctuary and the Mondulkiri Protected Forest areas). MAFF is also responsible for the CITES convention which Cambodia ratified in 1997. In essence, at present regulations for the conservation of biodiversity are poorly developed and much is not in place yet, making it difficult to implement comprehensive conservation measures.

Of the 23 protected areas[6] or areas of conservation importance[7] in Cambodia, seven are National Parks, ten Wildlife Sanctuaries, four Landscape Protected Areas and three Multiple Use Areas. The National Parks include Preah Soramarith-Kosamak (Kiririm), Preah Monivong (Bokor), Preah Sihanouk (Ream), Preah Cheyvaramann-Norodam (PhnomKulen), Virachey, Kaeb and Botum Sakor. Wildlife Sanctuaries comprise of Phnom Aural, Phnom Samkos, Lumphat, Phnom Prech, Snuol, Boeng Per, Peam Krasoab, Roneamdonsam, Kulen Promteb, and Phnom Namlir. Conservation Areas include the Seima Biodiversity Conservation Area (also listed under Landscape protected areas). Landscape Protected Areas comprise Angkor, Preah Vihear, Bantey Chhma, and Mondulkiri, and Multiple Use Areas include the Dangpeng, Samlot and Boeng Tonle Sap. For details see Wild Aid, Birdlife International 2005, Baltzer et al. 2001, Hourt 2005. There are two agencies with different roles responsible for natural resource management. These are the Ministry of Environment (MoE) and the Ministry of Agriculture, Forestry and Fisheries. MoE is responsible for officially designated PAs (Royal Decree in 1993) while MAFF is responsible for management of forest and wildlife resources outside of the designated PAs (see also Table 4.7). At present 18.5% of the land area is nationally protected (World Bank 2004).

The Srepok Basin in Cambodia has several protected areas (Table 4.7). In addition the selected areas or the whole area in the Srepok basin have been designated as conservation important areas: Important Bird Area (IBA) (IBA program coordinated by Birdlife International) and forests (Baltzer et al. 2001; WWF-Cambodia interviews). The WWF has classified the area around the Srepok river in the Forest of the Lower Mekong Ecoregion Complex (FLMEC) forming the Central Indochina Dry Forests (Baltzer et al. 2001). Specifically the area of concern here is in the ecoregion called the Eastern Plains Dry Forests (Priority Landscape DF4 in Baltzer et al. 2001), and its biological importance is rated as Critical by WWF. Classifying broadly, the main forest types[8] of this ecoregion also fall in similar categories as reported in the Land use Map of Cambodia (2003): Deciduous Dipterocarp Forest, Semi-evergreen forest and Savanna Woodland. The ecoregion without doubt is the one of the two landscapes that has the largest expanses of dry lowland forest mosaics of deciduous dipterocarp forest (dominated by *Dipterocarpus obtusifoius, D. intricatus, D.*

[6] On 01 November 1993 His Majestry King Norodom Sihanouk designated 23 protected areas for biodiversity and cultural protection. After this more areas have been added to list of conservation important areas, many of these via the concern and work of international NGOs (e.g., WWF-Cambodia and The Wildlife Conservation Society, Birdlife International, Wild Aid, etc.).

[7] The list is not complete for all areas of conservation concern as some are not official or recognized by MoE or MAFF. The areas of concern to this Report on the Srepok River are all listed.

[8] There is currently no standardized forest habitat classification for the Forest of the Lower Mekong Ecoregion Complex. However cross-reading of the descriptions easily reveals similar ecosystem and forest communities, with many common characteristic dominant species. For example the Semi-evergreen forest has also been termed as seasonal evergreen forest, tropical semi-evergreen forest, semi-deciduous forest or, more generally, mixed evergreen-deciduous forest (see also Champion and Seth 1968; Santisuk 1988; Maxwell undated; Baltzer et al. 2001; Ampornpan and Dhillion 2003; Hourt 2005).

tuberculatus, and *Shorea siamensis*) and Semi-evergreen forest (dominated by *Lagerstroemia caliculata*).

Table 4.7 Protection areas in the Srepok Basin of Cambodia (Source: literature, MoE, interviews)

Type of PAs	Name of PAs	Management Responsibility and formal establishment	Location of PAs	Size (ha)
1. Wildlife Sanctuary	1- Lumphat	MoE. Royal Degree of 01 Nov 1993.	Ratanakiri and Mondulkiri	250,000
	2- Phnom Prich	MoE. Royal Degree of 01 Nov 1993.	Mondulkiri	222,500
	3 - Snoul	MoE. Royal Degree of 01 Nov 1993.	Kratie and Mondulkiri	75,000
	4 -Phnom Namlyr	MoE. Royal Degree of 01 Nov 1993.	Mondulkiri	47,500
2- Landscape/ Forest Protected Areas	1 - Mondulkiri Protected Forest	MAFF. Forestry Administration. Established in 30 July 2002.	Mondulkiri	10,800
3. Conservation Area (also listed as a Landscape Protected area)	2. Seima Biodiversity Conservation Area	MAFF. Forestry Administration. Established in 30 July 2002 by Ministerial decree (PRAKAS).	Mondulkiri	--

This section will not cover fish diversity (see section on 4.1). Since the precise biological diversity status of all the areas by the Srepok river are not known, this report draws on records from the Lumphat Wildlife Sanctuary (which has some good and reliable biodiversity surveys) and the Mondulkiri Protected Forest (which has mainly observations information and few surveys) both of which are crossed by the Srepok River. In addition the report also relies on data collected from the Phnom Prech Wildlife Sanctuary. Since these three protected areas have contiguous areas and similar vegetation cover, their review sheds light on the biodiversity status of the area. As reported in Table 4.5 Riparian Forest, Deciduous Forest and Bamboo and Secondary Forest are the most important vegetation types along the Srepok River. The Riparian forest (also referred to as gallery forest in some reports, e.g., Maxwell undated, Hourt 2005) also occurs along the tributaries of the Srepok River. The vegetation cover on the land between waterways in Mondulkiri and Ratanakiri Provinces is dominated with deciduous forest communities (Maxwell undated; see also the Land use Map of Cambodia 2003; Ratanakiri Provincial Map and Land use 2005; Hourt 2005; Mosaic 2003).

Wildlife in the area that is reported to have global significance is, and limited to, the following highly threatened species: Sarus Crane (*Grus antigone*); Giant Ibis (*Pseudibis gigantean*); Lesser Adjutant (*Leptoptilos javanicus*); Green Peafowl (*Pavo muticus*); long-billed Vulture (*Gyps indicus*); White humped vulture (*Gyps bengalensis*); Banteng (*Bos javanensis*); and regionally threatened Asian Elephant (*Elephas maximus*) and Eld's deer (*Cervus eldii siamensis*); white-shouldered Ibis (*Pseudibis davisoni*); White-winged Duck (*Cairina scutulata*); Wild water buffalo (*Bubalus arnee*); Tiger (*Panthera tigris*) and the Siamese crocodile (*Crocodylus* *siamensis*) (Baltzer et al. 2001; WWF-Cambodia interviews; field interviews). For more details see Hout et al. 2003; Hourt 2005; Setha and Poole 2003; Timmin and Soriyun 1998; Claassen's 2004; Neath et al. 2001). Poaching (especially monitor lizards, crocodiles, turtles, birds) is a growing problem especially in the area of the Mondulkiri Protected Forest. Larger animals like the tiger are also targeted and are seriously threatened. Illegal logging also occurs (we saw several confiscated logs at the Lumphat Wildlife Sanctuary office in Lumphat District), and is serious in some areas. The presence of abundant and diverse wildlife with little protection allows for poaching, often reportedly stirred from across the border in Vietnam (interviews with rangers and WWF-Cambodia). Some of the animals listed above and others may have migratory paths that cross the Srepok River.

The riverbank of Srepok serves as habitat for a number of animals. Many bird species use the area for breeding (Table 4.8).

Table 4.8 Birds and Mammals inhabiting along Srepok River (see more details in Hout et al. 2003; Hourt 2005; Setha and Poole 2003; Timmins and Soriyun 1998; Timmins and Rattanak 2001; Claassen's 2004; Neath et al. 2001; Interviews in the field and with WWF-Cambodia)

Local name	Common name	Scientific name
Popoul Toek	Masked finfoot	*Heliopais personata*
Kh'tob Dei Mekong Leu	Makong Wagtail	*Motacilla samveasnae*
Tmart Phesh	White-rumped vulture	*Gyps bengalensis*
Thmart Phleung	Red-headed vulture	*Sarcogyps calvus*
Smoanh	Darter	*Anhinga melanogaster*
Antep Khmao	Black Drongo	*Dicrurus macrocercus*
	Blue Magpie	*Urocissa erythrorhyncha*
Orkprey Chreunpor	Changeable Hawk-Eagle	*Spizaetus cirrhatus*
	Chinese Intermediate Egret	*Egretta intermedia*
Staingtauch Slap Sruoch	Collared Falconet	*Microhierax caerulescens*
Chorchart Krem	Common/Blue-eared Kingfisher	*Alcedo atthis/meninting*
Tradev Tauch	Green Bee-eater	*Merops orientalis*
	Green pigeon spp.	*Treron*
Ka-aek	Large-billed Crow	*Corvus macrorhynchos*
Ka-aek Toek Tauch	Little cormorant	*Phalacrocorax niger*
Popoush Toek	Little Grebe	*Trachybaptus ruficollis*
Sat K'barl Thom Voin Trong Khmao	Little Ringed Plover	*Charadrius dubius*
	Needletail spp.	*Hirumdapus*
	Parakeet spp.	*Psittacula*
Kordorb Kbal Sor	Pied Kingfisher	*Ceryle rudis*
Tromakk Kh'la	Racquet-tailed Treepie	*Crypsirina temia*
Sek Sork	Red-breasted Parakeet	*Psittacula alexandri*
Tradevech Tonle	River Lapwing	*Vanellus duvaucelii*
Chha-orng Chha-ork Leung	Rufous Treepie	*Dendrocitta vagabunda*
Ngeav Kork	Stork-billed Kingfisher	*Halcyon capensis*
Popech Tracheak Chhnaut	Streak-eared Bulbul	*Pycnonotus blanfordi*
Kan Chreach	Vinous-breasted Starling	*Sturnus burmannicus*
Kh'tob Dei Khmao-Sor	White Wagtail	*Motacilla alba*
Kordorb Troung Sor	White-throated Kingfisher	*Halcyon smyrnensis*
Mammals inhabiting along Srepok River		
Local name	**Common name**	**Scientific name**
Sva Kdarm	Long-tailed macaque	*Macaca fascicularis*

Sva Pream	Silver Langur	*Semnopithecus cristatus*
Sva Kravatt	Douk Langur	*Pygathrix namaeus*
Phe Khluon Roloong	Smooth Otter	*Lutrogale perspicillata*
Ph'soat Tonle*	Irrawaddy Dolphin	*Orcaella brevirostris*
Krapeu Trei	Siamese Crocodile	*Crocodylus siamensis*

**Although it is said that the Irrawaddy Dolphin exist in the Srepok River, recent work by Ian Baird reports on the lack of sightings.*

In the next section key information is given on the most important protected areas that the Srepok River cuts through – as this is the focus of the report. This does not mean that the tributaries running across the landscape are not significant in the vegetation and wildlife habitat context.

BOX 1. Protected Areas used to describe and estimate biodiversity status in relation to the Srepok River

Lumphat Wildlife Sanctuary (LWS). LWS is located in the east of Cambodia and lies approximately between the longitudes 106°30'-107°25' and latitudes 13°15'-13°35'. The southwest of the sanctuary covers part of Koh Nhek District, Mondulkiri Province, while the rest cover large part of Kon Moum and Lumphat districts, Ratanakiri Province. The sanctuary covers an area of 2,500km², and main parts of the area is almost flat and ranging from 100 to 240m a.s.l.

Many rivers run through the sanctuary, of which Srepok River is considered as an important watershed for aquatic animal and plant. Srepok River flows through Yok Don National Park, Vietnam and passes through the sanctuary toward Mekong River in Cambodia. About 125km (c. 50 percent of total length of river in Cambodia) passing through LWS firstly defines the southern boundary of the sanctuary in the east, then runs through the center of the sanctuary, and finally defines the northern boundary in the west.

The southwest and north of the sanctuary is covered mainly by deciduous dipterocarp forest, and small patches of grasslands, gallery forest, bamboo grove, mixed deciduous forest and semi-evergreen forest, whereas the east is dominated by semi-evergreen and mixed deciduous mosaic forest. (text adapted from Hourt 2005, also consult Hourt 2005 for more details)

Phnom Prech Wildlife Sanctuary (PPWS). PPWS is located in Mondulkiri Province, bordering with Kratie province in northern part. It covers an area of 222,500ha or 2225km², and lies approximately between longitude 160°30'-107°10' and latitude 12°30'-13°00'.

There are many stream systems, running throughout the sanctuary and represent key watersheds for animal and human being. O Te, which is running through the southwest part of the sanctuary, is the main stream and flows toward Srepok River. Forest cover is a mixture of different types across the sanctuary and form a mosaic forest types including deciduous dipterocarp forest, mixed deciduous forest, semi-evergreen forest, evergreen forest, gallery forest, grassland and bamboo forest. Spring water areas and seasonal ponds are scattered throughout the sanctuary. These features are a satisfactory home for wildlife. (text from Hourt 2005, also consult Hourt 2005 for more details)

Mondulkiri Protected Area (MPA). Little is written about this area and it is not usually designated on official maps. It comprises the area between the above mentioned PAs and spans right to the Vietnamese border. Its area is thus contiguous with the above PAs and the Yok Don National Park in Vietnam (Birdlife International and FIFI 2001). MPA has the following zones: core, conservation, sustainable use, corridoe and community zones. Several wild animals have been reported in the MPA, e.g., elephants, wild buffalo, Eld's deer, crocodiles and the tiger.

In a study done by Hourt (2005) six forest habitats were identified in the PAs presented in Box 1 above consisting of deciduous dipterocarp forest, mixed deciduous forest, semi-evergreen forest, wetland and aquatic flora (riparian vegetation along streams and around ponds or lakes), grassland, bamboo grove. On the basis of forest cover map, evergreen forest is likely absent in LWS but present in isolated patches inside PPWS. A brief description of the main vegetation types associated with the river (Table 4.5) is presented below in Box 2. For more detailed descriptions of the communities presented below and those not elaborated upon here see Hout et al. 2003; Hourt 2005; Maxwell undated; Rundel 1999; Mosaic 2003; Baltzer et al. 2001). The PAs consist of many diverse forest habitats ranging from wetland to hill semi-evergreen or evergreen forest, although the dominating forest is the deciduous forest type. Lower plants include lichen, fungi, mosses and fern, whereas higher plants are dominated by angiosperms and a few groups of gymnosperms. Epiphytic orchids and ferns and other ornamental plant like *Hoya* spp. scatter throughout the forest. Mixed deciduous and semi-evergreen forests rich in valuable trees most of which are members of *Dipterocarpaceae* and *Fabaceae*. Those species have been cut for local commercial trading, and thus they are highly threatened. Based on the literature surveyed and interviews conducted we conclude that the riparian vegetation and associated wildlife (including riverbank animals like crustaceans, reptiles, amphibians and insects) are extremely poorly known – highlighting the need for thorough surveys.

BOX 2. Brief description of the main vegetation types associated with the Srepok River (Table 4.5) and protected areas which serve as habitat to wildlife, NTFP extraction and illegal exploitation.

Deciduous Dipterocarp Forest (DDF) : As mentioned earlier DDF is also referred to by different names, including dipterocarp woodland, dry deciduous forest, dry dipterocarp forest and forêt claire. It covers almost half of areas of the wildlife scantuaries, LWS and PPWS. The canopy trees are generally between 15-17m high, but on rich soil near the Crater Lake of Yeak May and Yeak Om in LWS trees are up to 25m high. The definition of DDF is drawn from the dominance of members of *Dipterocarpaceae*, which are well represented by *Dipterocarpus tuberculatus*, *Shorea obtusa* and S*horea siamensis*. *D. obtusifolius* and *D. intricatus* are, sometimes, also found associated with the DDF forest types but they are not significantly dominant in both the wildlife sanctuaries. Among the tall deciduous tree species in this forest type are *Terminalia alata* Hey. Ex Roth, *Terminalia chebula* Retz. var. Chebula, *Terminalia mucronata* Craib & Hutch, *Stereospermum neuranthemum* Kurz, *Schleichera oleosa* (Lour.) Oken, and *Kereya arborea* Roxb. *Sindora siamensis* Teysm. Small deciduous trees which are frequently encountered under the canopy trees are *Buchanania lanzan* Spreng, *Buchanania siamensis* Miq, *Catunaregam tomentosa* (Bl. ex DC) Tirv, *Morinda coreia* Ham., *Strychnos nux-vomica* L., *Phyllanthus emblica* L., *Simplocos racemosa* Roxb., *Eugenia bracteata* Wight, *Holarrhena pubescence* Wall. ex G. Don, *Aporusa* sp., *Xylia xylocarpa* and *Dillenia pentagyna* Roxb. A number of evergreen species are also associated in this forest type: *Memecylon scutellatum* (Lour.) Naud, *Mammea siamensis* (Miq.) T. And., and *Irvingia malayana* Oliv. ex Benn. Ground cover species include *Phoenix loureiri* Kurth, *Cycase siamensis* Miq., *Dillenia hookeri* Pierre, *Arundinaria pusilla*, and certain species of the *Fabaceae*, *Zingiberceae* and *Poaceae* families. All species in this forest type are fire-prone. Epiphytic orchids and ferns are fairly abundant in the canopy, and hemi-epiphytic plants, like the *Hoya* spp., are often found in this forest type. Forest fire, usually caused by humans, often occurs in the dry season between December and early April, and is considered a general phenomenon. Most of the trees and small plants start to produce new shoots and flowers after the first rain, especially in the middle of March and April.

Many termite hills are found scattered across DDF in the northeastern part of LWS. A number of species including *Polyalthia littoralis* (Bl.) Boerl, *Diospyros ferrea* (Willd.) Bakh. var *littoralis* (R. Br.) Bakh, *Melientha suavis* Pierre ssp. *suavis*, *Nervilia Crociformis* ((Zoll. & Mor.), Olax *scandens* Roxb., and *Cissus assamica* (Laws) Craib are abundant and appear to be confined to this ecological zone.
This was the common vegetation observed during the field work for this report.

