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Electricity of Vietnam

Power Engineering Consulting Company no. 1

FINAL REPORT

Environmental Impact Assessment on the Cambodian part of the Se San River due to Hydropower Development in Vietnam

December 2006

SWECO Grøner in association with
Norwegian Institute for Water Research, ENVIRO-DEV, and ENS Consult

SWECO GRØNER

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EXECUTIVE SUMMARY

Objectives

The purpose of this Study is to evaluate the impacts in Cambodia from the development and operation of Ialy Hydropower Project and from future hydropower development on the Se San River in Vietnam. The impact assessment is based on historical data from the development and operation of Ialy Hydropower Project and different future operation scenarios of the power stations, superimposed different hydrological situations.

On the Vietnamese side there are currently the Ialy HPP, which was commissioned in 2000 with 360 MW and in full operation with 720 MW from 2002, four power plants under construction (Pleikrong, 100 MW, Se San 3, 260 MW, Se San 3A, 96 MW, and Se San 4, 360 MW), and one plant is committed (Upper Kontum, 260 MW). In addition in 2004 construction started on the Se San 4A re-regulation reservoir, which will be completed in August 2007. There will be no installed generation capacity in the Se San 4A. The effect of Se san 4A as a re-regulation reservoir is taken into consideration in this study.

The Terms of Reference describes the main objectives of this Environmental Study of the Se San River as follows:

To describe the present situation of:
the river body (physical and biological) of the relevant reach of Se San River in Cambodia.
the land areas and settlement affected by the estimated water level fluctuation along the same river reach, both due to the flow in the dry and wet seasons
possible cultural relics along the same reach of Se San River and in the area affected by the operation of the hydropower stations in the river.
To assess possible positive and negative impacts on natural and especially social environment arising from different scenarios of operation of the Ialy Hydropower Plant as described in the result from the Hydrodynamic Modeling Study.
To describe possible impacts from the historical operation of Ialy Hydropower Station and compare with reported impacts along Se San River in Cambodia.
To describe possible mitigation measures to minimize or avoid possible impacts from operation of the hydropower stations and from accidental release of flow through the spillway of the dams.
To describe a monitoring program for the Se San River reach in Cambodia.

The study will further:
recommend environmental mitigation measures during construction of new hydropower developments and operation of these
recommend methods and program for monitoring actual environmental impacts.

Methodology

To assess the impacts along the Se San River in Cambodia, a rapid field survey was carried out after the 2005 rainy season on aquatic, terrestrial and social environmental 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:

(i) People living along the Se San River affected by the Ialy HPP operation and 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;
(ii) Public sector agencies: Ministries, provincial and district authorities, and commune leaders; and
(iii) 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 Se San 4A as a re-regulation power plant was provided in May 2006 and the report was adjusted accordingly.

The description of the baseline conditions is largely based on the field survey in November 2005. Where information comes from other sources, these sources are referred to in the text.

To describe the hydrology, a hydrodynamic modeling study for the Se San River (from the Ialy Hydropower Plant to the confluence with the Srepok River) was carried out by the Danish Hydraulic Institute (DHI) and high and low flow situations combined with different operation scenarios of the power station are explored.

Description of the Present Situation
On the Vietnamese part of Se San River there are several Hydropower Projects either in operation, under construction, or projects that are committed as shown below;

Under operation	Under Construction	Committed
Ialy	Pleikrong	Upper Kontum
	Se San 3	
	Se San 3A	
	SE San 4	

Water Quality
The study has comprised:

- Compilation and analysis of water quality data from 2001 provided by MOWRAM

- Compilation and analysis of one year of water quality monitoring 2004/2005 provided by MOWRAM
- Water quality data from Vietnamese monitoring of Ialy Reservoir and Se San River just downstream the Ialy Power Plant (2004 and 2006)
- New study of WQ in November/December 2005 in both the Se San River itself and in the Ialy Reservoir, including algal species composition, algal toxins, heavy metals and pesticides, in addition to standard water quality parameters.

The present situation can be described as:

- The water is soft with low content of dissolved ions with conductivity 3-4 mS/cm
- The water has weakly alkaline reaction with typical pH of 7.0-7.5
- Most of the year the turbidity is moderate (5-15 FNU), but in the rainy season turbidity can be very high (200 FNU corresponding to 250-300 mg SS per liter). This high particle content causes problems for the river ecology and for human use.
- The content of the plant nutrient phosphorus and nitrogen is low, and is not high enough to produce eutrophication problems.
- The algal biomass is low, and the species composition is normal.
- No content of algal toxins were observed in the sampling in Nov/Dec 2005, but this is not studied in the most intensive algal producing period (April-June).
- The concentrations of heavy metals, including arsenic, are low and reflect unpolluted water in this respect. Concentrations are below standards for drinking water including US EPA, which has the strictest regulations.
- The water has been analyzed for 55 pesticides with detection limit of 0.01 ppb, but no compound is detected. The conclusion is that pesticides are not a problem in Se San River.
- The content of coliform bacteria is periodically high, particularly in the rainy season. Drinking water should be boiled, or filtered, before consumption.
- It is not likely that the water coming out of Ialy Reservoir will contain enough nutrients to create any algal problems in Se San River in the future. However, Vietnamese monitoring data from 2004 found very high phosphorus content in samples taken just downstream the outlet from Yali Power Plant.

It should be noted that the present study was done just after the rainy season, when the reservoir was recently filled, and when the deep water still contained water of 50 % oxygen saturation or more. At the end of the dry season (April-June) the oxygen may be very low in the deep water, giving rice to release of bioavailable nutrients. The water quality, with analysis of algal species composition, and algal toxins, should be monitored through a whole dry season, to verify the conclusion given above.

The aquatic life in Se San River was known to be 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 used to constitute approximately 90 % of the protein supply of the local people. A large number of the fish fauna are migratory, and Vietnamese fish researchers told that more than 30 species migrate all the way from the Mekong and far up into Vietnam. A large part of the migration is for reaching spawning and nursery grounds.

All interviewed people said that the fish population had declined significantly over the last 10 years, and they blamed the Ialy Reservoir to have caused the reduction. They said that the fishery yield is now in the range of 10-30 % of what it was before the Ialy HPP was built. Some species were said to have more or less disappeared after the regulation, e.g. *Cirrhinus microlepis, Wallago leeri, and Pangasianodon gigas*. During the visit in November 2005 there were almost no fish from Se San River in the fish market in Ban Lung, 80-90 % of the fish was from Kratie in Mekong. Local people told that 10 years ago, the major part of the fish in the market came from the Se San River.

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 was the common practice and a high diversity of species were grown. At present riverbank gardening has reduced significantly and many backyards are abandoned. 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. Villagers depend on regular levels of water for agricultural, especially at the onset of the planting season, and claim that this has not been always predictable. The area to the north of the river buffers a protected area, which is yet to be assessed for diversity in detail, although key species and vegetative communities are known. Bird species relying on sand banks have been shown to be impacted by water level irregularities in the dry season. Local people also rely on the use of non-timber forest products (NTFPs), and this reliance has been growing in the past years.

There are 66 villages along the Se San River in Cambodia from the Vietnamese border down to the confluence with the Sre Pok River. Ethnic minority people from several different groups inhabit most of the villages. These people are in general the poorest in the whole country, their education level and health standards are below the average in Cambodia, and illiteracy is very common, up to 100% in some of the most remote villages. Infrastructure is poorly developed and people's access to social services is accordingly very limited. Seasonal water-related diseases are common.

People residing along the Se San River base their subsistence economy on utilization of the available natural resources in the area. The river constitutes a prerequisite for their present lifestyle. Most households take their drinking water from the river, boats are used for transportation in the river, and people wash clothes, bathe and water animals in the river. Livelihoods are based on rice and vegetables cultivation and fishery; consequently fish and rice is staple food, added with fruit and vegetables. Raising animals, NTFP collection and hunting as well as small-scale gold panning in the river are complementary activities adding to household nutrition and income.

Nutritional status of the riverside population has generally been satisfactory due to abundant fish resources. However, fish catches have deteriorated significantly during the past ten years, according to the local people. This decline can lead to serious health consequences, because fish constitutes the major protein source in the diet of the riverside population. Vegetables are cultivated and wild growing species collected on riverbanks and sandbanks in the river. This utilization is reported to have been notably reduced due to rapid water level variations and riverbank erosion.

Impacts from the Ialy Hydropower Project Reported by Other Studies
The most comprehensive study was made by Ratanakiri Fisheries Office in cooperation with NTFP Project in April-May 2000 with a survey on 59 villages located along the Se San River in Ratanakiri Province (Fisheries Office 2000). Most of the subsequent reports are based on the information in this study. The comments are therefore to a great extent linked to this study.

Change in Rainy Season Flooding
The natural rainy season flooding is reported to have changed considerably in the Se San River. The Fisheries Office report (2000) blames the strong rainy season floods occurrence on the large water releases done by the dam operation in response to rapid changes in water levels in Ialy reservoir due to heavy rainfall in the Central Highlands of Vietnam.

Consultant's Comments:
Floods in the period before 1999 were not caused by the operation of the Ialy Power Plant, since the reservoir was not in operation at that time. Lack of hydrological data from this period makes it difficult to come up with further comments for this period.

Extreme Flood in 1996
In 1996 there was a huge natural flood during the rainy season, probably caused by a tropical storm in the upstream parts of the watershed. The Fisheries Office (2000) report suggests that the huge water release was caused by an accident in the Ialy diversion dam during the construction of the main dam.

Consultant's Comments:
No information on such an incident has been available, and it is not likely, as the cofferdam only diverts the water in the river while the main dam is being built, and is not building up a reservoir. Meteorological and hydrological data from 1996 show that there was high flood this year, and most likely the flood reported in 1996 was an extreme natural flood.

Rapidly Rising Water Level
People living along the Se San River have experienced several serious incidents of floods and rapidly rising water levels.

Consultant's Comments:
Rapidly rising water level in the rainy season is most likely caused by spillway releases from the Ialy reservoir. Spillway releases will from time to time be necessary, however, with an effective early warning system, downstream effects should be able to be considerably reduced. Records of spillway releases from Ialy confirm that rapid water level increases might have occurred.

Dry Season Water Level Fluctuations
People living along the Se San River are moreover experiencing rapid daily changes in water levels caused by the operation regime of Ialy Hydropower Plant. The rapid

rising and then declining of water level takes place at different times of the day and night, in different parts along the river.