Mixed Deciduous Forest (MDF). MDF is referred to a forest type dominated by deciduous tree species which comprises of a few or no species of *Dipterocarpaceae*. Tree and ground cover plant composition is more diverse in MDF than in DDF. Species diversity and dominant species vary in MDF due to specific physical site conditions. MDF can occur in narrow stretches between DDF and other forest types or in isolated patches inside DDF or semi-evergreen forest. MDF was not encountered in northeastern part of LWS, but was present in the PPWS. Dominant species included, in the sites surveyed, *Lagerstroemia* sp., *Cratoxylon prunifolium* Dyer, *Terminalia mucronata* Craib et Hutch, *Dalbergia nigrescens* Kurz, *Xylia xylicarpa* TAUB and *Adina sessilifolia* Hk.f., and associated less dominant species included *Grewia paniculata* TOXB., *Sindora cochinchinensis* BAILL, *Pterocarpus cambodianus*, *Aporusa* sp., *Strychnos nux-vomica* L, *Ceiba pentandra* (L.) GAERTN, *Irvingia malayana* OLIV. Ground vegetation sometimes is dominated by short bamboo but often has a mixture of tree seedlings, very short shrubs, sub-shrubs and grasses. Forest fire usually occurs in this forest type, as a result of spreading from DDF.

Semi-evergreen Forest (SEF). SEF is also termed dry evergreen forest or forêts dense. This forest type was characterized by a mixture of evergreen and deciduous trees. Grasses and bamboos are almost absent on the ground because of shade, but members of *Araceae* and *Zingiberaceae*, ground fern (*Pteris venusta* O.K, and *Tectaria impressa* (Fee) Holtt), and certain evergreen shrubs which prefer shade are abundant. Lianas, rattans and strangler trees are frequently found in this forest type. Many small isolated patches of SEF were found in northeastern part of LWS. It could be that annual fires with the combination of other human-related activities has reduced this forest types to isolated patches. PPWS still has both large or small patches of SEF. In general, tree composition found in the two wildlife sanctuaries include *Hopea odorata* Roxb, *Dipterocarpus alatus* Roxb., and *Ficus* spp. (strangler trees), *Tetrameles nudiflora*, *Irvingia malayana* and *Lagerstoemia* spp. According to observation in LWS, those canopy trees reached 25-30m high and 110-125cm dbh. A *Dipterocarpus* sp., growing around the shore of Yeak Om was more than 25 m in height. Notably, *Lagerstroemia* spp. in SEF, is different from the ones in MDF or DDF, not shedding their leaves entirely in dry season. Epiphytic orchids and ferns, especially nest ferns, inhabit the canopy of big trees. Due to the valuable timber for construction and furniture in the SEF, this forest type has suffered exploitation and degradation. Some areas within the SEF areas only spiny bushes and climbers can be found. At present, some of the local people living inside the PPWS depend on soft resin collection from *D. alatus* Roxb (a NTFP species). Forest fire usually spreads from the MDF or DDF the ground level of this forest reaching its margins and stops because of high humidity and more moisture at the ground level in the SEF.

Riparian Vegetation (Wetland) and Aquatic Flora. The PAs and the Srepok riverbank vegetation falls in the following categories: gallery forest, riparian, riverine forest or wetland forest, ponds or small lakes that support aquatic and inundated herbaceous plant, and swamp which is dominated by stilt root trees or shrubs.

Riparian forests are found along the Srepok river and its tributaries (see dominant vegetation along Srepok River, Table 4.5). This forest type usually represents semi-evergreen forest in terms of the dominance of evergreen trees, ground plant composition and soil moisture. Thus, most of forests along the streams, running through the DDF appear as a ribbon-like green feature. However, this type of forest is sometimes discontinued and replaced by DDF, bamboo forest or shrubland. The change of forest type along the streams may be a result of forest fire, land clearance for cultivation or timber extraction, although this remains unclear. Tree and shrub species composition growing along the streams include *Barringtonia acutangula* Gagnep, *Ficus* spp. (L'vea & Chrey), *Syzygium* spp., *Dipterocarpus alatus* Roxb, *Gmelina phillipensis* Cham., *Homonoia riparia* Lour., *Combretum trifoliatum* Vent and *Phyllanthus jullienii* Beille. Climbers include liana and rattan and other herbaceous plants of the families of *Zingiberaceae* and *Araceae*.

Ponds and small lakes occur across the two sanctuaries, and most of them are dry during the dry season, except for the crater lakes in LWS and the top of Gunshall hill in PPWS and areas with springs that retain water all year round. Some plants occur permanently in the water whereas others are sub-aguatic species. Some particular plant growing by the shores inside LWS were identified by J.F.Maxwell. Those particular species include *Nympoides indica* (L.) OK. (*Gentianaceae*), *Hydrilla verticillata* (L.f.) Roy. and *Ottelia alismoides* (L.) Pers. (*Hydocharitaceae*), *Scirpu grossus* L.f and *Scirpus juncoides* Roxb. (*Cyperaceae*), *Dopatrium acutifolium* Bon. and *Limnophila cambodiana* Yama (*Scrophulariaceae*) and *Nomaphila stricta* (Vahl) Nees (*Acanthaceae*). Swamp forest was encountered only at Yeak Om and Yeak May crater lakes in LWS. The study on species composition has not been done. Diversity of species composition is probably low and confined to only this area. All trees in this forest types are small and short, and produce stilt roots. Ground vegetation is of low diversity and includeds a few plants of *Calamus* spp., and *Korthalsia* sp., growing in the gaps.

Grassland. Grassland was not seen in the northeastern part of LWS but it was seen in PPWS and MPF. Grassland in PPWS was surrounded by DDF. Grassland is a result of the clearing of DDF for farming and then abandonment. The physical characteristics of grasses (*Poaceae*) is that they are very short (about 0.2-0.3 cm above the ground) and associated with sparse and dwarf trees, all of which represented the once intact DDF e.g. *Terminalia alata*, *Antidesma* sp., *Phyllantus emblica* L., *Zysygium* sp. and *Cratoxylon prunifolium* DYER.

Bamboo Forest (BF). BF is also termed as Bamboo Groves when it is not larger than 5 hectares. It is defined as such due to the dominance of bamboos in a particular area. All bamboo species in this forest types comprise *Bambusa multiflex*, *Bambusa bambos*, *Dendrocalamus nudus* and the pygmy bamboo, *Arundinaria pusilla*. Forest fire usually occurs in this forest type.

(text adapted from Hourt 2005, also consult Hourt 2005; for more details, Maxwell undated; Rundel 1999)

a)

b)

c)

Fig. 4.10 Forest near Sam Ka Village, Ratanakiri Province

a) Ringing of bark for forest clearance
b) Logging to obtain extra land for agriculture
c) Old forest clearance with some crop plants

4.2.3 Use of Forest and Wildlife by Local People

Local communities reported collecting NTFPs from the forested areas, including protected areas (Table 4.6). Local rangers expressed the view that as long as the local people collected NTFPs for subsistence the damage is minimal. However, when collection is done for generating income and demanded by external actors, then damage to the forest is significant, taking the form of logging, hunting and the capturing of animals. Illegal trade is an issue that is well known and where authorities are putting some focus on at present. Several villagers mentioned, during interviews, illegal activities in the forest that they had been part of. Some of the illegal logging in PAs and good quality forest areas is done to obtain extra land for paddy and fruit orchards. For more details see the Land use section of this report (Chapter 4.2.1).

4.2.4 Dependency on Srepok River – Animals and Vegetation Needs

Animals depend on the Srepok River for; drinking water, spawning and breeding/nesting needs (sand bank structures, riparian vegetation and periodic forest/bamboo swamps), deep pools, non-fluctuating water levels, and water currents directing migration.

Low dry season water levels may also function to facilitate migration across rivers, and changes in water levels can be disorientating. Similarly small crustaceans, amphibians and reptiles are reliant on lower fairly stable water levels in the dry season and are unable to adjust to dramatic changes (long or short-term) as they move slowly, have specific nesting and spawning sites, and can easily get desiccated. Organisms are physiologically, anatomically, morphologically and behaviorally adapted for survival in a specific habitat. Thus the destruction or creation of such habitats can either lead to the elimination or multiplication of certain species, often with chain reactions on other dependent or competing species.

Riparian flora and aquatic plants are highly dependent on water levels and generally have life cycles, as do many animals, adapted to seasonal water flow levels. Many habitats created by riparian plant species are vital for faunal breeding and nesting. Many plants also hang over the edges of the riverbank dropping leaves, flowers and fruit into the river, which can be consumed by fish and other animals, and for dispersal.

4.2.5 Threats to Vegetation and Wildlife

The main threats identified by several studies and interviews (NGOs, local people and rangers) are: illegal logging and habitat degradation, illegal trade/hunting/fishing and poaching, forest clearance for agriculture, unsustainable collection of certain NTFPs (e.g., resin), and forest fires.

4.3 Socio-Economic and Cultural Issues

4.3.1 Livelihoods and Subsistence Economy

Village Setting

Livelihoods in all the villages along the Srepok River are based almost entirely on paddy cultivation and fishery. Complementary activities like raising animals, collection of forest products and hunting also contribute to nutrition and may bring some extra income.

In a typical village, houses are located along the river parallel with the village road; home gardens with vegetables lie closest to the river, and fruit trees are grown around the houses. Rice fields are found behind the rows of houses at a distance of approx. 0.5–2 km from the river. Some families may also have fields on the opposite bank of the river. During the rice cultivation period they move across the river and live in the semi-permanent houses they built next to these rice fields. Between the rice fields and the forest further up from the river many villages have plantations with corn and watermelon, sometimes cassava. A few households (e.g. in Lumphat village) have started growing cashew nuts further inland, where they purchased land belonging to other villages.

In a usual village there is a small shop in the center of the village by the road. The shop is a natural point for meeting and exchanging information. All the shops in the villages visited during the field study were run by women. Most households keep pigs, cows, buffaloes and chickens that roam freely in the village.

Agriculture

In all studied villages paddy is grown for one crop per year. There are no irrigation systems, so all the fields are rainfed and cultivation takes place during the rainy season. After the rice harvest, vegetables are grown during the dry season. Irrigation water is carried to the gardens from the Srepok River, and from contributory streams, ponds and lakes. All cultivation is based on manual labor. A rice field size per household in general varies from 0.5 to 2 ha, but some households in the visited villages told their fields were larger. According to the Cambodian Land Law (passed in 2001), each household is permitted to have 5 ha of cultivation land, and can claim to clear new land up to that size. However, according to the customary land management, land is not owned by individual households but by the village community that distributes the land among the households (see Section 4.3.3 below). Reported rice productivity shows variations between different areas along the Srepok River: 0.7 ton/ha in Nang Khi Loek Commune in Mondulkiri Province; 0.47 ton/ha in Chey Otdam Commune in Lumphat District; 1.6 ton/ha in Kbal Romeas Commune in Stung Treng Province. No reasons for the differences in production are apparent; in all areas rice is cultivated only during the rainy season and no irrigation apart from rain is available. The rate of families using chemical fertilizers is too low to make any impact on the total productivity: in Nang Khi Loek no chemical fertilizers are used at all, in Chey Otdam 2.3% of the families use them, and in Kbal Romeas 6.8%. There might be differences in field management practices, but finding out any is beyond this brief study.

Most households along the Srepok River have dry-season vegetable gardens on the riverbanks. Main cultivation season takes place from November to April when there normally is no more risk of flooding from the river. Melon, potato, pumpkin and eggplant are grown right along the river together with vegetables like morning glory, beans, cucumber and salad. Along some stretches of the Srepok River sugarcane is cultivated as well. Wild growing vegetables on the riverbank are also utilized by households. Around the houses most families grow fruit trees like banana, jackfruit, coconut, mango, papaya and milk fruit. In some villages cassava plants are located close to the houses.

Behind the rice fields furthest away from the river many villages have plantation fields with corn, cassava and watermelon. Some households have also started cash-bringing cashew nut cultivation and may have fields further away from the village.

The food and crop plants are listed in Table 4.4 in Section 4.2.1 above, where also more information on the grown and collected plants can be found.

Fishery

Fish along with rice is daily food for all the people residing along the Srepok River. Most households are fishing, and there are several households in each village that are specialized in year-round fishing and selling fish. A normal daily catch for a household varies from 2 to 5 kg, but sometimes up to 10 kg fish can be caught in one day. During the cultivation season, especially during the most intensive rice planting period in September and October, many households are busy in the rice fields and have no time for fishing. At that time fish is bought from the fishing households. Fish is eaten fresh on a daily basis and the surplus is dried for later use. In many villages fish is sold to markets in the provincial capitals of Ratanakiri and Mondulkiri through middle traders traveling by boat, jeep or motorbike. According to NGO Forum 1995b, several fish buyers pay fees to commune councils or commune chiefs for a license to buy fish in local villages. Fish therefore constitutes a considerable income source for the riverside people.

Both row boats and motorboats are utilized for fishery as well as for traveling. There is a rowboat per an average of 6.5 families and a motorboat per 11.5 families in the Nang Khi Loek commune villages in Mondulkiri, and a rowboat and a motorboat per 7.7 families each in Kaeng San village of Ratanakiri Province in the upstream area. In the riverside villages of Lumphat District approximately every 4 families have a rowboat and every 5.9 families own a motorboat. In Kon Moum District riverside villages every 2.5 families own a rowboat and every 5.7 families a motorboat. In Kbal Romeas Commune in Stung Treng Province there is a rowboat per 3.9 families, while every 7.4 families own a motorboat. (SEILA 2004). People without boat can borrow boats for fishing or follow neighbors on the fishing trips. During the dry season men often stay away fishing for several days and nights in places with fish and fish buyers. Women rarely accompany on these fishing trips.

Fishery in the Srepok River is high productive due to many deep pools of up to 30m in depth, due to a rocky river bottom and a low human population density along the river. The many tributaries contribute to bringing new fresh water and nutrients into the main river. However, people in the riverside villages say fish has been decreasing; they blame fishermen using explosives and poison, and the unexceptional low water levels in 2003 and 2004 rainy seasons (information given by local villagers). The chief in Srae Ankrong Commune estimated that approx. 1/3 of the fish had disappeared during his lifetime. Traditionally the Lao people rarely were fishing in the deep pools of the river because they were afraid of the spirits, serpents and crocodiles believed to dwell there. These areas appear to be the very same deep pools that are important for fish spawning and growing. Nowadays people are no longer afraid of the deep pool dwellers; crocodiles have become rare and spirits are thought to live mainly in the forests. Even though the Lao still offer home-made rice or cigarettes to the water spirits in order to secure the catch on a specific gear, tradition no longer protects the dry season refuges for fish, and apparently increased fishing has affected the fish stocks in the river (Baird 1995).

In order to preserve, protect and increase the existing fish populations, Fisheries Office in Ratanakiri has organized the riverside villages in four communes (Srae Ankrong, Serei Mongkol and Trapeang Chres in Kon Moum District, and Chey Otdam in Lumphat District) along the Srepok River into fishing communities. The fishing communities have each been given fishing rights and protection responsibilities over a specific reach of the river. Accordingly the deep pool areas are now fish sanctuaries where fishing is forbidden during the dry season. The fishing communities also have the right to protect the river against illegal fishing. The Srae Ankrong commune chief told the villagers had a few times been able to arrest illegal fishermen with no fishing rights in the area. However, according to NGO Forum 2005b, not in all villages people are aware of the meaning of being a fishing community.

In some villages people admit that apart from fishing they collect snails and frogs for food. Snails are collected during the low water, and frogs are mainly found in the forest water sources and in the fields. In other villages people gave the impression that frogs are eaten only by the poorest people or during shortage of food.

Fish species and fishing practices are discussed in detail in Section 4.1 above.

Forest and Wildlife Utilization

Many villages in Lumphat and upstream along the Srepok River border to protected areas, which affect their land use and natural resource utilization. Villagers are allowed to collect wild growing forest products but not to cut down trees for house construction, hunt animals or expand cultivation land areas into the nature reserves.

People living in the riverside villages have a long tradition and knowledge in utilizing many types of forest products for food, medicine, shelter, and for additional income. Wild vegetables and fruits make an important supplementary food, especially during the dry season between January and June. Most fruits ripen from April to June. Vegetables, mushrooms and leaves provide an additional source of proteins and minerals to the diet based on fish and rice. A previous study on natural resources utilization in Ratanakiri identified more than 60 forest vegetables and 21 different fruits, of which 11 vegetables and 8 fruits were collected in almost all studied villages (Emerson 1997). Different kinds of leaves and bark are moreover used for medicine.

Wood is collected for firewood and for house construction. Forest provides material for making baskets and other household crafts. Honey adds to the diet, and resin is collected for sealing boats and making torches for lighting.

Wildlife hunting has been a very important activity for food and income for generations in the villages along the Srepok River. Elephant trapping was in the past one of the main livelihood activities. In the 1990s the wildlife trade was expanded with more species being traded through expansive networks in the area. However, during the past few years, wildlife collection has been decreased, due to law enforcement and increasing control and to the establishment of environmental and wildlife protection areas. According to the villagers met during the field study they just kill deers and wild boars that damage rice fields close to the forests. However, it is difficult to assess the real magnitude of wildlife utilization. According to NGO Forum 2005b, wildlife collection of turtles, lizards, pangolins, deers, wild boars, etc. still is an important activity and income source for the local people, and there are probably wildlife traders in all the villages in Srepok River basin in Cambodia.

Forest products collected and wildlife hunted are listed in Table 4.6 in Section 4.2 above, where also more information on forest products utilization is found.

Domestic Animals

In a typical village domestic animals are moving around freely. They are kept both for food and for income. Chickens and ducks are raised both for family food and for selling. Buffaloes are mainly draught animals and also used in religious ceremonies by the ethnic minority people. Buffaloes together with cows are an investment that can be changed into a larger sum of cash when needed. Poultry and pigs are commonly an important source of household income in all villages.

Practically all households along the Srepok River own poultry. In all the riverside villages upstream from Lumphat more than 90% of families have cattle (cows and/or buffaloes) and pigs, in Lumphat the variation between different riverside villages is from 32 to 83% of families with cattle and from 35 to 92% with pigs. In Kon Moum an average of 85% of families keep cattle and pigs. In Se San District villages along the Srepok River 93% of the families have cattle and 86% pigs (SEILA 2004).

Yearly diseases occur among the cattle in practically all villages leading to a great loss of income. Epidemics with foot and mouth disease affecting buffaloes and cows are reported in all villages. Spread of another deadly disease gives the sick animal a severely swollen stomach and leads to death, according to villagers. This disease (Pasterela Moltosida) can be stopped by vaccination. According to the data collected in villages, more deaths of cattle have taken place during the previous year along the Se San than the Srepok River, but NGO Forum report 1995b states that in each village along the Srepok River in 2004 some 10-20 cows and buffaloes had died, and in two villages as many as 100 and 150 animals, respectively. Many people met during the field study had also recognized an increase in animal diseases in 2004.