Consultant's Comments:
These water level changes are most likely caused by the operation of the Ialy HPP. Hydrodynamic model simulation show that daily water level variations due to intermittent operation may be up to 1.1 meter at Andoung Meas, and correspondingly 0.3 meters at Ta Veaeng. The daily fluctuations will be mitigated when the Se San 4A re-regulation reservoir will be commissioned in August 2007.

Water Quality Problems
The water quality in the Se San River is reported to have seriously deteriorated since the construction of the Ialy Power Plant started. The river has become more turbid than before, and the water smells badly. In periods the water gave itchiness after bathing, and animals and people were reported to get sick (even died) from drinking the water. Headache, stomachache as well as respiratory problems are also reported.

Consultant's Comments:
The first years after the construction of the dam, breakdown of terrestrial vegetation will take place in the reservoir. This will release nutrient to the deep water of the reservoir, which may produce toxic algae in the reservoir as well as downstream the reservoir. Before filling of the reservoir, it is not likely that toxic algae have had the necessary concentration to create death of large animals.

It has not been possible to confirm the reported death cases, as the district and provincial authorities have no data on increasing death rates among the local population during the reported period. There seems to have been many periodic water-related health problems in the area, but the magnitude of these is not possible assess due to lack of proper data.

Respiratory and stomach problems are likewise prevalent in all areas of the province, related to poor living standards connected to poor clean water access and poor hygienic and health standards. Epidemic animal diseases have been occurring throughout the province, not only along the Se San River. However, toxic algae in the water might have caused some sudden animal deaths along the river.

During construction of Ialy Reservoir it is not likely that algae has occurred as a result of the construction work. The first few years after the Construction period and when the reservoir was filled – there could have been algae growth in or downstream the reservoir due to nutrients released from the reservoir.

Impacts on Riverine vegetation
It is reported that irregular fluctuations in the Se San River have seriously affected riverine vegetation, birds, reptiles and various aquatic life whose lifecycles are dependent on the natural rhythm of the river.

Consultant's Comments:
These water level changes are most likely caused by the operation of the Ialy Reservoir. Hydrodynamic model simulation show that daily water level variations due

to intermittent operation may be up to 1.1 meter at Andoung Meas, and correspondingly 0.3 meters at Ta Veaeng.

Vegetation on the riverbanks and in the water can be easily impacted due to wet and dry events, particularly reeds, algae and leafy aquatic plants. Birds reliant on sandbanks for nesting have also been shown to be impacted by water level fluctuations. The daily fluctuations will be mitigated when the Se San 4A re - regulating Reservoir will be commissioned in August 2007.

Impacts on Fish, Fish Habitat, and Fisheries
It is reported that native fish, fish habitat and riverine fisheries have been severely impacted by changes in the hydrological regime and water quality. Fish catches have reportedly declined drastically, which has badly affected villagers, who are highly dependent on fishing for food and income.

Consultant's Comments:
Deviation of natural flow patterns will in the long run reduce fish stocks due to less spawning success, reduced fish food production and impaired habitats. Increased erosion and diurnal water level fluctuation will reduce the production of fish food items in the river, and thereby reduce the fish productivity. Based on studies of fish species and historical reports of fish, as well as interviews, it seems that fish numbers and species in the Se San River have been reduced considerably the last 10 years. Most people said fishery yield was reduced to 10-30 % of what it was before. As hydropower regulations almost always result in reduced fish productivity downstream, it is very likely that the Ialy regulation has contributed significantly to the observed decline in fish. However, other factors can also have contributed, as e.g. increased fishing pressure by an increasing population, now using modern mono-filamentous fishing nets.

Impacts on Human Livelihood Systems
The overall impact of the Ialy HPP is reported to have severely disrupted human livelihoods system along the Se San River. The imbalance caused by the power plant impacts has negatively affected terrestrial resources.

Consultant's Comments:
Lower parts of the river banks become unstable and the use of many river banks for agriculture has become difficult and not possible in many areas. The decline in use of the riverbanks and sandbanks in the river for agriculture was apparent during the field survey. The increase in wildlife hunting, use of forest products, and encroachment had also increased and was attributed to the lack of riverbank use and reduction in river fish. For the poorest families and those with small pieces of land, the impact on their lives is regarded to be significant.

Impact Assessment
Hydropower development interrupts the 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 that have nesting sites by the river and on sand banks are highly depended on predictable water flow regimes. The deep pools in the Se San River can accumulate

sediments that can impact pool dependent aquatic life, and dry season refuges for many fish species. The filling of the reservoir will delay the flooding, and often reduce it as well. As the flow increase is one of the main triggers for fish migration, unsuccessful spawning migrations are often a result in regulated rivers.

Changes in hydrology can result in increased erosion activity, which induces water quality, siltation, and sedimentation problems. Large fluctuations in water levels in the river will induce riverbank landslips and weaken banks in general. Local people will not be able to practice riverbank gardening if riverbanks 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.

Given that the Se San 4A Hydropower Project is being built as a re-regulation plant (construction started November 2004) and will be in operation in August 2007 (Information from EVN), potential impacts during the operation phase will be reduced for several of the parameters. However, it is imperative to understand that if appropriate measures are not undertaken during the construction phase, impacts can carry over to the operation phase and be perceived, at least in the early stages, as those of the operation period. Such impacts can be related to sedimentation, erosion, and aquatic life.