Additional Income Strategies

In the riverside villages in general everybody is engaged in the farming economy. People rarely have any occupations outside the village apart from trading surplus rice and fish, which is mostly done through mobile middle traders coming from the provincial capital. Selling of chickens and pigs bring income as well. Wildlife trade still appears to be significant, while selling handicraft products seems to have little or no importance in the riverside villages.

In Srae Ankrong Commune cashew nut cultivation has been gaining in importance. Several households have cashew trees in their home gardens, resulting into an approximate harvest of 5–10 kg per household. In Lumphat village a few families have cashew fields at the distance of some 5 km from the village. These families have purchased land belonging to another village in order to expand their cultivations. Cashew is becoming an important source of income in some areas along the river, although the main cashew cultivation areas in Ratanakiri Province are located in the central plateau between the Srepok and Se San rivers.

In most villages there is at least one small local shop selling basic items for households. It is clear that it is women who are small traders; all the village shops visited during the field study were run by women. Among Khmer and Lao it is quite customary that women are involved in small trade and small business activities. Salt, kerosene and other items for lighting, fishing equipment, cooking and washing utensils, clothes etc. are traded in the village shops.

4.3.2 Water and Health

Household Water

The most common household water source in the villages by the Srepok River is the river itself. In some villages, the most well-off inhabitants have dug wells, but the number of wells is low. Most families also collect rainwater in big stone containers placed at the corner of the house. Pit latrines are very few according to the field survey and the SEILA (2004) data. In Lumphat Village, according to the village chief, households have been provided with latrine construction material by the Cambodian Red Cross, but in a village with 159 households there are only 14 latrines so far.

Various water and health projects by the Government, Cambodian Red Cross, NGOs and SEILA Program have been initiated in the villages. As a result, most families boil their drinking water, except when they are too busy working in the rice fields. In most of the villages along the Srepok River visited during the field study wells are missing, or some of the existing ones are not used due to muddy water or pumping problems.

In the riverside villages cattle drinks water in the river and also in forest ponds and lakes during the rainy season. Other animals do not usually go down to the river to drink, but water is carried up to the village for pigs and poultry.

Flood Occurrence

Many of the villages have reported occurrence of floods almost every year during the rainy season. Floods caused by rains in normal years cause no damage, but exceptional heavy floods, like the one in 2005, may spoil a large part of the yearly produce. Loss of 40–80% of the total year 2005 rice harvest was reported in different areas in Kon Moum District. Flooding appeared different in various sections of the river, leading to diverse consequences, but rarely damage of houses. People suffering from the loss of their crops (rice and home gardens) got assistance from the Provincial Government, District Health Center (DHC) and NGOs like Health Unlimited cooperating with the health authorities. This support consisted of aid with temporary relocation, rice supplies and chlorine tablets to prevent epidemic diarrhea caused by unclean water.

Fig.11. Different types of water wells. (Lmuphat Village and Khaeng San Village)

Water-related Diseases
Diarrhea occurs seasonally among the riverside population during the rainy season, but seldom leads to death cases. Most patients coming to the DHCs with severe diarrhea are children. DHCs in Kon Moum and Lumphat have provided villagers with chlorine tablets to clean drinking water during extreme floods (like the one during the rainy season year 2005) in order to prevent epidemic diarrhea.

Malaria occurs during the rainy season along the riverside, but is more frequent in the highland areas. Only a few children die of malaria each year according to the DHCs.

Upper and lower respiratory infections (the latter leading to pneumonia) are very common during the dry season both in highland and lowland areas. Death cases in these diseases have been reduced due to medication available in the DHCs, but no figures are available.

The most common health problem of the riverside population is itching skin during the rainy season. It was mentioned in all the villages visited during the field study. According to the Kon Moun DHC staff, the rainy season skin problems are caused by a parasite living in muddy water, prevalent both in low- and highland waters. Symptoms usually remain in 2–3 months and can be relieved only to some extent by medication. Villagers reported an increase in skin diseases during the past few years, but this has not been recorded by the District Health Centers.

Diet and Health
Fish and rice make up the cornerstone in the diets of the people residing close to the Srepok River, added with both planted and wild growing seasonal vegetables. Fish is still abundant in the river, and in all villages fishing is a daily activity. Fish is the most important protein source in the human diet. Meat is not eaten on a regular basis; according to the field study most people eat meat approximately 1–3 times a month. Animals are mainly a source of income and not basic food. Meat is also ceremonial and festivity food.

Vegetables and fruit like cassava, green beans, pumpkin, tomatoes and banana are cultivated in riverbank gardens. In many villages, gardens with banana, mango, milk fruit and many other fruit trees are located around the houses. Vegetables, fruit, nuts, roots, mushrooms and leaves collected in the forest add to the diet. Previously wildlife played an important role both as food and as an income source, but as wildlife hunting has decreased, the importance of fish in the diet has grown accordingly. However, hunting habits appear varying from village to village and the importance of wildlife is difficult to assess.

According to the health care authorities iron deficiency is frequent, especially among pregnant women. Undernourishment is still common among children in Ratanakiri, but occurring less in the riverside villages than in the highlands due to fish in the daily diet. In general, the health status and general living standards are better among the people living along the Srepok River than in the highland villages.

Fig. 4.12 Mother with children in Lumphat Village, Ratanakiri Province

Health Care

In every district there is a DHC with counseling staff and midwives but no doctors. Doctors are regularly available only at the provincial hospital. Currently a health care structure of Health Posts at commune level is being established in order to bring the basic health care closer to villages. However, only a health counselor or, in the best case, a midwife can be available at the health post. Upgrading and provision of health services are in great need of both funds and staff. In Cambodia, especially in the northern provinces, NGOs play an important role in providing health services in cooperation with the health authorities. In Ratanakiri the provincial and district health care authorities are cooperating with NGOs like Cambodian Red Cross, Health International and Health Unlimited in developing the health care services as well as in efforts to bring water and sanitation competence and facilities into villages. Child vaccination campaigns are brought into villages, and DHCs provide children with Vitamin A. Consequently the under five mortality has been reduced considerably during the past ten years, but no exact figures have been available.

Utilization of health care services depends both on distance and transportation conditions to the DHC. In remote villages people rely on traditional medicines, traditional healers and traditional midwives. Especially among the Khmer and Lao there is an established tradition of treating both people and animals with medicines derived from plants. Most women in the riverside villages give birth in villages, assisted by traditional midwives. Only those living close to a DHC deliver their babies assisted by district midwives. Mobile midwives from the DHC, however, aim to serve the expecting mothers in the villages and distribute preventive medication to avoid e.g. iron deficiency, which is common among pregnant women in Ratanakiri. They also make regular check-ups of pregnant women in the villages. DHCs also cooperate with the traditional midwives and have invested in increasing their competence through training projects. The most common birth spacing methods according to DHCs are injections and pills for women, and condoms, but no exact figures have been available on frequency of birth control methods usage.

4.3.3 Cultural Significance of Natural Resources Utilization

The livelihoods, culture and lifestyle in the villages along the Srepok River are entirely based on utilization of available natural resources and on closeness to the river. Villagers strongly recognize the importance of the Srepok River for their lives. Water for drinking, washing, watering animals and for cultivation is taken from the river. Fish is everyday food and the river is still the major transportation way for several villages lacking proper road infrastructure.

Apart from the river, the traditional land management and forest utilization contribute to the livelihoods. Accordingly, the traditional thinking and culture are totally built upon man’s relation to nature. Nature is alive in both biological, physical and in spiritual meaning. Especially among the ethnic minority people, nature is inhabited with spirits that are important to consider related to agriculture, fishing, hunting, house construction and other important activities.

Spirits and Traditions Related to Land and Water

Areas inhabited by spirits both in the river and in the forest are part of the traditional resource management system. In the Srepok River traditionally some areas were scary for humans due to the spirits believed to dwell there. These areas appear to be the deep pools that are important for fish reproduction. The newly recognized fishing communities have the right to protect these areas and also protect their stretch of the river against illegal fishing.

In the whole river basin area there are many sacred forests, dwelling places for the spirits and the dead, and where also the departed family members lie buried. These forest are not allowed to be utilized but should be left in their natural state. According to a land inventory study, the soils in these forests have poor regenerating capacity, indicating sustainability in the traditional land management system.

In all studied villages the dead are buried in the forests on the other side of the cultivation lands, at a considerable distance from the river. No cultural artifacts or sacred places could be found on the riverbanks or close to the river in the visited villages.

Along the Srepok River some occupational and calendar traditions are connected to the river. Traditionally fishermen offer to the water spirits in order to secure an abundant catch connected to a specific fishing gear. Villagers also told about a yearly water festival tradition on the full moon day with boats floating in the river and prayers being offered to the gods.

The Current Context of Customary Land Management

The land use customs in the study area are recognized by a tradition of community land ownership, according to which all land belongs to the village, and the right to utilize a certain plot of land is distributed to a household or an individual within the village through the decision of the traditional leaders. Land can neither be distributed to outsiders (non-members of the village), nor can it be sold, but it can be inherited within the family or given to relatives in the same village. If a person with a land entitlement dies without an heir, the land is reverted to the community and can thereafter be redistributed. Both cultivation and residential land is treated according to this tradition.

Villages own traditionally a strong concept of community membership. There is a clear boundary between the land area of each community, which can be crossed to fish or collect forest products, but not to clear land. A non-member in the village is not entitled to retain a land plot within the community land unless he is first accepted to become a community member. This concept of community land and membership appears different in different villages, being stronger in ethnic minority and Lao villages than among the Khmer (NGO Forum 2005b).

Traditional land management is based on beliefs and customs. For the people entirely dependent on natural resources management, nature is throughout inhabited with spirits associated with particular places. Observance of the spirits is an integral part of life; before fishing or hunting or clearing a new cultivation land ceremonies are held to the spirits. Especially the daily lives of the ethnic minority people are enclosed by presence of the spirits in nature. In many places in Ratanakiri, spirit forests with specific rules and graves of the dead encompass areas up to several square kilometers. These spirit forests most often are an integral part of the ethnic minority people's tradition.

According to the Land Law 2001, communal lands have to be registered for ownership as either individual titles of communal titles. The law claims land to be defined as either residential or agricultural land, or as reserve land for rotational cultivation system. Areas of forest can also be included in collective land titles.

The Forestry Law (2002) and its Sub-decree (2003) on Community Forestry Management create a legal framework for communities' management and user rights of forest land. However, the issue of forest management rights appears more biased than that of cultivation land. Implementation of the decree has been delayed and questions of interpretation remain, such as how large areas can be allocated for community forest management. Meanwhile the authorities have granted concession rights to both Cambodian and foreign companies in many parts of the North-Eastern provinces. Added to the logging, mining and plantation activities of these companies, illegal land sales, land grabbing and illegal logging constitute a major threat for community land management. Due to the weakness of the provincial governance system, the Land Law and the Forestry Law are not respected and enforced, while the economic value of the natural resources in Ratanakiri and Mondulkiri is increasingly attracting outside actors to the area. At the same time, in parts of Ratanakiri and Mondulkiri provinces local communities' land management is restricted by establishment of protected areas such as Lumphat Wildlife Sanctuary and Mondulkiri Protected Area.

Provincial government in Ratanakiri is working with partner organizations to promote land security through community-based natural resource management programs. In many communes, villages' ownership of a specific land area and their rights to manage the natural resources in this land have been recognized accordingly. Especially the SEILA program (originally implemented in 1996 to establish a pilot model for improving local governance for poverty alleviation in rural areas) has since 2001 strongly focused on e.g. community-based natural resource management. The projects connected to SEILA (by NGOs and international donors) have in Ratanakiri brought together different stakeholders and the interests of both the local communities, district authorities and the provincial government in natural resources management.

5. IMPACT ASSESSMENT

This section highlights potential significant negative as well as positive impacts of the construction and operation of hydropower projects in Vietnam, which will result in changes to the baseline situation in the Srepok River in Cambodia. The operation scenarios described in Chapter 2 and in the Hydrodynamic Modeling Study (Appendix 7) are taken into consideration when potential impacts are assessed.

5.1 Impacts during Construction of New Hydroelectric Projects

5.1.1 Impacts on Water Quality, Aquatic Life, Land Use and Biodiversity

The assumption is that the water flow during construction of new power plants will be the same as it was before the construction started. The following construction phase activities may affect water quality, aquatic life, and biodiversity downstream the river.

- Erosion from road building, construction of camps, construction work in the reservoir, soil deposits etc.
- Erosion in downstream river due to accidental water releases
- Sedimentation in the slow flowing river stretches, with shallowing of deep pools
- Reduced primary production due to siltation of periphyton producing substrates, as well as due to reduced light penetration in the water column because of increased turbidity.
- Run off from rock material from the drilling, blasting and stone crushing plant (quarry)
- Sanitary effluents from the camps
- Oil and chemical spills
- Leaching of ammonia and nitrogen from the tunnel blasting and rock deposits
- Possible dry-ups during filling the reservoirs

Erosion from Natural Soils

<u>Impacts on aquatic life</u>

The flora and fauna of the Srepok River are adapted to considerable variations in the concentration of particles. While pure clear water rivers are very susceptible towards large inputs of erosion material from construction work, the Srepok type of river can most likely tolerate considerable amounts in shorter periods. During the construction phase, the excavation, filling, deposit and clearance activities will increase the concentrations of suspended sediments in the river to a much higher level than before the construction starts. Particularly high concentrations can occur as a result of sudden rain showers. This will disturb aquatic life through a number of impact mechanisms, like siltation of the bottom making problems for organisms that live in the sand and gravel (oxygen and water renewal problems), problems for periphyton and other organisms that live fixed to the bottom substrate like stones, etc. The submerged vegetation will have reduced light condition.

The erosion material will settle on the bottom in quiet river stretches, particularly if the river is loaded with particulate matter during the dry season. The important deep pools of the river can then be filled with sediments, and become shallower. These pools are very important fish refuges during the dry season, particularly for the big fish species. According to fishermen in the villages, there are many pools in Srepok River. According to fish community leaders in the villages these pools can be up to 30 m deep.

In the undisturbed river, the content of particles is very low during the dry season, but can be fairly high during the wet season. However, during the wet season the flow is so strong that the pools will not be filled with sediments. On the contrary, it is the current conditions during this period that are clearing the pools for sediments.

In rivers the bottom dwelling animals are normally the most important fish food. Most of the bottom dwelling animals in quiet stretches of a river live like the earth worm (i.a., oligochaeta, chironomidae, some trichoptera), i.e. they eat the surface sediment and digest nutrient containing organic material. Under normal conditions the sediment consists of a mixture of organic and inorganic material. When a river has been exposed to heavy erosion material, the sediment are converted to inorganic sand and silt (like a dessert) of low nutritional value for the bottom animals. As a result, the production of fish food is often much reduced.

<u>Impacts on land use and biodiversity</u>
Domestic animals that drink water from the river can be impacted.
Impacts on riverbank agriculture are expected to be minimum, although riparian vegetation (riverbank) and aquatic plants may be impacted.
This can affect aquatic animals, amphibians, reptiles, and wild and domestic animals that are dependent on the river for drinking, spawning and nesting. Note that since no exhaustive studies of fauna (other than some large mammals and fishes) and flora (other than tree communities types) diversity have been conducted and little is known of the ecology of most species and precise impacts are unknown.

The deep pools in the Srepok River can accumulate sediments that will impact pool dependent aquatic life – both flora and fauna.

Erosion Products from Blasting, Drilling and Stone Crushing
The natural erosion products are coming from erosion in natural soils. This consists of particles that have been weathered for thousands of years and the particles have got rounded edges. The newly formed erosion particles from rock drilling, blasting and crushing have often sharp edges. Thus, in addition to the damage created by turbidity and sedimentation, these particles can make direct damage to gill tissue of fish and other aquatic organisms.

Leaching of Ammonia and Nitrogen from Blasting and Spoil Rock Deposits
Modern blasting techniques include use of ammonium-nitrate containing explosives. The spoil rock, particularly from tunnel blasting, can contain large amounts of ammonium and free ammonia. If shotcrete is used at the same time as tunnel lining, the high pH in the runoff may convert the ammonium into free ammonia, which is very toxic to fish and other river animals and may also affect riverbank agriculture. This can lead to significant damage in small rivers, and also in large rivers during the low flow period.

Sanitary Runoff from Construction Workers Camp
Construction of hydropower projects requires many workers who normally live in temporary camps often near the river. If the sanitary discharge enters directly into the river, it may cause a health problem for people living in downstream areas due to water pollution (drinking water, irrigation water etc.). Untreated sanitary effluents should not be discharged to the river.

Oil and Chemical Spills
Construction of hydropower plants include use of a large number of machines of different kinds, like drilling- and boring machines, dumpers, tractors, trucks, shovel dozers, bulldozers, excavators, cars, etc. All these need maintenance, which will require workshops and machine parking areas and storage of large amount of fuel, motor oil, lubrication oil, cooling liquids (glycols), battery acids and other chemicals.

Necessary measures should be taken to prevent oil spill and other chemicals from these sites.

Reservoir Filling
Filling the reservoir for the first time often takes long time. Large reservoirs can take often more than a year to fill. If an ecological flow is not maintained during reservoir filling, it may cause severe damage to the aquatic life and fish in the downstream river. Filling the reservoir during the wet season is recommended but the way this is done has to be configured to the needs of river water levels for flooding paddy fields at the onset of the wet season. If the water level is not ample, rice seedling establishment can be retarded and in fact can result in seedling death. In the long run the productivity of the paddy can be impacted due to a poor early start in growth and establishment. It is also noteworthy to mention here that the contribution of the many tributaries to the water level and flow in the Srepok River will be significant.

5.1.2 Impacts on Socio-Economy and Culture

The anticipated negative impacts on aquatic and terrestrial environment along the river will affect the people living in the downstream villages. Accordingly, the evaluation of the expected impacts on people’s lives follows the assessment in Section 5.1.1 above.

Water and Health
During the hydropower plant construction, the downstream area *can be* affected by various activities in the construction site as listed in Section 5.1.1 above. Erosion, sedimentation, sanitary runoff, oil and chemical spills, ammonia and nitrogen leach etc. all affect the water quality downstream in a negative way. During the construction phase more people move into the project area, leading to increase of agricultural and human waste as reported in Section 5.1.1. Experience shows that spontaneous migration into the project area give a permanent population increase even after the construction period. Consequently agricultural runoff and human wastewater from the upstream area will increase.

Poorer water quality potentially leads to negative human and animal health effects. The Srepok River is the main household water source in all villages along the Cambodian side of the river. Domestic animals drink river water and are therefore exposed to all material carried by the river. Most often people boil river water prior to drinking it, which kills bacteria but does not change the chemical composition or reduce the toxins causing poisoning risk for people and animals. Chemicals, ammonia and nitrogen may impact on peoples and animal health. If sanitary discharge from the construction workers' camp enters the river, diseases may spread with the water into the downstream populations. The effects of different material in the river water enter the human and animal bodies both through drinking, bathing and washing. There is therefore an increased risk of: 1) acute poisoning syndromes, 2) acute diseases in stomach and skin, 3) spread of water-borne diseases and 4) health effects that may appear a long time after the exposure.

River water is used for irrigation of food crops. Chemicals and other contents in the water may go directly into the growing plants and end up in the humans eating the plant products, potentially causing negative short and/or long-term health effects.

Fishery
The potential effects of the hydropower plant construction on fish populations have been described above in Section 5.1.1. Changes in fish will affect the fishery and lead to negative impacts on people's diet and nutrition, with potential effects on worsened health status.

Fish is daily food and the main protein source for people living along the Srepok River. Decline in availability or quality of fish will have a serious effect on human nutrition along the riverside. Because fishing is an important income-bringing activity as well, reduced or lower quality fish will also harm the economy of many households in the riverside villages.

Economic and Mental Effects
Accidental floods can occur during filling of the reservoir. Experiences from previous accidents show that such incidents have devastating short-time and long-term economic and mental effects on people residing by the riverside.

Sudden floods can flush away boats and fishing equipment as well as riverside gardens. Houses have been destroyed and both people as well as domestic animals drowned in sudden accidental floods, leading to great economic losses. The risk for human lives is especially serious if sudden accidental water releases cannot be avoided.

All adjustments in the basic conditions for economic and cultural life imply an uncertainty to people. Both gradual and rapid changes can affect the downstream populations. The potential negative effects from hydropower development in Vietnam on people living along the Srepok River in Cambodia include those on access to household and cultivation water, on cultivation, on access to the river, on fishery, on nutrition, and on human and animal health. Such changes imply a major threat experienced by people. Sudden changes due to accidental flooding or dry-up lead not only to immediate losses but also to a fear of future incidents that can impact the lives of the people during a long time.

5.2 Impacts during Operation Phase (without Srepok 4 as a Re-Regulation Reservoir)

The impacts described below are possible impacts without Srepok 4 operated as a re-regulation reservoir. Beyond the negative impacts there will also be some positive impacts. The effect of Srepok 4 when operated as a re-regulation reservoir is described under Chapter 5.3.

5.2.1 Ecological Flow

With reference to Chapter 3.1, table 3.1, due to inflow of tributaries between Srepok 4 and the Cambodian border, the flow at the border will be nearly 50 % of natural flow with 0 release from Srepok 4. Further down the river in Cambodia this figure will increase. For example, at the confluence with the Se San River the flow will be close to 70 % of natural with 0 release from Srepok 4. These flow figures show that a minimum release from Srepok 4 in order to maintain ecological flow on the Cambodian side of the river, is not required.

In order to maintain an ecological flow immediately downstream Srepok 4 on the Vietnamese side, a certain release will be required, however, this is not evaluated in this study.

5.2.2 Impacts on Water Quality and Aquatic Life

Impact on Erosion Activity

Operation of hydropower plants affect many of the erosion processes taking place in a watercourse. Often the erosion activity increases, and the river water become more turbid. However, in the long run (after 10 years or so) the reservoir will trap sediments, and the water from the reservoir will contain less sediments than before regulation. On the other hand, if the power plant is operated in a daily peaking mode, the daily flow variations will cause in increased riverbank erosion along the downstream stretch of the river.

<u>Erosion in the reservoir area</u>

In the first period after the regulation several erosion processes will take place. The banks of the reservoirs will be eroded. The sediment binding roots will be destroyed by the inundation, and the soil will be prone to erosion from waves and the varying water levels. Most of the heavy sediments will be deposited in the reservoir, while much of the fine silt and clay will be transported downstream and make the water turbid. This erosion will create downstream problems only during the first years of the operation, as long as the erosion activity goes on in the reservoir.

<u>Erosion due to daily peaking operation</u>

The diurnal variation of water flow and hence water level will cause erosion in a long stretch of the downstream river. The impact will be most significant during the dry season. Figure 3.1 – 3.4 (Chapter 3 – Hydrology and Flow Regime), show the simulated water level fluctuation downstream of Srepok 4 during different operation scenarios. Figure 3.4 shows for instant that 6 hour peaking (6 hour operation at full capacity, thereafter 18 hours standstill) results in daily water level fluctuation of 1 meter at the border, 60 cm at Ea Hleo, and 20 cm at Lumphat.

The mechanism behind this type of erosion can be described as follows: The dry season up-and-down movement of the water level, combined with differences in flow speeds, will create erosion in the lower part of the riverbank, making this steeper, and causing slides, etc. When the water level is high during operation the riverbank will be soaked with water until it is achieved equilibrium between the water pressure inside the bank and the external pressure exerted by the river water. When the power plant is stopped, the water level will drop. The external water pressure will disappear while the internal pressure is still present. This will cause rapid outward directed water movements in the bank, loosing up the soil structure in the river bank surface. When the flow is increasing again due to start up of the power plant, the scouring forces of the current will easily dig out some part of this loose bank zone. In the long run this will excavate the lower part of the riverbank causing slides, tree-fall, bamboo-fall, and important riverbank stabilizing roots will eventually disappear. The riverbank will be more vertical, and will be prone to large scale erosion during flood periods. The increased steepness, and inorganic character of the changed riverbank, will make it less suitable for riverbank gardening than before.

It should be noted that even though the water level fluctuations in the central and lower part of the Cambodian Srepok River will be low, the erosion material from the erosion further up will be transported downstream, and will sediment in the deep pools in the dry season. Slowly, these deep pools may become shallower, and their ability to serve as dry season fish refuges will be reduced.

Therefore, it will be important to reduce these diurnal water level fluctuation as much as possible, particularly in the dry season.

<u>Erosion due to increased human activity</u>
A large scale hydropower development, as is planned in the Vietnamese part of Srepok River, normally results in permanently increase in human activity in the project area. Several of these activities give rise to increased erosion, such as building of roads with erosion prone road sides, residential areas, agricultural activities, etc.

Impacts on Water Quality

<u>Turbidity</u>
In the first period after the regulation the water will be more turbid. However, after the initial erosion from the reservoir banks is over (approximately 10 years) the reservoirs will collect particulate matter.

However, diurnal water flow and water level variations can create riverbank erosion along Srepok River in the lower Vietnamese stretch and the upper Cambodian stretch, and thereby cause turbidity problems, see the chapter on erosion for more details.

<u>Coliform bacteria and hygienic pollution</u>
The Vietnamese part of the Srepok River catchment has high population density. It is therefore likely that the river is considerably hygienically contaminated by domestic sewage water and runoff from livestock animals. The river should not be used for drinking without pre-boiling. The reservoirs will reduce the content of coliform bacteria in the river water, due to sedimentation and by the fact that several planktonic organisms eat bacteria. The longer the residence time is in the reservoir, the more

efficient is the reduction in the bacteria numbers. From a drinking water perspective, this is a positive impact.

Impact on eutrophication
Eutrophication is the result of over-fertilization of the water by plant nutrients, first of all phosphorus. The sources are normally discharges from domestic wastewaters and runoff from different agricultural activities.

In May 2005 there was observed a super-saturation of oxygen of more than 120%. At the same time the pH of the water was as high as close to 9. Both of these high values occurring at the same time strongly indicate high concentration of algae in the water. At the same time the villagers along Srepok River reported that the water was very green in the deep pools (village interviews). Most likely there was an algal bloom at this time. There was, unfortunately no monitoring of Chlorophyll (algal biomass) in this period. (See chapter 4.1 dealing with the baseline conditions for more information.)

Most of Dak Lak Province with a population of 1.8 million people drains towards Srepok River. In addition there is a lot of agriculture in the area. It is therefore likely that there might be eutrophication problems in the reservoirs with possibilities of having blue-green algal blooms in the dry season. In the national Hydropower Plan Study for Vietnam (NHP) projects model calculations indicated that Srepok 3 and Srepok 4 would get an average algal biomass of approximately 14 µg Chla/l (eutrophic level), while Duc Xuyen would be oligotrophic (2.5 µg Ckla/l) (NHP). In the NHP study each project was treated independently which means the cumulative impacts of all reservoirs were not considered.

The plant nutrient phosphate is the main factor causing eutrophication in fresh waters. Part of the phosphorus (P) that enters a lake is retained in the lake sediment. The retention is a function of the residence time in the reservoir. As the residence time is defined as V/Q (volume divided by flow) building of reservoirs will retain P in the watercourse and prevent some of this plant nutrient from reaching downstream stretches of the river. This process does not happen in rivers. In the NHP model calculations (the frequently used Vollenweider 1976 model) the retention of P in upstream reservoirs is not taken into consideration. This means that when all the reservoirs in Vietnam are built, the danger of developing eutrophication in downstream reaches in Cambodia is less than today.

In the first years after the construction of the dam, the reservoir often get eutrophic due to release of nutrients from decomposition of organic material in the inundated terrestrial catchment. They can then develop blue green algal blooms which in special cases can contain toxic algal species. The reason why they develop toxicity in some instances, are not well known. After 5-10 years this initial eutrophication is over. In the long run reservoirs always causes oligotrophication the downstream stretches due to trapping of nutrients in the reservoirs.

This is an advantage when using the river for drinking water, but a disadvantage when it comes to fish productivity, which will be reduced.

<u>Temperature</u>

The water for the turbines is withdrawn from the deep water of the reservoirs (at LWL). The temperature can be approximately 2 degrees centigrade lower than normal just downstream of the reservoir of Srepok 4, but will not be notable in Cambodia. This is not expected to create any notable problem. There may be some small impacts on the hatching period of fish eggs in the upper reaches between the border and Srepok 4.

Impacts on Aquatic Life

<u>Impact on the growth of attached algae</u>

Algae growing on stones, sediments, on macrophytes, on branches of trees, on mosses, are the most important primary producers in rivers. A lot of bottom animals (fish food) are subsisting on periphyton, and some fish species are eating periphyton as part of their diet, among them several of the cyprinids and the big pangasid catfishes. When the water gets more turbid, less light penetrate to the bottom where the periphyton grows, and the production of periphyton is reduced.

Sedimentation of erosion material onto the algal cover (siltation) is also impeding the primary production, as well as is makes it more difficult for the periphyton grazers to utilize the periphyton as food. The periphyton will be intermingled with inorganic, indigestible material.

<u>Sight problems for the carnivorous fish and other water animals</u>

Several carnivorous fish and other water animals are depending in the eyes when hunting. Reduced visibility is a constraint to their hunting ability, making the hunt less efficient. It requires more energy to get the same amount of food as before, which leads to reduced growth rate of the single fish, and reduced production for the fish population.

<u>Impacts on bottom sludge</u>

The bottom sludge (sediment), in the slow flow stretches of natural rivers consists of a mixture of organic and inorganic material. A lot of bottom dwelling animals are living in this sediment in the same manners as the earth worm. They eat the surface sediment and digest the organic material it contains. These animals are very important fish food. When the erosion material, which is more or less inorganic, settles in the slow flowing stretches, the sediment are converted to inorganic sand and silt like in a dessert. The production of the bottom animals is strongly reduced in such sediment.

<u>Impacts on fish migration</u>

Dams in the river will create migration barriers. Most likely several fish species are migrating far up in Vietnam for feeding, spawning and nursery purposes. This may be species that in other periods of their life cycle stay in other areas of the Mekong River system. Some of these migratory fishes are likely to live most of the year in the sea or at least in the Mekong Delta Region (see Baird 1995).

The water flow pattern is also an important aspect with regard to fish migration. For many species it is the first flow increase in the beginning of the rainy season that triggers the migration. These triggering flow is often delayed, or have disappeared in a regulated river with reservoirs.

Some small (often step-like) falls are only passable by fish when the flow is above certain size. The filling of the reservoir may delay the reaching of this flow size by considerable time, and the fish is not able to reach their destination in time, e.g. a spawning ground.

<u>Impact on fish spawning and nursery</u>
As described above, the spawning migration is often hampered by lack of triggering flow, or by too low flow throughout the migration period, for the fish to reach their spawning ground.

Spawning areas may be tributaries, flooded wetlands or forest, and rapids in the river. These areas must be accessible, and they must be wetted for a sufficiently long period of time to allow the eggs to hatch, and to provide suitable living conditions for the first life-stage of the fish larvae. The filling of the reservoirs in the first part of the rainy season is often a major reason why spawning conditions are not reached in regulated rivers. It may be lack of flooding, or that the flooding comes too late, and the flood does not last long enough to allow for nursery of the fry.

Erosion can be a problem for some spawners, e.g. those who are having their eggs in gravels in rapids. Settling of erosion material between the stones reduces the oxygen concentration in the gravel bed, which can be a problem for oxygen supply to the eggs and larvae.

<u>Impacts on the production of fish food and fish feeding</u>
The production of fish food is often strongly reduced in a regulated river. There are many reasons for this:

- Periphyton is reduced due to siltation and low light due to turbid water.
- Frequent water level fluctuations destroy the periphyton, macrophytes, and bottom fauna in the shoreline area.
- The increased sedimentation in the deep areas makes the sediments become inorganic, and contains little digestible food for the bottom animals.
- Reduced flooding of forest and wetlands prevent feeding migrations into these areas.
- The dams also makes barriers toward feeding migrations (total barrier).
- The altered flow pattern also makes problems for feeding migrations.
- The trapping of nutrients in the reservoirs leads to oligotrophication, which also results in less fish food production.
- The erosion of the riverbanks reduces the overhanging trees and riparian vegetation which reduces the organic litter fall (leaves, insects, etc) to the water.

<u>Impacts on dry season refuges – the deep pools</u>
Srepok River is known to have many deep pools, which are important refuge areas for those species that are staying in the river also in the dry season. Some of the pools were told to be as deep as 30 m at dry season water level. All activities that increase the content of soil in the water (erosion process), particularly those who contribute to suspended sediments in the dry season, will contribute to the filling of these deep pools. Filling of the pools will cause a great loss in fish abundance and species richness. Diurnal flow variation in the dry season is probably the worst situation.

During the high flow period the physical forces of the current is so strong that it does not allow net sedimentation in the river channel itself, only in the floodplains and in the Mekong Delta.

Impact on aquatic biodiversity

The Mekong River System is after the Amazon, the most species rich river in the world. However, the biodiversity is not yet fully described. About 600 fish species are described, but it is estimated that the river system contains approximately 1200 species (Rainboth 1996).

Some of the (for the science unknown species) have local names, but many small bottom living fishes are even not known among the local residents. In such species rich systems, the ecological niches are very narrow, and only small physical encroachments can wipe out several species.

There does not exist enough knowledge concerning the requirements of all these organisms with respect to water flow, water level variation, water quality, etc., to be able to manage the different populations properly in the new regulated river situation. The only way of trying to save as many species as possible is to try to keep these parameters as close as possible to the natural conditions.

Fishing

The planned regulation schemes in Vietnam can very easily give large negative impact on the fish stock in the Cambodian part of Srepok River. The mechanisms behind the impacts on the fish populations are described earlier in this chapter. Here we describe the impacts on the fishery:

- Reduced fish catches due to reduced stocks.
- Reduced fish sizes due to shift in species composition, but also due to reduction in growth rate.
- Some species will more or less disappear.
- The fish will get another spatial distribution and it will be necessary to fish in other places than to day.
- Fishery may be particularly poor in the dry season if the fish will migrate out of the river in their search for dry season refuge.
- It may be necessary with stricter fish management rules than today.
- More dangerous boating due to turbid water.
- Loss of fishing equipment due to sudden releases of water.
- Reduced catch will send the fish buyers to Mekong mainstream (e.g. Kratie) because of un-secure delivery from the Srepok fishermen.
- The local residents cannot subsist only on fish as protein source, they have use more livestock animals as food, or develop aquaculture.

Impacts on Aquatic Life from other than Hydropower Development

Aquatic life can be impacted in several ways other than hydropower development alone. Fishing using conventional and illegal (etc. explosives, electro-fishing, poison) methods can lead to over fishing, something which is already being pointed out as a concern by district and commune authorities. Conventional methods using the highly efficient machine made monofil gill nets are particularly harmful to fish, and this was brought up an important cause of decline in fishes. For example in the deep pools during the dry season, gill nets can take out much of the important brood stock population. Unsound and unregulated fishing practices can also lead to the spatial and compositional changes in the fish community, resulting in fishermen having to go to fishing in other places than today, causing changes in fishing practices and culture. Fishery management has to be considered seriously, and stricter rules for fishing rights and fishing might become necessary in order to protect the current stocks from extinction.

Another human activity that can impact aquatic life (all groups) is agricultural runoff. Today this appears not to be problem, however this needs to be kept checked as both inorganic input (fertilizers) and pesticide use may increase in the future.

5.2.3 Impacts on Land Use and Biodiversity

The assumption is that the flow of water will not be the same as it was before and during the construction phase. The following operation phase activities can affect land use practices and biodiversity down stream.

Erosion Resulting in Increased Sediments in the River Water

- Impacts on riverbank agriculture are expected to be marginal, although riparian vegetation (riverbank) and aquatic plants may be impacted.
- This can affect aquatic animals, amphibians, reptiles, and wild and domestic animals that are dependent on the river for drinking, spawning and nesting sites. Note that no exhaustive studies of fauna (other than large mammals and fishes) and flora (other than tree communities types) have been conducted and little is known of the ecology of most species.

Daily Water Level Fluctuation in the River

Usually high daily water level fluctuations can increase riverbank erosion, impact fauna drinking water, spawning and breeding/nesting needs (sand bank structures, riparian vegetation and periodic forest/bamboo swamps), influence riparian and aquatic vegetation.

Riverbank agriculture would not be possible during the dry season, as this has been reported by the Se San Riverbanks where water level fluctuations have been said to be unpredictable. The same is expected to be the situation along the Srepok River.

Animals (e.g. elephants) crossing the Srepok River on their migratory routes may be influenced by the unusual water levels and may be deterred by such uncertainty and new environmental conditions.