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 Se San River are:

(i) The Se San 4A re-regulating reservoir will level out the diurnal flow variations and is the most important mitigation measure for existing and future developments. The flow out of Se San 4A should be as equal to the natural flow as possible.
(ii) Establish an early warning system for spillway releases and sudden flows
(iii) Prolong the wet season filling of the reservoirs
(iv) Reduce the nutrient inputs to the reservoirs
(v) Consider building fish bypass systems
(vi) Consider establishing fish stocking program
(vii) Develop a program for aquaculture

Mitigation has also to include specific measures during construction of new projects among others;

(i) 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),
(ii) runoff from tunnel blasting and drilling,
(iii) soil deposits and soil rock deposits,
(iv) sanitary effluents from the construction workers camps,
(v) oil and chemical spill, and measures related to the operation of the power plants, such as;
(vi) accidental water releases,
(vii) dry-ups,
(viii) animal nesting areas and migration paths,
(ix) water and health changes related to changes in water quality,
(x) (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 Se San downstream area at least the following groups should be involved in the stakeholder consultation process:

(i) Directly affected people living in the riverside villages;
(ii) Indirectly affected people living in the adjoining areas:
(iii) People utilizing the river for their livelihoods activities but not residing along the river;
(iv) Women in the directly affected villages;
(v) People’s organizations;
(vi) District health care staff and traditional health providers;
(vii) Village and commune chiefs of directly affected areas;
(viii) District administration representatives;
(ix) Provincial ministries representatives and;
(x) 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 Se San 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 Se San River for implementing the mitigation measures, should be carefully evaluated in order to guarantee a sustainable development after the commissioning of the hydropower projects. 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 mitigation 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 chosen for monitoring should have indicative value for the anticipated impacts. Those are:

(i) erosion problems (described by turbidity, suspended sediments and water level fluctuations),
(ii) eutrophication problems (described by pH, oxygen, nutrients, chlorophyll and algae amount and species composition, and algal toxins (blue- greens)),
(iii) hygienic pollution (described by coliform bacteria), and
(iv) 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 thermo stabile coliform bacteria, 44^{o}C; total coliform bacteria, 37^{o}C), Chl-a, algal toxins using algae-filters, fish yield (CPUE)

Terrestrial/Land Use/Agricultural Monitoring.

A monitoring program for physical, biological and agricultural components related to and dependent on the river are recommended. Since the region is of conservation value (especially as it buffers protected areas) 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:

(i) Riverbank stability,
(ii) Animal diversity and occurrence, e.g. targeting nesting/breeding site presence,
(iii) Plant community type and habitat structure (key species/community focus). In addition specific monitoring should be developed to include 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, and specific target species should be the focus reducing costs and time for monitoring.

Social Monitoring.

The proposed indicators listed below are based on the baseline study in the villages along the Se San 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;

(i) Water use and availability,
(ii) (Health and water-related diseases,
(iii) Land access,
(iv) Fishery and food security.

1. INTRODUCTION AND METHODOLOGY

1.1 Background

The Se San River is a trans-boundary river originating in Vietnam and running through Northeastern Cambodia where it ends up in Mekong River. The hydropower potential in the Se San River Basin is primarily concentrated to the main Se San River and to some extent to its two main sources, Krong Poko and Dak Bla Rivers. However, also the potential for high-head developments in smaller tributaries has been investigated over the years.

The hydropower potential on the Vietnamese side of the Se San River has been exploited since 1993 when the development of the Ialy Hydropower Project started. The first unit of Ialy was commissioned in 2000, and the project was completed in 2002 when the fourth unit was commissioned. Today another three projects are under construction on the Vietnamese side of the Se San River; Pleikrong HPP located upstream the Ialy reservoir, and Se San 3 HPP and Se San 3A HPP located downstream the Ialy Reservoir. Further two more projects are planned in the river, Upper Kontum HPP, located upstream the Ialy Reservoir, and Se San 4 HPP located downstream the Ialy Reservoir near the Cambodian border. By the development of the Se San 3, 3A and 4 HPPs, the total hydropower potential between the border with Cambodia and the existing Ialy Hydropower Project would be utilized. These projects will make use of the already regulated outflow from Ialy Reservoir, thus limiting the need for additional large active storages.

The main cross-border water resource issue is the downstream impacts from the hydropower plants in Vietnam, up to now in particular the releases from Ialy Reservoir, in Ratanakiri and Stung Treng Provinces in north-eastern Cambodia.

Several reports (among others, the report from The Fisheries Office, Ratanakiri Province 2000), as well as information from people living along the Cambodian part of the Se san River report that since the construction of Ialy HPP started, the physical, chemical (water quality), ecological and social environment in and along the river has deteriorated.

Reportedly, the dam was put into operation with limited consideration to its effect on Cambodia. The past operations of the dam have reportedly caused sudden flow surges in Se San River, which has taken a toll on human lives, crops (stock losses), boats and fishing equipment and communication systems. There have also been changes in water quality over the past with notable impacts on wildlife and decline in fish stocks. There are daily flow fluctuations causing riverbank erosion, the water has become more turbid, it is colored, it smells bad, swimming in it gives itchiness, and in periods people and livestock get sick when they drink the water.

The fishery yield has declined immensely and is reported to be only 10-30% of what it was before the regulation. Particularly large catfish species have disappeared. The same has happened to mussels and crayfish (crabs). One of the reasons to this is that the deep holes (pools) of the river have become filled in with sediments. These pools used to be good fishing places in low flow periods, but now these areas are shallow and without fish.