Small crustaceans, amphibians and reptiles may have difficulty in adjusting to water fluctuations in that these animals may not be able to move rapidly enough, be more vulnerable to desiccation, loose nesting and spawning sites. Organisms are physiologically, anatomically, morphologically and behaviorally adapted for survival in a specific habitat. Thus the destruction or creation of such habitats can either lead to the elimination or multiplication of specific species, often with chain reactions on other dependent or competing species. Note that since no exhaustive studies of fauna (other than large mammals and fishes) and flora (other than tree community types) have been conducted and little is known of the ecology of most species and precise impacts are unknown.

Riverbank erosion can become serious due to the gradual eroding of soil in the region of water level fluctuation. Such fluctuation eventually results in whole slope slippage into the water leaving steep slopes. Riparian vegetation comprising large trees and bamboo are vulnerable to such fluctuations are rare, the water level changes eating away the soil between roots of trees and advantageous roots of bamboos.

Filling of Reservoir and Delay in Release in Water

Decrease in floodplain (recession) agriculture can be a serious impact of hydropower projects. Filling the reservoir during the on-set of the wet season without allowing ample water to flow in the river can have serious impacts on the needs of relevant river water levels for flooding paddy fields. If the water level is not ample at the on-set of the wet season, rice seedling establishment can be retarded and in fact can result in seedling death. In the long run the productivity of the paddy can be impacted due to a poor early start in growth and establishment.

Accidental Releases of Water (e.g., spillway gate malfunction)

Any large release of water can have considerable impact by increasing erosion, destroying agriculture both on the riverbanks (in the dry season) and home and backyard gardens. Similarly domestic animals can be affected.

Impacts on flora and fauna associated with and entirely dependent on the river, can also be traumatic when there are sudden releases of water. For example, amphibians and reptiles can be seriously impacted by the profound changes in the water levels. Many representatives of these groups of animals may be local and endemic to the microhabitats with limited geographical ranges around water bodies.

5.2.4 Anticipated Impacts on Socio-Economy and Culture

Most of the potential impacts on human settlements during the operation phase are similar to those assumed during the construction phase. However, with the stabilized situation in the river after finished construction, during the operation period, some of the negative impacts felt during the construction period will reduce. Regulation of the river potentially contributes to flood control and to more even water flows throughout the year, which are positively felt by the people relaying on the river. Yet the anticipated negative impacts on aquatic and terrestrial environment along the river will affect the people living in the downstream villages. Accordingly, the evaluation of the expected positive and negative impacts on people’s lives is based on the assessment in Sections 5.2.1 and 5.2.2 above and on the experiences from existing hydropower operations on the downstream populations.

Water and Health

During the first years after the regulation, increased content of suspended sediments (erosion material), and possibly algae produced from nutrient released by decomposing terrestrial litter in the reservoirs, will affect human and animal health if river water is used untreated for drinking. After 5–10 years, the initial erosion will be over, the reservoir will trap sediments and nutrients, and the water in the river is anticipated to clear up. In the long run, the concentrations of algae and bacteria contents in the Cambodian part of the Srepok River will be less than before, because the reservoirs will trap both nutrients and bacteria. The effect may be improved water quality in the downstream area.

In the first years after the regulation the increased turbidity of the water will give some reductions in the suitability of the water for washing, but after 5–10 years the river water is anticipated to reach of the same turbidity as at present, or even better.

Construction of a hydropower plant potentially leads to increasing population in the vicinity of the plant. Human waste in the river water therefore tends to increase. Bacteria and other material are carried with the water and may affect the downstream population using the water for drinking, washing, bathing, irrigation, and for watering domestic animals. Unhealthy water can increase both acute and long-term health problems. However, the effect largely depends on the location of the increased population and their activities in relation to the reservoir and the river, their cultivation and animal keeping habits, sanitary conditions and waste management.

The downstream population depends on the river water for drinking, bathing and washing, irrigation of food plants and watering of domestic animals. People and animals drinking and utilizing the contaminated water are exposed for both increasing health problems and for acute poisoning risk during the construction and up to the first ten years of operation of hydropower plants. The current district health care systems in the areas along the Srepok River suffer from both lack of trained staff and lack of funds. The DHCs have no resources to provide any extra support or assistance in case health problems increase.

Along most of the Srepok River in Cambodia there are no alternative water sources available close to the villages. Tributaries can be used during the rainy season, but many of them dry up during the dry season. Likewise with forest ponds and lakes. Besides, the distance from the villages to these water sources may be considerable.

River water is used for irrigation of food crops. Contents in the water go directly into the growing plants and end up in the humans eating the plant products, potentially causing negative long-term health effects.

The only known drinking water treatment methods at present are filtration in water containers, boiling and chlorine tablets delivered by DHCs during extreme floods. Wells are few and latrines virtually non-existent in the riverside villages. Villagers are utterly dependent on the Srepok River for their household water supply.

Riverbank Use

If daily water fluctuations due to HPP operations are great, they will cause serious erosion affecting people’s and animals’ access to the river. Riverbank gradually becomes steeper making the access to the river difficult. This will negatively affect the daily activities like catching water, washing and bathing, boat transportation and animal watering.

Erosion will cause riverside vegetation to slip down into the river and can lead to sudden landslides on the riverbank. If there are gardens, houses or people on the riverside, such rapid collapse of land into the river will be devastating and cause serious accidents. If riverbank erosion becomes considerable, it will be impossible to continue cultivation close to the river. Consequently, people will loose cultivation land and have to find new areas to replace the riverside gardens. As access to new land is limited in parts of the river basin due to protected areas and land conflicts, impoverishment due to lack of land may be anticipated in some cases.

Navigation

For the people along the Cambodian part of Srepok, the river is the main transportation route. Most families own one or more boats, which are used for transportation across and along the river. The transport along the river is risky due to rapids with submersed rocks. When the water will be more turbid in the first years after the river regulation, rocks will be more difficult to see, and accordingly the boat transport will be more risky. Turbidity in the river may cause people to refrain from boating during certain periods. However, after some years of the HPP operation the turbidity is anticipated to reduce and may even be less than before the regulation of the river.

Water level is also important for navigation, particularly in the dry season. The kinds of regulation normally undertaken in the Vietnamese hydropower plants, result in higher water flow in the dry season, which should facilitate dry season boating.

Fishery

The potential effects of the hydropower plant operation on fish have been described above in Section 5.2.1. Reduced fish and the expected extinction of some types of fish will lead to smaller catches and impact negatively on both people's economy, nutrition and consequently culture.

Fish is daily food and the main protein source for people living along the Srepok River. Decline in availability or quality of fish will have a serious effect on human nutrition along the riverside. At the moment there seems to be no available alternative to replace fish as a major protein source, as wildlife hunting is regulated and domestic animals are mainly raised for selling and not for family food. Protein deficiency affecting especially the growing children can be anticipated if fish is dramatically reduced in the river and no alternative protein sources are used. Consequently a comprehensive change in the food production culture may be required in the riverside villages.

Because fishing is an important income-bringing activity, reduced fish or lower quality will also negatively affect the economy of many households in the riverside villages. Less income from fish will impoverish some households. As the spatial distribution of fish may be changed, fishermen have to go fishing in other areas than today, which will lead to changed fishing practices and culture. Stricter rules for fishing rights and fishing might become necessary in order to protect the remaining fish stocks from extinction. Reduced catch causing un-secure deliveries from the Srepok fishermen will probably make the fish traders concentrate to other areas like to the Mekong mainstream.

Economic and Cultural Effects

Accidental releases of water may cause considerable erosion and be destructive to cultivation lands. Experiences from previous accidents show that such incidents have devastating short-term and long-term economic and mental effects on people residing by the riverside.

Boat transportation will be affected by turbid waters as well as by floating trees and bushes in the water due to riverbank erosion. Daily fluctuations and accidental floods will further affect navigation and people's security on the river. Rapid changes in the water levels may capture boats, fishing equipment and other assets as has occurred in the Se San River. Lost fishing assets will take from the fishermen their basic prerequisites for attaining food and income. Moreover, the expected fish decline in the river will have a major negative effect on the economy of the fishing households. Especially the poorest households with poor land production will be seriously affected if fish catches be severely reduced.

If riverbank cultivation land is lost, it will increase the pressure on obtaining new land for dry season vegetable cultivation.

If there are accidental incidents, people's relationship to the river will change and their inclination for fishing, river transportation and other river-related activities will grow weaker. The experienced attitude may be the first step towards a change of the riverside culture.

Likewise if the reservoir is seasonally filled without securing a mean water flow in the river it may lead both to reduced fish and poorer water quality in the river. If too little water is allowed to be released in the beginning of the rainy season, there might be too little water for flooding the paddy fields, which affects the growth of the rice seedlings and may cause poor crop. This will affect both nutrition and economy of the affected people.

Both gradual and rapid changes potentially affect the downstream populations. There will be possible impacts on water access and quality, on cultivation land, on fishery and navigation, on nutrition, and on human and animal health. People in general experience such significant changes very dramatic. Moreover, sudden changes due to accidental flooding or dry-up cause not only immediate losses but can also lead people living in fear for future incidents. People may experience poorer life quality compared with the past and consider the future as unknown and threatening, due to unknown forces ruling over the basic natural resources in their lives. Changes in fishery, land and river use may lead into increasing poverty and into forced changes in the culture.

5.3 Impacts during Operation Phase (with Srepok 4 as a Re-Regulation Reservoir)

By operating Srepok 4 as a re-regulation reservoir, the negative impacts described under Chapter 5.2 will be considerably reduced.

As described in Chapter 3.1.5 and 3.2.5 the river flow will be close to the "normal", the daily water level fluctuations will be marginal, and the impacts related to such water level fluctuations will consequently be marginal as well. These impacts comprise:

- Erosion due to daily peaking operation will be marginal and hence the impact related to this little (for instance sedimentation of the deep pools).
- Turbidity will be reduced or in long term even improved.

- All riverbank activities will (e.g. river bank agriculture, non-migratory aquatic life use, river and river bank related vegetables, river water use) be little affected and the overall impact on social life and economy reduced accordingly.

The following impacts will remain the same as described under Chapter 5.2:

- Impacts related to accidental flow releases.
- Impact on water quality related to establishment of the reservoir.
- Impacts related to delaying the flood and reducing the flood peak.

5.4 Positive Impacts

Beyond the negative impacts related to hydropower development, there are also some positive impacts achieved, particularly in the operation phase.

Flood Control
The reservoirs can be operated in a way to reduce the flood peaks, which may reduce flood damage downstream in Cambodia. Some of this effect is described in Chapter 3.

Increased River Flow during Dry Season
The reservoir will store water in the wet season to be released during the dry season. This may increase the average river flow during the dry season that will benefit the use of the river during dry season.

Reduction of Coliform Bacteria
The reservoirs will reduce the content of coliform bacteria in the river water, due to sedimentation and by the fact that several planktonic organisms eat bacteria. The longer the residence time is in the reservoir, the more efficient is the reduction in the bacteria numbers. From a drinking water perspective, this is a positive impact. See Chapter 5.2.2

Reduced Turbidity of the river Water
On a long term, the reservoirs will contribute to reduce sediment transport from the upper part of the Srepok River and reduce turbidity of the water.

6. MITIGATION AND ENHANCEMENT MEASURES

This section identifies the environmental mitigation measures intended to address the potential adverse impacts of the project, which involve changes to the baseline conditions, as identified in Chapter 4 of the report. The Chapter 6.2 below takes into account that Srepok 4 will be built and operated as a re-regulation plant. This chapter (in Chapter 6.3) discusses additional mitigation measures to be taken in case this presumption should not be fulfilled.

The basic philosophy aims to outline measures appropriate to mitigate the adverse impacts to levels required by national and regional standards and guidelines. Another approach is to reduce the impact to what may be considered a tolerable level, in circumstances where direct qualification of the impact is not practical or possible, or where no specific standards apply or exist. Any adverse impacts remaining after specific impacts have been lessened by the mitigation actions would be categorized as residual impacts that are those impacts remaining after the mitigation measures have been implemented.

6.1 Mitigation of Impacts from Construction of New Hydroelectric Projects

6.1.1 Measures Against Erosion

Construction Roads and Permanent Roads

Excavation of roads in the steep valley sides in soft soils leaves large areas of denuded soils open for rain and water erosion. This problem applies to the inner side of the roads with the drain ditch, the road itself and the outward facing of the road. Even for temporary roads this will create wounds in the terrain that will slide and erode during the construction period if no stabilization is done.

The construction of roads should begin at the onset of the dry season with the excavating and bulldozering. Before the wet season starts, the road sides should be sowed by a convenient grass type.

The road ditch should be lined in erosion prone areas. The water in the road ditch should be released into existing brooks/streams. The road ditch should be released as often as possible, i.e. wherever there is a natural brook/flood brook. Road ditch outlets should not be allowed to be discharged into the valley sides in places where there has been no waterway before. If this is necessary in some places, relevant enforcement should be made to prevent erosion.

All road construction (access roads and broadening roads) will require similar procedures adjusted to the specific sites. The team responsible for this ought to work out a strategy for structured procedures for bio-engineering and revegetation allowing for adjustment based on site specifics.

Parking lots, camp areas and construction sites should be given the same mitigation measure as recommended for roads.

The permanent roads and sites should be paved as soon as possible after the construction.

Erosion in the Reservoir

To avoid erosion in the reservoir area clearance of woody vegetation from the inundation zone prior to flooding (nutrient removal) should be carried out as well as weed control measures taken. Weeds may be harvested for compost, fodder or biogas as well as regulating water discharge and manipulation of water levels to discourage weed growth should be considered. In similar lines sedimentation of the reservoir and subsequent loss of storage capacity may be minimized by control of land use in water shed (especially prevention of conversion of forests to agriculture). These require reforestation and/or soil conservation activities in watersheds coupled with the hydraulic removal of sediments (flushing, sluicing, release of density currents) and the operation of reservoir to minimize sedimentation (which can entail loss of power benefits).

6.1.2 Runoff from Tunnel Blasting and Tunnel Drilling

The water from the tunnel excavation performed either by blasting or full profile drilling, should pass a sedimentation pond prior to be discharged into the river.

In the low flow period, the sedimentation pond should be monitored with respect to ammonium, free ammonia, and pH. If necessary, pH should be adjusted to neutrality before discharge into the river. In the wet season, the ammonia discharge will not harm the river biota.

6.1.3 Soil Deposits and Spoil Rock Deposits

In the first period after a major tunnel and hydropower construction work the spoil rock deposit is normally used for construction purposes, filling material for road construction, quarries, etc. After some years they are abandoned, and should be closed in a proper way.

To prevent impact on water environment, the location is important, the water handling, and the final rehabilitation is important.

Location and Water Handling

These deposits should not be placed in steep terrain. The best location is in natural depression with infiltration outlet. Such depressions are, however, not always easy to find in the terrain near the construction area. The second best would be to place the rock deposit in a flat area with little runoff (i.e. upstream catchment) and good infiltration capacities (sandy soils).

If the deposits are placed in a valley-like depression, incoming water should be drained through by a pipeline of necessary capacity to safely by-pass storm runoff. Downstream of the deposits there should be constructed a sedimentation pond to settle out as much as possible of the eroded particles. The drainage from areas upstream of the deposit should be by-passed the sedimentation basin. If possible the runoff from the rock deposit should be infiltrated in the terrain.

Runoff from blasted tunnel material should be controlled with respect to the content of nitrogen and particularly ammonia and pH. Water with high concentration of ammonia and high pH can cause fish kills in low flow periods. In such cases the pH in the sedimentation pond should be adjusted to neutrality before released from the pond.

Final Rehabilitation of the Spoil Rock Deposit

When there is no more use of the spoil rock, the deposit should be leveled and formed into nature-looking terrain and covered by vegetation. Deposits with material from full profile drilling can often be sowed and planted directly, while material from blasted tunnels first must be covered by fertile top soil.

The top soil, gravel and soil from the tunnel ideally needs to be separately deposited. Upon spoil deposition top soil needs to spread onto spoil material, a multilayered technique ought to be used. This will allow roots of trees to reach and proliferate into rich soil zones within the spoil thus increasing anchorage and overall stability of the spoil. Most of the top soil must be placed on top. Immediately planting of tree species needs to be done at edges and grass lines on contours. Open flat areas of the spoil deposits where top soil is deposited, should immediately be made available to the local people for agricultural practices of agroforestry. It is vital that the rehabilitated areas is not open for grazing until all vegetation is established.

6.1.4 Sanitary Effluents from the Construction Workers Camp

During the construction phase there will be much activity at the different construction sites. There will partly be residential camps for construction workers, and partly administration buildings, workshops, machine parks etc. At these sites there has to be built sanitary systems with no direct discharge to the river. If possible, the camps should be placed in areas with good infiltration capacity. In such areas standard pit latrines may prevent hygienic pollution to enter the river.

If suitable infiltration soils cannot be found, toilet water (black water) and wash water (grey water) should be separated. Toilet water should be collected in watertight tanks and infiltrated at a safe place. The grey water can be infiltrated in the terrain.

An alternative is to have mobile latrines. These can be emptied every day/every second day at the sewage system of the nearest town or at a safe infiltration site.

6.1.5 Oil and Chemical Spill

During construction there will be a large park of machinery such as trucks, tractors, excavators, bulldozers, drilling machines, cars, etc. These will need diesel and gasoline, motor oil, hydraulic oil, battery acids, etc. Storage places for such chemicals must be established in secure areas where such compounds cannot enter the Srepok River.

The storage and fuel filling should take place on paved area, which is water-tightly drained to a collecting tank in case of accident spills. Workshop floors should be drained to a collecting tank from where the content can be removed and correctly treated.

Parking areas should consist of loose material with infiltration capacity which can absorb small spills. Such area should be constructed of stones, gravel, sand and silt.

6.1.6 Measures against Accidental Water Releases

The functioning of the spillway gates should be tested out properly with respect to both opening and closing before filling the reservoir.

A flood warning system to people living downstream the construction site should be established.

6.1.7 Measures against Dry-ups

The initial filling of the reservoir is suggested to be done only in the wet season with bypass of at least 10-15 % of average annual flow at the dam site. In the dry season, the normal low flow should be allowed to bypass the dam. It is important that the river is not dried up.

6.2 Mitigation of Impacts from Operation of Hydropower Projects

This EIA only assesses downstream impacts in the Srepok River in Cambodia and only includes measures that reduce the negative impacts along this part of the river. Measures that may be taken in the reservoir area, aimed to improve the aquatic ecology, and water use in the reservoir area, are therefore not considered.