The above challenges highlight the importance of proper basin-wide planning, co-operation and notification, across the national borders for dams and other water development interventions. It also requires major operational changes of the existing dam to ensure public safety, economic activities, and aquatic environment downstream of Ialy Dam.

Se San River is a tributary to Mekong River, and the Mekong River Commission (MRC) attempts to negotiate a series of trans-boundary water allocation rules to achieve a reasonable and equitable utilization of the Mekong River waters, as envisioned in the 1995 Mekong Agreement. As part of the co-operation within MRC, the Se San hydropower development in Vietnam is now based on the Agreement on Co-operation for the Sustainable Development of the Mekong River Basin and associated rules and procedures, which represent an important legal framework for hydropower development on the river. Vietnam has now notified Cambodia and the MRC of the hydropower projects on Se San River.

For the prevention of further negative impacts on Se San River, Vietnam and Cambodia have also set up the Se San River Water Management Committee. The two parties have also established mechanisms of regular information exchange, emergency alerts on the flow regime, operating process and discharge of water from the hydropower plants, as well as flood alerts and river water quality control. The first meeting of this committee was held on July 26, 2001.

EVN has provided funds for a Hydrodynamic Modeling Study and an EIA Study (this study) to investigate the impacts on the Cambodian side of the Se San River due to hydropower development in Vietnam.

1.2 Objectives of the Project

The purpose of this Study is to evaluate the impacts in Cambodia from the development and operation of Ialy Hydropower Project and from future hydropower development on the Se San River in Vietnam. The impact assessment is based on historical data from the development and operation of Ialy Hydropower Project and different future operation scenarios of the power stations, superimposed different hydrological situations.

The Terms of Reference describes the main objectives of this Environmental Study of the Se San River as follows:

1) To describe the present situation of:
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    - the land areas and settlement affected by the estimated water level fluctuation along the same river reach, especially due to the flow in the dry and wet seasons
    - possible cultural relics along the same reach of Se San River and in the area affected by the hydropower stations in the river.

2) To assess possible positive and negative impacts on natural and especially social environment arising from different scenarios of operation of the Ialy Hydropower Plant as described in the result from the Hydrodynamic Modeling Study.
3) To describe possible impacts from the historical operation of Ialy Hydropower Station and compare with reported impacts along Se San River in Cambodia.
4) To describe possible mitigation measures to minimize or avoid possible impacts from operation of the hydropower stations and from accidental release of flow through the spillway of the dams.
5) To describe a monitoring program for the Se San River reach in Cambodia.

The study will further:

- recommend environmental mitigation measures during construction and operation.
- recommend methods and program for monitoring actual environmental impacts.

1.3 Baseline Description

No historical (pre 2000) baseline data has been available for the Cambodian part of the Se San catchment. Previous reports ("Worley – Se San 3 HPP Environmental Impact Assessment (2001)" and "Fisheries Office Ratanakiri Province – A Study of the downstream impacts of the Yali Falls Dam (2000)") confirm the lack of previous baseline studies and data.

Consequently, this report contains a Description of the Present Situation as found in the Rapid Assessment carried out during November – December 2005, supplemented with inputs from existing reports, such as the ones mentioned above and "Baird – A rapid study of fish and fisheries, livelihoods and natural resources along the Se San River (1995)". For a complete list of existing reports reviewed in this study, see References in Appendix 1.

1.4 Data, Methods 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 Se San River both in Vietnam and Cambodia.
2) A rapid field survey was carried out on relevant issues along the Se San River to supplement possible existing information and to collect new data of importance to the assessment of impacts on the natural and social environment and on possible cultural sites. The field survey took place just after the end of the rainy season. The International and Cambodian consultants, representatives from the Client and representatives from the Cambodian Ministry of Water Resources and Meteorology participated in this work. The basis for the assessment has been the present baseline of the river and the land affected by the reported 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 reported change in river conditions have been evaluated. In addition, in relation to the water quality the aquatic ecologist made a survey to the Ialy Reservoir and the immediate downstream part of the Se San River in Vietnam. New water samples were taken to analyze water quality and some biological parameters, and to elucidate the anticipated problems directly or indirectly related to toxic algae, pesticides, heavy metals, deep water nutrient releases causing eutrophication, and other water quality questions. Data on other river ecology and aquatic life is based on existing information.

3) A study on the Hydrodynamic Modeling of the Se San River has been carried out from the Ialy Hydropower Station in Vietnam to the confluence with the Se Kong River in Cambodia (DHI 2005) using hydrological time series from relevant hydrological stations. High and low flow situations combined with different operation scenarios of the power station were studied. The study will be used to assess the flow regime of Se San River before and under operation of the hydropower stations.
4) The results from the technical study of the National Hydropower Plan Study of Vietnam (EVN 2005) 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 endeavours to ensure that both subjects are taken into account in the assessment.

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 above-described objectives..

1.5 Study Area

The Se San River is one of the main tributaries to the Mekong River. The total catchment area of Se San River basin is 18,570 km^2 with nearly 40 % (6,960 km^2) located in Cambodia and some 60 %, or 11,450 km^2, located in Vietnam. The river flows in a southwestern direction through the Kontum and the Gia Lai provinces of Vietnam. It joins with Srepok River in Cambodia, 20 km upstream of the confluence with Mekong River at Stung Treng.

Se San River and its main sources, Sa Thay, Dak Bla and Krong Poko rivers, drain part of the Central Highlands of Vietnam with mountain peaks exceeding 2,500 m on the southwestern slopes of the Ngoc Linh massive. The length of the river is about 462 km, of which 210 km in Vietnam. At the border to Cambodia the average flow is about 380 m^3/s. The specific runoff from different parts of the Upper Se San River Basin varies from around 40 l/s per km^2 in the upper western part of the basin to 30-35 l/s per km^2 in the lower parts.

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 main problems in many parts of the river basin.

The study area is the area along the Se San River from the border between Cambodia and Vietnam to the confluence with Srepok River and further to the Se Kong River. In addition to the river body itself, the study area comprise 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 Se San River as a socio-economic and cultural resource.

With respect to water quality and water ecology, the study area also included Ialy Reservoir and the immediate downstream part of the Se San River in Vietnam.

1.5.1 Landscape and Ecology

The landscape comprises mostly of agricultural areas, and open canopy forest dominated by deciduous forest types with shrubby to grassy ground cover. There are vast areas with rubber, cashew, fruit and sugar cane plantations. Near inhabitations agriculture is dominant with areas of rice paddies (rainfed), permanent crops (cashew), secondary crop plants, and home gardens. As forest dominates the land type in the northern part of the Ratanakiri province in the Se San Basin and there are remnants of forest communities near rivers, some wildlife is seen on occasion by the river. This is however much lower than that by the Srepok River. People rely on and use both wild animal (hunting deer and boar in particular) and plant resources. A significant stretch to the north of the Se San River forms the buffer zone of the Virachey National Park. This area is highly populated and is also exploited for timber and non-timber products. 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 is obtained by clearing land, often for permanent rice fields or permanent crops like cashew.

Fig. 1.1 Se San River at Veun Sai ferry crossing, Ratanakiri province

1.5.2 Aquatic Ecology

The Se San 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 part of the fish populations are highly migrative, and several species perform migrations as long as from the Mekong Delta and most likely far up in Vietnam. The fish contributes about 90 % of the protein supply for the population along the river. The river has gentle slope, and used to contain a large number of deep pools, which made it possible for large fish specimens to survive in the dry season. The river is the main transportation road 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 for the people living in the area.

1.5.3 Administrative Areas and Population

The Se San River in Cambodian territory runs from the Vietnamese border through areas belonging to the two Northeastern provinces of Ratanakiri and Stung Treng. Prior to merging into the Mekong River, the Se San River first confluences with the Srepok River, which also runs from Vietnam through first Mondulkiri and then Ratanakiri Province into Stung Treng Province, and then further downstream it unites with the Se Kong River running from Laos into Cambodia. The upstream areas closest to the national border in Ou Ya Dav and Andoung Meas districts are more sparsely populated than the stretch further downstream in Ta Veaeng and Veun Sai districts in Ratanakiri Province and in Se San District in Stung Treng Province. 66 villages in 16 communes are located by the Se San River, from the national border down to its confluence with the Srepok River. Of the total number of villages in the districts, in Andoung Meas 11 out of totally 21 villages are located by the river. Of the totally 20 villages in Ta Veaeng 19 lie by the river, in Veun Sai 27 villages out of 34. In the Stung Treng Province district of Se San, all the two, respectively four villages in the communes of Srae Kor and Ta Lat lie by the river. In the upstream Ou Ya Dav District only one commune, Se San, with all its three villages is located by the Se San River.

The villages, communes and districts 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 Se San River is compiled from different sources[1], which differ from each other.
2) The administrative borders and names of villages are frequently changed in the Northeastern provinces, and several of the names appear different on various maps and other sources.
3) Authorities and inhabitants use different names and also different definitions for villages. Both inhabitants, village and district chiefs seemingly call “village” entities that are not recognized as villages by the authorities (according to SEILA)[2].

[1] Sources: Maps: Ratanakiri unofficial Province Map; unofficial working maps from District Health Centres and from the Se San Protection Network; Cambodia Road Map (Cambodia Country Maps), Topographic 1:50,000 maps (US Military 1967). Village names: SEILA Database 2004, DHCs, district officials and village chiefs. The list of villages and their locations on the Figure 1.2 are defined using the approximation of the most number of sources giving the same location. However, some mistakes may appear due to the varying data on the sources used.

[2] The Team for example visited two hamlets in Nhang Commune in Andoung Meas Districts, which are not recognized as villages neither in any map (apart from the topographic US Military maps from 1967) nor in the SEILA village database.

4) The names of villages, communes, districts and provinces and their English transcriptions are taken from SEILA database for the year 2004.
5) Data on the numbers of families and inhabitants is according to the data from SEILA for the same year.