Changes in hydrology are often the main reason for the environmental impacts caused by hydropower development. The aquatic life has over thousands of years adapted to a certain hydrological regime that is relatively predictable from year to year. The monsoon rain causes a flood flow, which triggers the spawning migration of hundreds of fish species. At the same time the floodplains get flooded and the farmers plant rice in the paddy fields. In November-December the water levels start to reduce and the dry season begins. At the onset of the dry season, fish begin to migrate back to the larger rivers, the farmers harvest the rice, farmers start their river bank gardens, and so forth. Every year, approximately the same cycle is repeated, with some deviation in years in between. These deviating years are also important in that the prevailing conditions can prevent certain organisms from developing too robust and dominating populations.

Hydropower development interrupts this normal hydrological cycle which both the aquatic life and the human use are adapted to. The dams, and any dry stretches, break the ecological continuum of the river, and prevent fish from reaching their spawning grounds, feeding grounds, nursery areas, etc. The changes in hydrology often result in increased erosion activity, which induces water quality, siltation, and sedimentation problems.

The most efficient way of reducing these impacts is to use the Srepok 4 reservoir to level out the diurnal flow variations. The flow out of Srepok 4 should be as equal to natural flow as possible. EVN has confirmed their intention to build Srepok 4 as a re-regulation reservoir with construction start 2006. With this scenario taken into consideration, the most relevant additional mitigation measures are listed below:

6.2.1 Prolong the Wet Season Filling of the Reservoirs

The reservoirs should be filled gradually with an increasing percentage of the inflow.

The start of the high flow season is important both for fish migration and for irrigation of rice paddies, and fish spawning wetlands. To allow the initial flow and water level rise close to a normal manner will increase the time used to fill the reservoirs. This is also important to allow for necessary time for fish egg and larvae development as well as ripening of the rice crop.

Gradually filling of the reservoirs will also give better protection against large floods.

6.2.2 Reduce the Nutrient Inputs to the Reservoirs

Densely populated areas with corresponding high sanitary effluents in the Dak Lak Province drain towards the Srepok River. The reservoirs are therefore prone to be eutrophic lakes, which can give rise to blue green algal problems. These can be mitigated by collecting the sewage water and build treatment plants before the effluent water is discharged into the rivers. Agricultural runoff should also be controlled, particularly if there are large scale animal husbandries.

6.2.3 Building Fish Bypass Systems

It is likely that fish from Srepok River migrate far up in Vietnam, as the river does not seem to have any physical barriers. According to a recent Vietnamese fish study in Srepok, more than 50 species of fish migrate from Mekong into Vietnam (Dr. Ho Thanh Hai, Inst. Ecol. Bio-Res. – personal comment). Another migration factor is that there are many flood prone wetlands in Vietnam well suited as spawning and nursery grounds for the kind of fishes present. However, this is not well known. <u>It should be further studied</u>, and if proved correct, one should consider building fish bypass systems allowing the most important migratory fish species to pass upstream.

Three different types can be used:

- Canals
- Ladders
- Lifts

Which systems will be best fitted in Srepok River, needs to be considered very carefully by expertise on the fish species present.

6.2.4 Fish Stocking Program

If the regulation after some years prove to have reduced the biomass of particularly important fish species, for example by destroying their reproduction success, it should be considered to replace the loss by fish stocking programs.

6.2.5 Development Program for Aquaculture

It is likely that the hydropower development in Vietnam will result in considerable loss of fish production along the Cambodian part of Srepok River. This will be a problem for the protein supply for the local residents along the river. This loss can be compensated by development of aquaculture along the river. There is very little tradition for aquaculture in this region of Cambodia, and it is necessary to develop a program aimed at low cost production in simple pond systems, or floating cage systems. In principal only local species should be utilized, but as the villagers now claimed that Tilapia already is spread to Srepok, this could also be considered.

6.2.6 Protected Areas

The presence of PAs in the area can be regarded as an asset in that such areas generally house expertise to deal with faunal and floral management. For example, in the case of Lumphat Wildlife Sanctuary local rangers have good knowledge of species and some of their movement paths. International NGOs (e.g., WWF-Cambodia, Wild Aid and Birdlife International) are building up knowledge on the species diversity and ecologies. It will thus be important to draw on national and international expertise to develop ways of minimizing impacts of large fluctuations in water levels during the dry season, if these occur. There is no doubt that many animals will be affected seriously, and that mitigation would have to be case specific. Creating of alternative (artificial) nesting and breeding areas may be explored as an option.
It may also be important to have a warning system which informs PAs, so that precautions can be taken where possible. Of utmost importance would be to establish an environmental monitoring system targeted on both physical and biological components. As mentioned in the baseline section the whole region (including adjoining Vietnam with Yok Don National Park and swamp areas) is of high conservation value and a comprehensive river related monitoring will be needed.

6.2.7 Mitigation of Socio-economic Impacts in the Downstream Area

The impacts from hydropower construction on people's lives in the downstream area depend on the measures taken firstly in the construction site and secondly along the river in order to reduce the anticipated negative effects related to water pollution and reduced fish stocks. The social mitigation and enhancement measures discussed in this section for the Cambodian downstream area of the Srepok River, are based on the expected impacts specified in Chapter 5 and on the recommendations on how to mitigate these effects at the hydropower construction and operation site as given above in Sections 6.1 and 6.2.

The social mitigation measures consider the "worst case", i.e. the negative impacts from hydropower construction and operation as given in Chapter 5, without implementation of the above-recommended mitigation measures. The capacity of the suggested mitigation measures to reduce the negative socio-economic impacts is evaluated against the worst-case situation. Experiences from a forthcoming study (by the same group of consultants as the present study) on the impacts of Yali hydropower plant on the downstream areas along the Se San River in Cambodia have been utilized. Also experiences from previous hydropower projects in Vietnam, like Song Hinh are drawn upon.

Water and Health

Development of water supply and sanitation systems in the riverside villages is of first priority and should be done before construction of any hydropower plant upstream. Local people should participate in wells and latrines construction and management in order to guarantee sustainable clean water supply. Awareness raising and training should be included in the water supply and sanitation schemes; traditional healers and women are obvious resource groups for taking responsibility for management of water, health and sanitation in villages.

There are no efficient available measures in the downstream area to treat the river water once it gets toxic or if it gets contaminated apart from the measures taken in the upstream: Careful implementation of the recommended mitigation measures in the hydropower site prior to the construction start in order to minimize the erosion and the discharge from construction materials, and to avoid sanitary, chemical and toxic releases in the water. Major reconsideration of construction methods and operation schemes might be needed in order to avoid destructive effects on the downstream area.

Fishery
Decreased fish catch leads to impacts on both nutrition and economy. Fish is the major protein source for people, and has to be substituted with other sources if fish will reduce significantly. Domestic and wild animal meat should be the best protein source, but currently people eat meat approximately only 1–3 times per month. Hunting is restricted by wildlife regulations and pigs, poultry and cattle are mainly kept for selling.

Changes both in the food habits (eating meat more often) and in economic resources (other sources of cash, or more efficient animal raising, demanding e.g. more pasture land, extension and training inputs and introduction of new fast growing species, e.g. rabbits) are needed to guarantee the future nutrition status of the riverside people.

Economic and Cultural Impacts
Awareness raising on hydropower development should be arranged for the riverside people. Positive and negative impacts from hydropower plants, and affected people's rights should be an integral part. Participatory capacity building with the aim of diminishing people's economic and cultural vulnerability should be arranged. Coping mechanisms and new skills development related to the potential changes in the environment as well as alternative income generating activities development are central for increasing capacity in the riverside villages. Naturally any material losses should be compensated at their real value, but these compensations should be focused on guaranteeing sustainable livelihoods development for the affected people and not be a one-time cash payment only.

6.2.8 Planning of Social Mitigation

People residing along the downstream area of the Srepok River base their subsistence economy on available natural resources in the area. They rely on water, cultivation land and forest. In the current situation food security is good for most of the riverside population. People's nutritional status is satisfactory and no children are undernourished due to the abundant fish in the river, providing the main protein source. In most villages households have enough cultivation land and can even produce a rice surplus, which together with fish and animals can regenerate cash.

Mitigation of the expected impacts from hydropower development along the Srepok River has to be based on restoring the present situation or compensating with equivalent resources. The required minimum level for mitigation measures should ensure the basic needs satisfaction at the present level for the people to be affected, as recommended in the MRC Hydropower Development Strategy (2001). Compensation in cash should be avoided, based on experience from previous hydropower projects. Cash compensation frequently has not lead to sustainable livelihoods for the affected people but in most cases to accelerating poverty. Instead the compensation should ensure basic resources restoration and viable livelihoods development through training and extension services.

Planning mitigation measures should always be made together with the different stakeholders involved in the project implementation. The stakeholder consultation process and mitigation planning should be started prior to project implementation in order to avoid much of the negative consequences. Following the recommendations of the WCD (2000) of involvement of various stakeholder categories, in the Srepok downstream area at least the following groups should be involved in the stakeholder consultation process:

1) Directly affected people: People living in the riverside villages as given in Table 1.1 in section 1.3.3.
2) Indirectly affected people: People utilizing the river for their life activities but not residing along the river, e.g. seasonal fishermen in Ratanakiri Province.
3) Women in the directly affected villages.
4) People's organizations, e.g. Srepok Committee in Lumphat, Kon Moum and Se San Districts.
5) District health care staff and traditional health providers.
6) Village and commune chiefs of directly affected areas.
7) District administration representatives from Lumphat, Kon Moum, Se San and Kaoh Nheaek districts.
8) Provincial ministries representatives from Ratanakiri, Stung Treng and Mondulkiri provinces.
9) NGOs working in the affected areas (e.g. Health International, Health Unlimited, Cambodian Red Cross, 3S Protection Network etc.)

The stakeholder consultation process should be based on the risks and rights assessment (see WCD 2000) and lead to agreed measures for mitigating the negative impacts along the Srepok River in Cambodia due to hydropower development in Vietnam. The institutional capacity in Lumphat, Kon Moum, Se San and Kaoh Nheaek districts and the affected communes and villages along the Srepok River for implementing the mitigation measures should be carefully evaluated in order to guarantee a sustainable development after the hydropower project operation. Both planning and implementation of mitigation measures should take place in cooperation with and supporting the existing institutional organizations like commune councils and district health centers. People's organizations and NGOs working in the area should be involved in the activities as well.

6.3 Additional Mitigation Measures without Srepok 4 operated as a Re-Regulation reservoir

Chapter 6.2 has taken into account that Srepok 4 will be built and operated as a re-regulation plant, which will be one of the main mitigation measures for the cascade development on the Vietnamese side of the Srepok River.

This chapter discuss additional mitigation measures to be taken in case this presumption should not be fulfilled. Obviously, according to international standards, detailed EIA studies will have to be conducted for each project in order to outline potential impacts and propose detailed mitigation measures.

6.3.1 Erosion

Erosion is one of the most significant problems associated with hydropower development and operation. Poor land use practices in catchment areas resulting in increased siltation and changes in water require land use planning efforts which include watershed areas above the dam and in the project area. Mitigation through revegetation or rehabilitation has to be monitored during the different phases.

Erosion will be one of the prime impacts related to the removal of vegetation, disruption of pasture areas and road cuts. This impact will be exaggerated when slopes are steep due to the seasonal conditions when the construction starts. Erosion does not only result in loss of valuable top soil but also leaching of soil nutrients and loss of organic matter. Mitigation or restoration measures must be planned ahead of the construction.

Rehabilitation (bio-engineering and revegetation) measures must include (Table 6.1):

1) using fast growing species for slope stabilization and possibly soil enrichment;
2) using nurse plants (grasses) which help stability in open patches and
3) encourage perennial herbaceous species and slower growing tree species to establish in parallel to fast growing species.

Table 6.1 Benefits and limitations of different vegetation types (Dhillion, unpublished)

Vegetation type	Benefits	Limitations
TREES	Deep rooting zone, root soil binder.	Slow to develop additional weight to slope.
	Increased transpiration modifying slope hydrology; deters raindrop impact.	Effects on hydrologic function negligible during monsoon rains, but improves micro-climate for most of the year.
	Increases infiltration on hard, compacted soils with high surface runoff.	Increase in infiltration is not desirable on low tensile strength materials that are susceptible to down gradient movement.
	Leaf litter of broadleafs produces good quality humus and improves understory growth.	Coniferous leaf litter increases soil acidity, degrading understory and increasing potential for erosion.
SHRUBS	Form a dense lower cover; have moderately deep roots.	Do not effectively control surface erosion.
	Moderate increase in infiltration.	On naturally unstable slopes, the slightest change in slope hydrology can produce failure.
	Light in weight; multistemmed thus more resistant than trees to debris damage.	
GRASSES (and small bamboos)	Dense root mat, intercepts rainfall, good surface soil binder, minimizes surface erosion.	Shallow rooting, limited application for landslides as they control erosion only a few centimeters from the surface.
	Rapid development produces humans. Recover from damage and burial.	
BAMBOOS	Deep, dense rooting; huge massive clumps with low turning effect on slopes.	Difficult to propagate and slow to develop.
	Increase infiltration on compacted soils.	Increased infiltration can be a problem. Clumps high on unstable slopes can fall depending on the slope.

The impacted land may strategically be restored for grazing (pasture with some trees) and agriculture where possible (depending on slope and soil fertility). The steepest areas should strictly be used for planting tree species (with grass) and not grazing.

Ideally a site evaluation should be carried out by a rehabilitation/mitigation team to assist in selecting the specific mitigation and monitoring procedures. After the site evaluation a detail mapping may be necessary, if the area is very large, generally the latter will require some simple sketches. The last step would be to select methods for vegetation and soil (also gully) stabilization based on physical features. After this is completed a final evaluation of all details is to be done in line with the ecosystem management scheme established before beginning mitigation steps.

Choosing of vegetation for rehabilitation and revegetation studies can be based on whether simply creating natural species rich environment is a goal or if local use has to be considered. Often long term community participation and concern declines when conservation is the sole goal. In a hydropower project there are two basic types of sites that need to be rehabilitated - one where no harvesting or resource removal can take place (includes permanent areas of the dam project) and the other where upon rehabilitation local use or agro-cultural practices may be allowed. The collection and suitability of the species at each site of revegetation will have to consider soil characteristics, hydrological/drainage conditions and slope. The need to have plants (seeds, seedlings or cuttings) ready before hand is of utmost importance. Generally cleaning and sorting of seeds, germination trials, and cutting and seedling cultivation needs to prepared. Therefore pre-project planning is essential (note that 6 months set up time prior to project beginning is recommended).

6.3.2 Daily Water Level Fluctuations (and sudden releases of water)

Impacts on agriculture (especially riverbank), riverbank stability and flora and fauna can be devastating especially in the dry season. These can be minimized by regulating dam releases to partially replicate natural flooding regime. Erosion prone areas and bare slopes can be rehabilitated/revegetated based on the above recommendations for erosion. Riverbank rehabilitation / stabilization can be necessary at some erosion prone areas.

6.3.3 Riverbank Agriculture

In case of increased erosion of riverbanks and irregular water fluctuations, riverbank agriculture will not be possible. The most dependent families on this form of agriculture will need to have land allocated to grow the daily consumed vegetables during the dry season. For the poorest in the community this would be necessary as they also are the ones which have the least amount of land.

6.3.4 Flooding and Land Use

Unexpected flooding may cause lost property like boats and fishing equipment, as has taken place along the Se San River. Rapid water level changes cause uncertainty in riverside people due to the river getting unreliable and its water movements unpredictable.

Families loosing riverbank cultivation land due to erosion and landslides have to find substitute land for dry season vegetable cultivation. Irrigation of cultivation land, however, can become more difficult as the distance to the river increase and the erosion makes the riverbank steeper and the access to the river becomes harder. Also wild growing plants that are collected for food along the riverbank will be affected and consequently this source of nutrition will disappear.

The need to develop pumping of irrigation water from the river up to the fields may become more acute if fields have to be moved higher up from the river. Measures for protection and rehabilitation of the riverbank through vegetation are given above in Section 6.3.1.

In case accidental flooding takes place from the hydropower plant, causing property losses, full compensation in cash and/or kind should be provided.

During the operation phase the hydropower plant should be operated in a manner to avoid large daily flow fluctuations and a minimum flow should be guaranteed.

7. MONITORING PROGRAM

This section outlines the scope of environmental monitoring and auditing program on the Cambodian side of the Srepok River likely to be associated with the implementation of the environmental management program for hydropower development in the Vietnamese part of the Srepok River. The full environmental management program is normally elaborated during the full EIA study of the project, and will reflect the final design considerations.

It is emphasized that in line with international recommendations monitoring is necessary even if Srepok 4 is built and operated as a re-regulation plant.

7.1 Requirements for Environmental Monitoring

The Environmental Impact Assessment specifies, in general, requirements for environmental monitoring. An Environmental Management Plan will be required, which consolidates and then defines responsibilities for the various mitigation measures, as well as indicating where, when and how the mitigation measures will be implemented. Secondly, an Environmental Monitoring Plan will be required which defines responsibilities for the monitoring, the parameters that will be monitored, where the monitoring will take place, and how often it will be required. Monitoring is an important element of environmental management as there is always some uncertainty as to the extent of the impacts on the natural environment, as well as on the socio-economic and cultural environments.

The mitigation and monitoring plans are prepared directly by, or on behalf of the licensee during the detailed design phase.

The environmental monitoring activities for the project development to come are expected to be divided into three parts:

1) *Baseline and Pre-Construction Monitoring*: the aim is to identify, collect and verify the environmental baseline data, which is scientific or sociological in nature, and needed to augment information on baseline conditions initially generated during the EIA. Such information will be used to finalize the priority and details of specific mitigation measures for potentially significant environmental impacts, such as where detailed field study or and multi-season, or multi-year trends and patterns are needed to fully understand the nature of the issues.
2) *Construction Phase Monitoring*: this is generally subdivided into two related activities:
    - **Compliance Monitoring**: in which the licensing entity oversees and ensures implementation of the required mitigation measures, according to guidelines, and the approved mitigation plan; and
    - **Impact Monitoring**: which involves actual measurement of the impacts of construction phase activities on the environment, such as water quality samples being taken at regular intervals to assess pollution concentrations in the river from construction work camps, after mitigation steps have been taken.

3) *Operational Monitoring*: similar to construction monitoring, operational monitoring is needed both to assess the degrees of on-going compliance with environmental regulations, and to directly assess long-term impacts of the project on the environment. The aim is to identify whether the mitigation measures that have been prescribed are sufficient and are having the desired effect, and otherwise to provide advanced warning and highlight any need for stronger or further mitigation or enhancement activities.

7.1.1 Baseline and Pre-Construction Monitoring

Baseline Monitoring

The primary concern during this phase will be to implement field data collection programs needed to enhance the knowledge of baseline conditions; such as to obtain scientific and sociological information needed to finalize the design and cost of the mitigation measures. The baseline data collection during the EIA study may not be sufficient for this purpose.