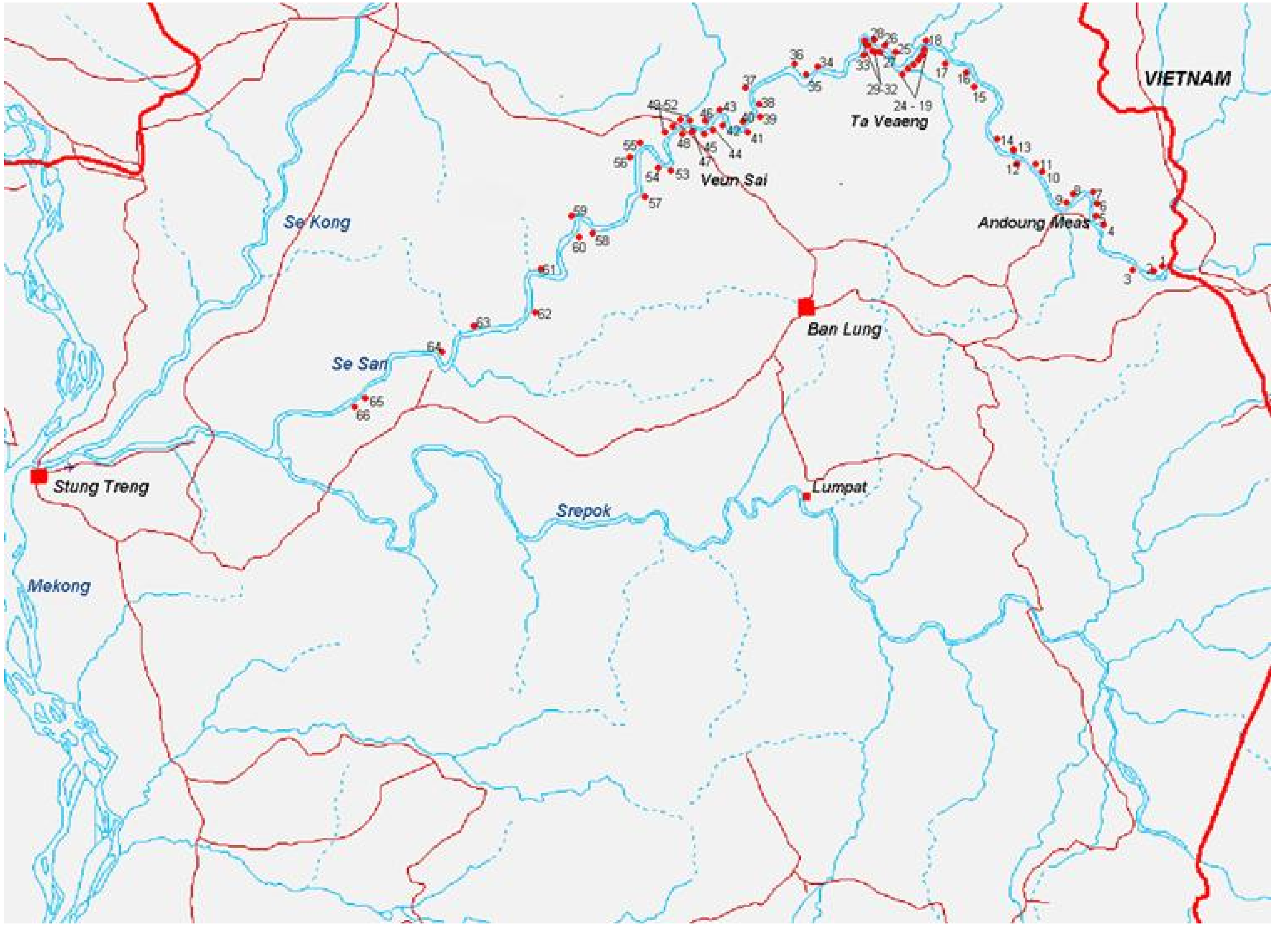


Figure 1.2 Map of villages along the Se San River. For name of villages, see Table 1.1

Table 1.1 Administrative areas located along the Se San River from up- to downstream. Village number refers to Fig. 1.2 map of villages along the Se San River

Province	District	Commune	Village	Village no.	No. of families	No. of people
Ratanakiri	Ou Ya Dav	Se Sant	Phi	1	98	482
			Ka Tang	2	42	241
			Pa Dal	3	91	375
	Total Ou Ya Dav	1	3		231	1,098
	Andoung Meas	Nhang	Nhang	4	42	185
			Tang Se	5	203	930
			Dal	6	95	477
			Tang Chi	7	53	245
			Nay	8	62	327
			Ka Chut	9	92	500
		Ta Lav	Ka Nong	10	53	253
			Katae	11	95	423
			Ka Nat	12	116	764
			Ta Lav	13	100	365
			In	14	55	300
	Total Andoung Meas	2	11		966	4,769
	Ta Veaeng	Ta Veaeng Leu	Chan	15	40	204
			Chuoy	16	73	407
			Ta Bouk	17	88	513
			Bangket	18	63	286
			Rieng Vinh	19	52	237
			Phlueu Thum	20	38	169
			Ke Kuong	21	43	200
			Sanh	22	41	209
			PhlueuTouch	23	37	184
			Ta Veaeng	24	151	877
		Ta Veaeng Kraom	Vieng Chan	25	35	168
			Tumpuon Roeung Thum	26	84	407
			Kaoh Pong	27	10	54
			Phav	28	135	591
			Tumpuon Roeung Touch	29	44	228
			Sieng Say	30	42	198
			Pha Yang	31	50	267
			Ke Kuong	32	23	118
			Ta Ngach	33	30	133
	Total Ta Veaeng	2	19		1,079	5,450
	Veun Sai	Kaoh Pang	Pa Hay	34	45	191