Pre-Construction Monitoring

In the pre-construction monitoring, it will be necessary to confirm that all procedures regarding land acquisition and compensation have been properly set out and followed, and that the construction mitigation is in place (particularly so in transboundary rivers). Priorities in this regard will inter alia include;

- Verification that the EIA mitigation recommendations relevant to the Contractor’s responsibility are incorporated in the tender specifications;
- Verification that all government permits and approvals are in place prior to construction;
- Verification that the land, property and crop and livestock disturbance compensation valuations have been completed prior to construction;
- Verification that all the necessary sub-plans within the framework of the environmental mitigation plan have been identified and prepared; such as the Acquisition, Compensation and Rehabilitation Plan or equivalent Relocation Plan;

7.1.2 Construction Phase Monitoring

Construction phase monitoring is more comprehensive and multi-faceted. The construction phase mitigation management program will be a shared responsibility among the licensee, main contractor and sub-contractors. For the purpose of compliance monitoring, monthly monitoring reports will be required and incorporated in an annual monitoring report. The report will provide the basis for assessing the compliance with regulations to be followed.

The impact monitoring will focus on key indicators to assess whether the impacts have been accurately predicted, and whether the mitigation measures are sufficient and effective.

Suggested variables or indicators to be used in the monitoring program and the data collection methodologies are shown below. It is also anticipated that an environmental audit will be prepared on an annual basis by an independent monitoring specialist.

7.1.3 Operation Phase Monitoring

The licensee will have the primary responsibility for the operation phase monitoring. Similar to the construction phase monitoring there will be compliance monitoring and impact monitoring. The compliance monitoring will focus on determining that the prescribed mitigation and enhancement measures are being carried out.

The impact monitoring will again focus on key indicators to assess whether the impacts have been accurately predicted and whether the mitigation measures are sufficient and effective.

Special attention in the first years of operation should be paid to the impact of the minimum release and the maneuvering regime of the hydropower plant, i.e. effects of peaking production on the downstream aquatic life. In particular an assessment will be required of minimum release and the adequacy for maintaining aquatic habitat and fish species.

7.1.4 Environmental Auditing

Auditing refers to a general class of environmental investigations that are used to verify past and current environmental performance. In the context of the environmental management of a project, environmental impact auditing assesses the actual environmental impacts, accuracy of prediction, effectiveness of environmental impact mitigation and enhancement measures, and functioning of pre-construction, construction and operation phase monitoring mechanisms.

7.1.5 Reporting of Monitoring and Reviews

The project Environment and Community Unit (ECU) which will have Environmental Monitoring Officers, has the responsibility to review all the mitigation works of the contractors and to regularly monitor the impact of the Project against the proposed series of indicators and standards. During project construction the ECU will undertake the following three levels of monitoring:

1) *Regular monitoring*: This covers the day-to-day monitoring carried out by the ECU, through the Environmental Monitoring Officer. He will report on a weekly basis to the Project Manager, as well as immediate reporting when a particular issue or problem arises. This will include monitoring of the contractors, as well as the mitigation and other activities of the Project. A monthly progress report as well as an annual report at the end of the fiscal year should be submitted to the relevant authorities in Cambodia and Vietnam.
2) *Annual Review:* This will be undertaken in co-operation with the project, the ECU and the relevant authorities, but will be carried out by a team of expatriate specialists assisted by local experts who will review the records, and comprehensively look at the project activities. The report will be submitted to the Project Manager. This will form the basis for preparing an Annual Environmental Monitoring Report, which will be submitted, to the relevant authorities, lenders, and others as appropriate
3) *Interim Review*: This will be similar in nature to the Annual Review, but will be prepared by a smaller local team.

7.1.6 Implementation of Monitoring

The responsibility for monitoring during the various phases will lay by the Project Owner, but should be discussed with and confirmed by Cambodian and Vietnamese authorities.

***Baseline Monitoring*.**
The Licensee is responsible for initiating the various baseline monitoring activities like for instance on going hydrological and sediment data collection program. The Project Owner will also be responsible for providing appropriate funding to all studies found necessary.

Pre-Construction Monitoring.
The monitoring activity includes mainly of verification that rules and regulations pertinent to hydropower development have been adhered to. It is the responsibility of the developer (licensee) to ensure that all permits and approvals have been obtained.

Construction Phase Monitoring
The Project Owner will have the overall responsibility of establishing and executing a comprehensive monitoring program. The program should be approved by the relevant Cambodian and Vietnamese authorities. The licensee should fund all activities included in the approved program.

***Operation Monitoring*.**
Through discussions with the appropriate authorities in Cambodia and Vietnam, an operation monitoring program should be developed. The licensee will have the overall responsibility for funding and implementation of the monitoring program.

7.2 Monitoring Program for Water Quality, Aquatic Life and Erosion

7.2.1 Monitoring Stations

Figure 7.1 shows the proposed stations in Srepok River for monitoring the water quality, aquatic life and erosion.

1) Bridge where Road 38 crosses Srepok River
2) Lumphat
3) Border to Vietnam

The 2 lowermost stations are easily accessible by car. According to the map, the station 3 should also be accessible by car, but the quality of the road may be questionable. Anyhow, there should be a station downstream of the Srepok 4 reservoir as close as possible to the border.

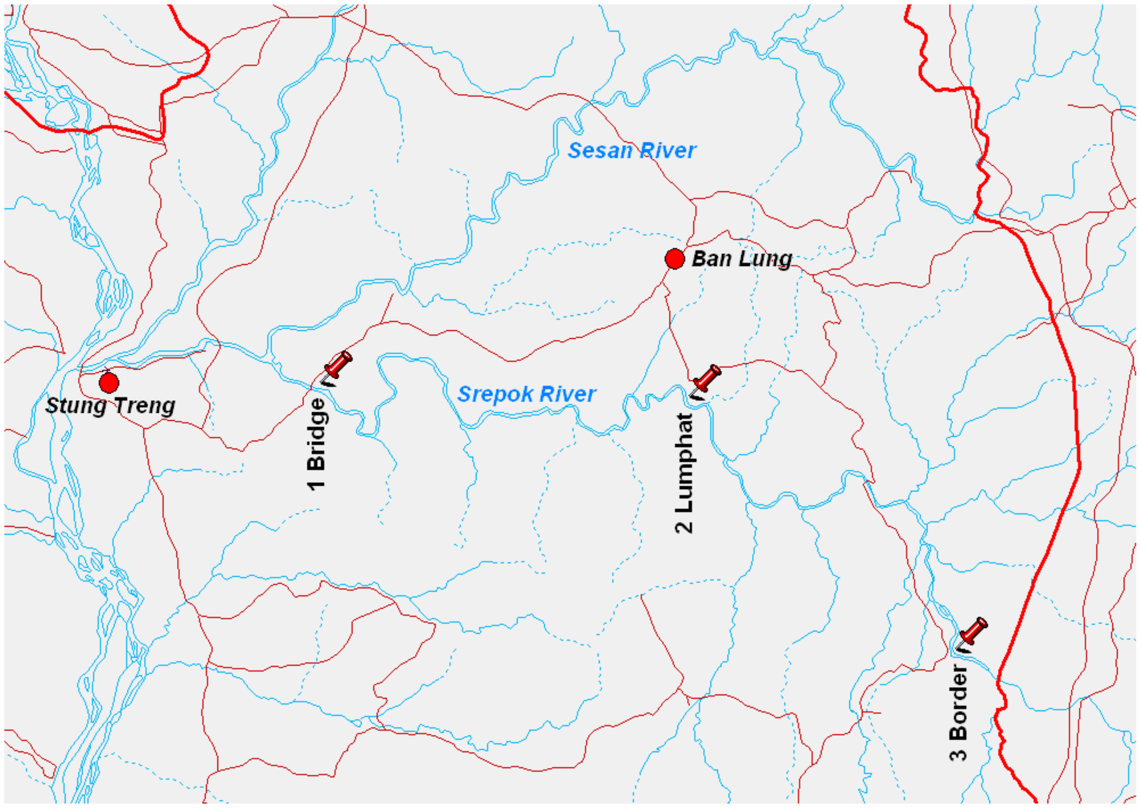

Fig. 7.1 Proposed stations for monitoring water quality in the Srepok River

7.2.2 Parameters

The parameters should have indicative value for the anticipated impacts. Those are erosion problems (described by turbidity, suspended sediments and water level fluctuations), eutrophication problems (described by pH, oxygen, nutrients, chlorophyll and algae amount and species composition, and algae-filter (blue-greens)), hygienic pollution (described by coliform bacteria), reduced fish stocks (described by fish yields by fishermen (catch per unit effort, CPUE)).

- Water level fluctuation
- Temperature
- pH
- Oxygen
- Turbidity
- Suspended sediments
- Total Phosphorus
- Total Nitrogen
- E. Coli (or Termostabile coliform bacteria 44 ºC)
- Total Coliform Bacteria 37 ºC
- Chl-a
- Algae-filter
- Fish yield (CPUE)
- Riverbank large scale erosion

7.2.3 Observation Frequency

To get a data material that can be used for statistical secure statement about improvements or deteriorations of the water quality, water samples should be taken every month. The water quality sampling could be performed by the MOWRAM office in Ban Lung and sent by plane to Phnom Penh for analysis.

The Fish yield study should be arranged with a selection of fishermen (or frequently fishing families) in each of the sites, who should note their daily catches of different species in a certain manner. Every month, during the water quality sampling, the MOWRAM personnel collect the yield results for the last month. It will likely be necessary to give the fishermen some payment for the extra work this registration will imply.

The water level fluctuations should be monitored by deployment of battery driven pressure sensors in deep areas that can be tapped to a PC by the MOWRAM people when taking water samples.

7.3 Monitoring Program in Relation to Land Use and Biodiversity

A monitoring program for physical and biological components related to and dependent on the river will be required. Since the whole region is of high conservation value such a monitoring program will need to be developed with local environmental and forestry departments along with international NGOs, PAs managers and river users. Local communities can be involved in the monitoring. The monitoring program to be developed can consist of:
Riverbank stability (riverbank soil slips, tree drops, slope changes, vegetation cover)
Animal diversity and occurrence, nesting/breeding site presence (indicator species can be targeted)
Plant community type and habitat structure (micro-environmental conditions) – (indicator species can be targeted for each group/community of relevance)

- Migration routes
- Riverbank agriculture sites
- Flood water levels and flooding regimes.

Typically some of the sites for monitoring should be designated by villages so that agricultural related activities can be monitored.

7.4 Monitoring Program of Social Consequences

The proposed indicators listed below are based on the baseline study in the villages along the Srepok River in Cambodia. The indicators focus on the obvious issues which potentially will be problematic and where vulnerability is likely to increase after the upstream hydropower implementation.

7.4.1 Water use and availability

The baseline study has pointed out the dependence of the Srepok riverside population on the river for drinking water, washing and bathing, animal watering and irrigation. The monitoring program should follow the water use, water availability and access. If well construction is part of the mitigation activities, monitoring well water quality and use should be included as well.

7.4.2 Health and water-related diseases

The health and nutritional status are interconnected. Any deterioration in nutritional status or increase in health problems should be alarming. Increase of water-related diseases like diarrhea and skin problems should be followed carefully.

7.4.3 Land access and food production

According to the baseline study most villagers along the Srepok River have today enough cultivation land for food production. However, if cultivation land will be lost along the river due to flooding and erosion, pressure for more cultivation land higher up from the river will increase. In some areas land availability is restricted by nearness to protected areas or administrative procedures. Households' land use (how much cultivation land) and access to different types of land as well as distance to fields should therefore be monitored in the long term.

7.4.4 Fishery and food security

Fish is staple food and eaten practically every day in the villages along the Srepok River. The frequency of fishery and the volume of fish catches per household should be monitored carefully. In case fish decrease, it also indicates changes in river water and in people's food security situation.

7.4.5 Waterway/road transportation

At the moment the Srepok River is the most important transportation route in parts of the river where road infrastructure is lacking or very poor. The number of boats and the frequency of navigation indicate the importance of the river infrastructure. If road infrastructure is upgraded, there is a tendency for navigation to decline. But if the number of boats and frequency of navigation decline without upgrading of road network that might indicate increasing river-related problems like turbulent waters and accidental floods leading people to decline from using the river for transportation.

The indicators suggested for monitoring the downstream impacts along the Srepok River in Cambodia above should be developed in detail to give measurable values that can be followed on a regular basis. This is a matter for a further study prior to hydropower implementation to design. Determining measurable indicator values should be based on the current baseline situation. There is reliable village level data available in the SEILA database on several of the issues covered in the suggested indicators. This data could be used for determining the values on the scale from good through normal to alarming (increased vulnerability) for the different indicators. However, qualitative data on socio-economic indicators should be included as well, in the way that has been done in the NHP Study (with a scale of Magnitude measuring the quantity and Importance giving the quality dimension). When and which measures should be used to mitigate negative consequences from hydropower development could then be decided upon these measurable scales.

APPENDIX 1 - REFERENCES

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APPENDIX 2 - RECORD OF CONSULTATIONS

Phnom Penh

Government officials

H.E. Mr. Bun Hean, General Director of Technical Affairs, Ministry of Water Resources and Meteorology (MOWRAM). July 2005, Oct. 2005, Nov. 2005

H.E. Mr. Kol Vathana, Deputy Director of Ministry of Environment (MoE), Deputy Secretary General, Cambodia National Mekong Committee. July 2005, Oct. 2005, Nov. 2005

Mr. Mao Hak, Director Dept. of Hydrology and River Works, Ministry of Water Resources and Meteorology, Oct. 2005, Nov. 2005, Dec. 2005.

Mr. Theng Tara, Director Dept of Water Resources Management & Conservation, Ministry of Water Resources and Meteorology

Mr. Kim Song, Director Inland Fisheries Research and Development Institute, Ministry of Agriculture, Forest, Fisheries. Oct. 2005

Mr. Lieng Sopha, Director Inland Fisheries Research and Development Institute, Ministry of Agriculture, Forest, Fisheries. Nov. 2005

Representative for SEILA Program, Data Base Office, Ministry of Planning. 05 Dec.

NGOs

Ms Lam Saoleng, Environmental Program Coordinator, NGO Forum. 22 Nov.

Mr. Russel Peterson, Head (Representative) of NGO Forum, Phnom Penh, Oct 2005

Ms. Ame Trandem, Information Advisor, 3S Protection Network. 22 Nov.

Mr Warwick Browne, Regional Program Officer, Oxfam America. 24 Nov.

Ms Jessica Rosien, Oxfam Australia. 24 Nov.

Mr. Rob Shore, Program Officer for WWF Living Mekong, WWF-Cambodia. 23 Nov.

Mr. Nick Cox, Coordinator, Lower Mekong Dry Forest Ecoregion, WWF-Cambodia. 23 Nov.

Mr. Martin von Kashke, Officer, Mondulkiri Protected Forest Area, WWF-Cambodia. 23 Nov.

Mr. Senk Tenk, Director WWF-Cambodia. 23 Nov.

Mr. Khim Lang, UNDP Office Cambodia. Oct. 2005

Consultants

Mr Henrik Garsdal, Senior Hydraulic Engineer, DHI, Danish Hydraulic Institute. 22 Nov.

Ratanakiri Province

Government officials - Provincial

Second Deputy Governor, Ratanakiri Province. 28. Nov.

Mr. Yorn Chetana, Director Department of Water Resources and Metereology, Ratanakiri Province. Nov./Dec. 2005.

Department of Water Resources and Metereology, Ratanakiri Province staff meeting. 29 Nov.

Mr Phan Dhirin, Director Department of Rural Development/Rural Dev Committee. 29 Nov.
Mr Yat Sokhan, Director Department of Planning. 29 Nov.
Mr Sim Sonlay, Director Provincial Health Department. 29 Nov.
Mr Kim Tuen, Vice Deputy of Provincial Health Department (at Koun Mom DHC). 02 Dec.
Mr. Sar Sona, Vice-Director, Department of Agriculture of Ratanakiri. 29 Nov.
Mr. Hao Hong, Director, Department of Environment of Ratanakiri. 29 Nov.
Mr. Chou Sophark. Park Director (BPAMP), Virachey National Park. 30 Nov.
Mr Phan Dhirin, Director Department of Rural Development/Rural Dev Committee. 02 Dec.
Mr. Lun Kimhy, Deputy Provincial Program Advisor, PLG-SEILA Program in Ratanakiri. 02 Dec

NGOs

Mr Kim Sangha, Project Coordinator, 3S Protection Network. 29 Nov.
Ms Ame Trandem, Information Advisor, 3S Protection Network. 29 Nov.
Mr Hien Serem, Information Officer, 3S Protection Network. 29 Nov.
Ms Nag Noi, Field Officer, 3S Protection Network. 29 Nov.
Mr Meach Meam, Field Officer, 3S Protection Network. 29 Nov.
Mr Heng Sovann, Health Unlimited. 29 Nov.
Mr Houng Heng, Health Unlimited. 02 Dec.
Mr. Heng Sokha, Program Coordinator, NTFP, Non-Timber Forest Products Project. 02 Dec.
Mr. Him Samith, Team Leader, CIDSE (DPA, Development and Partnership in Action –from January 2006 onwards). 02 Dec.
GAA, German Agro Action.
Mr. Willi Kohlmus, Project Manager-Water, Hygiene, Sanitation and Environment, Deutsche Welthungerhilfe, Ban Lung, 30 Nov.

Scientists

Ian Baird, Ph.D. Candidate, Univ. BC. Canada, Independent Scientist living in Laos, performed several fish and livelihood studies in Se San River since 1995, Ban Lung 30 Nov

District level authorities

Mr Klot Son, District Governor, Lumphat District. 01 Dec.
Ms Sem Soplat, Member of the Srepok Committee, Lumphat District. 01 Dec.
Mr Kong Sokchea, Consultation Staff in Lumphat District Health Centre. 01 Dec.
Mr. Eum Sokon, Chief, Environmental Office at Lumphat District. 01 Dec.
Mr. Daeng Tae, Ranger. Lumphat Wildlife Sanctuary. 01 Dec.

Mr Chum Chan Theang, District Deputy Governor, Koun Mom District. 02 Dec.
Mr Keo Sasoun, Deputy Director of Koun Mom District Health Centre. 02 Dec.
Mr Chin Saruen, Dentist, Medical Manager of Koun Mom DHC. 02 Dec.
Mr…….. (Fishery expert) Ministry of Agr. Fish., Ratanakiri Office.
Mr………(Veterenary) Ministry of Agr. Fish., Ratanakiri Office.

Commune and village level meetings

Villagers in Sam Kha Village, Chey Otdam Commune, Lumphat District. 01 Dec.

Village chief and villagers in Lumphat Village, Chey Otdam Commune, Lumphat District. 01 Dec.
Villagers in Kaeng San Village, Seda Commune, Lumphat District. 03 Dec.
Village Chief, and villagers in Srae Pok Thom, Lumphat District. 02 Dec.
Commune chief of Srae Ankrong Commune, Kon Moum District (in Phum Bei Village). 02 Dec.

Stung Treng Province

Government officials
Mr Dong Peuv, Director Provincial Department of Planning. 26 Nov.
Mr Puy Chandra, Deputy Director, Provincial Department of Water Resources and Meteorology (PDOWRAM). 26 Nov.

Commune and village level meetings
Commune chief for Kbal Romeas Commune, Se San District. 03 Dec.
Villagers in Kra Bei Chrum Village, Kbal Romeas Commune, Se San District. 03 Dec.

Mondul Kiri Province

Commune and village level meetings
Vice Deputy commune chief in Nang Khi Loek Commune, Kaoh Nheaek District. 03 Dec.
Villagers in Peam Chi Miet Village, Nang Khi Loek Commune, Kaoh Nheaek District. 03 Dec.

Srepok River Villages Visited
Sam Kha Village, Chey Otdam Commune, Lumphat District. 01 Dec.
Lumphat Village, Chey Otdam Commune, Lumphat District. 01 Dec.
Phum Bei Village, Srae Ankrong Commune, Koun Mom District. 02 Dec.
Srae Pok Thom Village, Kon Moum District. 02 Dec.
Krabei Chrum Village, Kbal Romeas Commune, Sesan District. 3 Dec.
Kaeng San Village, Seda Commune, Lumphat District. 03 Dec.
Peam Chi Miet Village, Nang Khi Loek Commune, Kaoh Nheaek District. 3 Dec.

APPENDIX 3 - PROJECT STAFF LIST

International Team
Tore Hagen, Team Leader (SWECO Grøner)
Sven Erik Hetager, Environmental Planner (SWECO Grøner)
Dag Berge, Aquatic Ecologist (NIVA)
Shivcharn Dhillion, Terrestrial Ecologist (ENVIRO-DEV)
TiiaRiitta Granfelt, Socio-Economist (ENS Consult)

Cambodian Team
Chann Sopheap, Aquatic Ecologist
Khou Eang Hourt, Terrestrial Ecologist
Tem Sareivouth, Socio-Economist
Meas Rithy, Socio-Economist

APPENDIX 4 - ENVIRONMENTAL AND SOCIAL SURVEY

Village	
Commune	
District	
Province	
Contact person: **Name** **Sex** **Age** **Position**	
How long has lived in the village	
Date	

PEOPLE	
Number of people/households in the village	
Estimated number of households living along the river	
Ethnic groups (Names and approx. % of total population)	
ANIMALS	
How many animals are there in the village? Average how many pigs, chickens, buffaloes, cows etc. per household?	Pigs Cows Buffaloes Chickens Ducks Other
Where do you get water for the animals?	

Can you get water easily for the animals?	
Has this changed in any way recently?	
WATER	
Where do you take you water for drinking and cooking? During the rainy season During the dry season	
Is there enough water? Water shortage ____ months per year?	
Do you think water is good today? How was it when you were a child?	
Has water (access and quality) changed? When and how?	
Do you boil water before drinking?	
AGRICULTURE	
Where are your fields?	
How big are they? (Area)	
Which crops do you grow? How important are the different crops?	
Is the cultivation land enough? Or do you need to get more for your family? Why/why not? Is the land good?	
What is the distance of the fields from the river? Do you have fields both at the river side and far from the river?	

How do you get water to your fields?	
Do you grow crops in terraced fields by the river? What types of crops? How big area? Which part of the year?	
Do you grow crops on sand banks and or sand bars of the river during the dry season? Has this practice changed in any way?	
If there is any destruction of the terraced fields (riverbank fields) what can you do to minimize damage? (Any special ways known to you?)	
Is there enough water for irrigation? (Different crops and seasons, observations)	
Do you need more irrigation water?	
How many years do you use the same field?	
Do you have fields in the forest? How far from the village are they?	
Are there any regulations for the use of land in the forest?	
How do you make fields in the forest? (swidden)	
Do you need river water for your fields in the forest?	
Is having produce from swidden fields important for you?	
FOREST	

Does the village have forest land? Do families own it or is it commonly owned by the whole village?	
Do you own forest? Where is the forest?	
Do you collect firewood? From where?	
Are there any regulations/restrictions for fire wood collection?	
Do you hunt animals in the forest? If yes, which ones?	
What do you do with the animals?	
What fruits, plants, vegetables do you collect in the forest?	
How far is the good forest?	
Has forest use been always like this or have there been changes? In: Firewood Plants Animals	
PLANTS	
Do you use plants growing near the riverbank? Which types-names?	
How often do you collect plants? – use for food, craft (including baskets, roofs etc.), firewood, selling, exchange?	
How often do you eat these plants?	

Do these plants make special contributions to your food intake or income?	
Do you collect plants growing on riverbank? Which types-names?	
How often do you collect? –use for food, craft, selling, exchange?	
How often do you eat them?	
Do these plants make special contributions to your food intake or income?	
Do you use plants growing in the water? Which types-names? How often do you collect? –use for food, craft, selling, exchange?	
How often do you eat it?	
Do these plants make special contributions to your food intake or income?	
Does your family have enough food? If not why?	
Do you have lack of food every year and when? (seasonality)	
Was food enough in the past? (Changes)	
Do you get income from something else than cultivation and fishing? (forestry, forest products, handicraft, trade?)	
WILDLIFE	

Have you seen wild animals in the area? Which ones?	
Have you seen wild animals come down to the river for water? When? (dry season)	
Have you had problems with your agricultural fields due to wild animals? Which types?	
WATER ANIMALS	
Do you use animals by/in the water? (turtles/frogs/snakes, fish) Which types-names?	
How often do you collect? –use for food, craft, selling, exchange?	
How often do you eat them?	
Do these animals make special contributions to your food intake?	
HEALTH	
Where do you put waste? (Observations on latrines and waste)	
Have your household members/other villagers been sick during the past year?	
What kind of diseases?	
Do you think people are more/less sick now than before? When?	
How do you treat the sick?	
How far is it to a nurse/doctor/midwife/healthcare station?	
BOATS/COMMUNICATIONS	

How do you travel from the village? (Boat, road, vehicles?)	
How many households have a boat?	
How many boats are there in the village?	
Is there electricity in the village?	
Is there a road to the village? How far is the nearest road?	
FISHING	
How many households do fishing in the river?	
How often do they go fishing in the river?	
Which fishing methods are used?	
Have they been changed during the years?	
How often do people eat fish today? Changes?	
Are there fishponds in the village?	
How many different kinds of fish are there today? Were there more before?	
Has fish changed in the river? When?	
Is the river important to people? (even cultural/sacred meanings)	

Are there graves near the river? Other cultural/religious relics?	
Have there been changes in the river during past years? Which kind?	

APPENDIX 5 - LIST OF ABBREVIATIONS

DHC	District Health Center
EIFAC	European Commission for Inland Fisheries
MAFF	Ministry of Agriculture, Forestry and Fishery (Cambodia)
MoE	Ministry of Environment (Cambodia)
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
MRC	Mekong River Commission
NGO	Non-Governmental Organization
NHP	National Hydropower Plan Study, Vietnam
NTFP	Non-timber forest product
PA	Protected Area
PDOWRAM	Provincial Department of Water Resources and Meteorology (Ratanakiri)
WWF	World Wide Fund for Nature

APPENDIX 6 – DRAFT TOR FOR FUTURE HYDROPOWER DEVELOPMENTS IN SREPOK RIVER

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR XXXXX HYDROPOWER PROJECT IN THE SREPOK RIVER BASIN, VIETNAM

TERMS OF REFERENCE (TOR)

1. Objectives

The objective of the consultancy is to prepare an Environmental Impact Assessment of the planned hydroelectric power project, XXXXXX, in the Srepok River basin in Vietnam to ensure that the development options under consideration are environmentally sound and sustainable, and that any environmental consequences are recognized early in the project cycle and taken into account in project design, during construction and under operation.

Srepok River is a cross border river and should be handled accordingly.

The specific objectives of the EIA are:

- To identify the positive and/or negative alterations of the human/social and natural environment which may affect the quality of life as well as present and future options for sustainable social and economic development in the Srepok River basin
- to identify preventive or mitigation measures to minimize or avoid the negative impacts and enhance the positive impacts of the projects construction, operation and dismantling
- to determine whether the proposed projects is the optimal or at least a viable solution to the development needs it addresses after the costs and benefits of impacts, mitigated or nor, are internalized; and
- after comparing the alternatives, including that of no action, to recommend a course of actions including preventive or mitigation measures as well as follow up and control actions presented as Resettlement Plan, Environmental Management and Action Plan and Monitoring Plan.

2. Environmental Impact Assessment Regulations and Requirements

The preparation of the EIA shall take due account of;

- Vietnamese Laws and Regulations

- Mekong Agreements and Procedural Rules, 1995
- Cambodian Laws and Regulations
- Documents/guidelines from Finance Institutions (like ADB's Environment Policy (2002) and Environmental Assessment Guidelines (2003), WB guidelines and regulations) to ensure that the study will be "bankable". The key documents/guidelines are operational directives on environmental assessment, public consultation and disclosure requirements, involuntary resettlement, guidelines for preparation of an EIA, and various safeguard policies.

3. Scope of Work

The implementation of the EIA Study will require the services of a multidisciplinary team of consultants comprising of international and domestic consultants. An international firm of consultants will be engaged for this assignment and they are expected to procure the services of both international and domestic experts to undertake the different component of the assignment. The international consultancy firm will be responsible for the quality and timely delivery of the entire assignment. The main issues of the study are outlined below;

Description of the Project

The proposed hydroelectric power project and its geographic, ecological, social and temporal context (temporary and permanent land use) shall be described. This shall include any off-site investments that may be required (improvement of roads, transmission line etc.) according to the following aspects:

- Location and layout of all the development sites related with the project, the transmission line and substations and with the access road into the project area
- Location and lay out of all project related components
- Environmental Hydrology
- Concisely describe pre-construction-, construction-, and operation activities
- Provide maps at an appropriate scale to illustrate the above-mentioned works
- Other investment projects, if any, planned in the basin shall be described

Legislative and Regulatory Framework

The EIA shall give a comprehensive overview of the pertinent policies, regulations and standards governing development of hydroelectric power projects in Vietnam and Cambodia; inter alia related to environmental quality, public health, resources protection, cultural protection, land use control.

The consultant shall follow the two countries EIA legislation in detail, the public consultation and disclosure requirements for such projects and the countries capacity to manage key safeguard issues like involuntary resettlement, cultural property, forestry, natural habitats, pesticides and safety of dams.

Description of the Environmental and Socio-Economic Baseline Conditions

The EIA shall give detailed information on the baseline situation in the catchment area with existing environmental impacts of already implemented investment projects. The task of the consultant will be to evaluate and present updated (if required) baseline data on the environmental (physical and biological) and socio-economic conditions/characteristics of the study area. Information on any changes anticipated before the project commences shall be included. The base-line shall build on existing information and reports from relevant field studies and the result from the two field study periods being part of the EIA Study

The description of the physical environment shall include, inter alia, geology, topography, soils, land use, climate and meteorology, hydrology (minimum, maximum flows, daily flows, monthly flows, etc.), sediment transport, air quality, noise, water quality, water use and natural resource.

The description of the biological environment shall include, inter alia, vegetation, wildlife, aquatic ecology, fish, biodiversity aspects, sensitive habitats, rare/threatened species, protected areas and National Parks.

The description of the socio-economic environment shall include, inter alia, population, land use (year round and seasonal), community structure, communication (access and telecom), employment and labor markets including child labor, distribution of income, goods and services, tourism and aesthetics, public health including water supply and sanitation, education, gender issues, cultural properties (archaeological and historically significant sites), indigenous peoples, customs, aspirations and attitudes.

Other planned investment projects/programs in the river basin will be discussed.

Determination of Potential Impacts Including Cumulative Impacts

The consultant shall predict and assess the projects' likely direct and indirect positive and negative environmental and social impacts taking into account cumulative impacts. This assessment shall be given in quantitative terms to the extent possible for both the construction and operation phases. The analysis shall distinguish between significant positive and negative impacts, direct or indirect impacts, and immediate and long-term impacts. Identify which impacts are unavoidable or irreversible. To the extent possible describe impacts quantitatively, in terms of environmental costs and benefits and economic values will be assigned when feasible. The potential impacts of the project and the changes it may cause shall be determined according to the basic environmental conditions (physical, biological and socio-economic) as outlined under 3.3 above.

Assessment of cumulative impacts shall be based on an evaluation of existing impacts caused by other development activities in the river basin and the impacts caused by the hydropower project. The sum of these impacts shall be assessed.

The extent and quality of available data shall be characterized, significant information deficiencies be explained and described.

Preparation of a Resettlement Plan

A Resettlement Plan (RP), based on the findings in the EIA Study for the Project (social baseline description and impact assessment), shall be prepared. The RP shall describe time - bound actions and budget, and the resources, time and effort put into the resettlement shall commensurate with the overall resettlement impacts and the implementation of the Project. A summary of the RP shall be included in the EIA Study Report.

The RP should inter alia include;

- Objectives, policies and strategies
- Organizational responsibilities
- Community participation and integration with host populations
- Socio-economic survey and assessment (taken from EIA Study)
- Describe legal framework and mechanisms for resolution of conflicts and appeal procedure
- Valuation and compensation principles for lost assets
- Identification and selection of relocation sites with draft plans for shelter, infrastructure and social services
- Landownership and tenure
- Acquisition and transfer process
- Training to avoid or minimize negative resettlement effects, access to employment and credit
- Implementation schedule and budget
- Monitoring and evaluation program

Development of an Environmental Management and Action Plan

The consultant shall prepare an Environmental Management and Action Plan (EMAP) which will consist of the set of mitigation, management, monitoring and institutional measures to be taken during implementation and operation to eliminate adverse environmental and social impacts, offset them, or reduce them to acceptable level. The EMAP shall; identify and summarize all anticipated significant adverse impacts, describe with sufficient technical details each mitigation measure, including the type of impact to which it relates and the conditions under which it is required, together with design, equipment descriptions, and operating procedures; estimation of any potential environmental impacts of these measures. The EMAP shall contain a detailed schedule for implementation of mitigation measures, assignment of responsibility, plan for environmental supervision, estimation of costs and a description of the institutional and training requirements necessary to implement them.

The EMAP shall be prepared in a stand-alone format to facilitate updating during negotiations with the financiers and contractors.

Development of an Environmental and Social Monitoring Plan

The Consultant shall prepare a detailed plan to monitor and follow up the implementation of mitigating measures and the impacts of the project during construction and operation. The plan shall include an estimate of capital and operating costs and a description of other inputs (such as training and institutional strengthening) needed to conduct it. The Monitoring Plan shall provide a specific description, technical details, parameters to be measured, sampling locations, frequency of measurements, detection limits, and definition of thresholds that will signal the need for corrective issues. Furthermore monitoring and reporting procedures shall be proposed.

Description and Quantification of Benefits and Costs of Unmitigated Impacts

Expected environmental and social benefits of the project shall be described and when possible quantified. The costs of any unmitigated environmental and social impact will be determined.

Assist in Public Consultation

The consultant shall assist the project sponsors (clients) in coordinating the environmental assessment with local and other government agencies, in obtaining the views of NGO's and affected groups, and in keeping records of meetings and other activities.

The consultant is expected to participate in a scoping meeting to be held before the EIA work commences, and in a meeting where the main results and findings of the EIA will be presented to local stakeholders. In co-operation with the client a public consultation and disclosure plan shall be prepared and implemented.

4. Reports

The consultant shall prepare and submit to the Client the following reports:

Inception Report / Scoping Report: This report shall present findings in the initial phase of the project and describe an updated work plan. The report shall be presented not later than 2 months after the commencement of the EIA study.

Progress Reports: A short progress reports shall be submitted to the Client within one week after every month.

Draft Final EIA Report: The draft Final Report shall be submitted to the Client for comments 3 months after the last field study period.

Final EIA Report: The final EIA Report shall be submitted to the Client 1 month after receiving comments from the Client.

The final **EIA Report** shall be concise and limited to significant environmental/social issues focusing on findings, assessments, conclusions and recommendations (management plans, control and environmental follow up). Details, discussions and data that are not appropriate for the main text shall be presented in annexes.

The EIA – report shall be organized as outlined below:

- Executive Summary
- Study Methods and Objectives
- Policy, Legal and Administrative Framework
- Description of Proposed Project
- Baseline Conditions
- Impact Assessment

- Cumulative Impacts
- Mitigation and Enhancement Measures
- Resettlement
- Environmental Management
- Environmental Monitoring
- Analysis of Alternatives
- Government and Public Consultation
- Environmental Monitoring
- Appendices
    - Records of Inter-Agency and Public/NGO involvement
    - List of references
    - Subject memos

5. Time Schedule

The time frame of the EIA study is dependent on the field investigations. For several parameters field measurements from the extreme situations (dry and wet period) need to be incorporated in the study program. The wet period is normally at maximum during the months September to December and the dry period generally occurs from March to July.

6. Study Topics

Based on the Scope of Work the EIA study shall be built up with the following project tasks arranged in five main tasks. Preparation of the Resettlement Plan (RP) and the Environmental Management Plan are described as separate tasks.

000 Project Management

100 Physical Environment
101 Environmental Hydrology
102 Climate
103 Air Quality and Noise
104 Erosion, Sediment Transport and Sedimentation
105 Water Quality and Sanitation
106 Irrigation and Other Water Use Aspects
107 Watershed Management

200 Biological Environment
201 Aquatic Ecology/ Aquatic Flora and Fauna
202 Fish and Fish Biology
203 Terrestrial Flora and Fauna
204 Forest and Forestry
205 Agriculture
206 Preservation-/ Restricted Areas, National Parks

300 Social- and Cultural Environment/ Public Consultation
301 Social Aspects
302 Social-, Local- and Regional Economy
303 Ethnicity

304 Gender Issues
305 Resettlement
306 Cultural Aspects
307 Archaeology
308 Public Consultation

400 Preparation of the EIA Report

500 Preparation of the Resettlement Plan

600 Preparation of the Environmental Management Plan

APPENDIX 6 – SREPOK RIVER – HYDRODYNAMIC MODELING