			Pa Tang	35	77	303
			Lam av	36	42	214
		Kaoh Peak	Kaoh Peak	37	182	946
			Phak Nam	38	256	1,083
			Khun	39	106	473
		Ka Choun	Ka Choun Leu	40	89	409
			Ka Choun Kraom	41	77	397
			Tiem Leu	42	68	292
		Kok Lak	La Lai	43	72	333
			Trak	44	48	233
			La Meuy	45	103	501
			Rak	46	132	555
		Ban Pong	Ban Pong	47	181	898
			Ban Hvang	48	242	1,250
		Veun Sai	Thmei	49	43	263
			Veun Sai	50	85	517
			Pak Kae	51	69	431
			Ka Lan	52	171	1,006
		Phnum Kok	Phnum Kok Prov	53	57	280
			Phnum Kok Lav	54	44	304
		Pa Kalan	Pa Kalan	55	131	740
			Kampong Cham	56	77	422
		Phnum Kok	Tiem Kraom	57	66	412
		Hat Pak	Hat Pak	58	192	873
			Veun Hay	59	58	351
			Lam Poar	60	16	63
	Total Veun Sai	9	27		2,729	13,740
Stung Treng	Se San	Ta Lat	Talat	61	59	311
			Rumpoat	62	39	188
			Svay Rieng	63	246	1,066
			Khsach Thmei	64	230	1,069
		Srae Kor	Phum Pir	65	134	602
			Phum Muoy	66	156	658
	Total Se San	2	6	864	864	3,894
TOTAL SE SAN RIVER		16	66	5,869	5,869	28,951

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. In Ratanakiri Province more than 20% of the population are migrants, and almost half the migrants originate in other provinces or abroad. Proportion of the population born in the area, but out-migrated due to historical reasons and returned later is likewise rather large, but no figures are available. Most of the ethnic minority groups along the Se San River have resided historically in Ratanakiri, but not necessary in their present location. Many minority groups like Brau and Kavet originally resided in the mountain areas. Historically the people living along the Se San River with longest time back in history (more than 200 years) are Lao (Fisheries Office 2000).

1.5.4 Ethnicity

Ratanakiri Province is a traditional area for Cambodia’s ethnic minority populations, the so-called hill tribes or indigenous people. More than half of the country’s approx. 101,000 ethnic minority people reside in Ratanakiri (64,000 persons). The largest ethnic minority groups in the province are the Tampouen (more than 22,000), the Jarai (15,670), the Kreung (almost 15,000), the Brau (7,130), the Kachac (2,050) and the Kavet (1,730) (ADB 2002, according to the National Population Census 1998).

People from nine different ethnic groups reside in the villages along the Se San River. In the upstream area in Ou Ya Dav District, riverside villagers are mainly Jarai and Tampouen but also some Kreung ethnic minority people reside in the area. In Andoung Meas District most riverside inhabitants are Jarai, Kachok or Tampouen but also Brau, Kreung, Lao and Khmer. In Ta Veaeng District’s riverside villages the main ethnic groups are Brau, Kreung and Luen. Ethnic variation is great along the Se San River in Veun Sai District, where there are both Brau, Katchok, Kreung, Tampouen and Lao villages as well as one Chinese village. People from other ethnic groups also mix with these groups in some of the villages. In the Stung Treng Province area Lao, Khmer and Vietnamese populations are common. (Fisheries Office 2000, Ratanakiri unofficial map and field data).

1.5.5 Socio-economic Setting

The landscape along the Se San River from the Vietnamese border through Ratanakiri Province varies from hilly scenery with relatively steep riverbank slopes in the upper part of the river close to the Vietnamese border through gradually less sloped land into a relatively flat lowland area in the lower part of the basin in Veun Sai District. It is in the lower areas in Ta Veaeng and Veun Sai that most of the riverside villages are located and that are also most prone to floods. To the North of the river locates Virachey National Park with large forests and different kinds of wildlife. To the South the central plateau of Ratanakiri Province where the most populated areas in the province, apart from along the Se San River side, are located, inclusive the provincial town of Ban Lung. In general, population density in the entire Ratanakiri Province is very low, only 9 persons/km^2. The Province is rural, and the provincial town comprises the whole urban population.

Villages

The habitations along the river are ethnic minority villages. They typically follow the same pattern of houses in rows along the riverside, in between the home gardens closest to the river and the rice fields further up. Subsistence economy is based on rain-fed paddy cultivation and on fishery. Some villagers also have swidden upland fields further up from the village. 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 Sre Kor Village, Stung Treng province

Infrastructure

The basic infrastructure in the Study area is poor, but road network to villages is being developed. Yet some villages are rather inaccessible during the rainy season. There is a main road to each district center, and the road No. 78 through Ou Ya Dav District cross the border into Vietnam. The Se San River is frequently used for travel and transportation, which the great number of boats in the villages also indicate. In Veun Sai there is ferry across the Se San River, connecting the road from Ban Lung town to Siem Pang town by the Se Kong River in Stung Treng Province. Motorbikes are mainly used in transportation of people and goods wherever road access to villages is convenient. 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 Ratanakiri Province are the lowest in the whole Cambodia. The general literacy rate in Cambodia is 72.8%; but 66.2% for women and 64.2% for rural women (CIPS 2004, 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 Stung Treng Province, the literacy rate among rural women at the time of the census was 31.2% (63.5% among urban women) and 46.9% among rural men.

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 Se San Commune, Ou Ya Dav District, 97.3% of the total population, and 100% of the women are illiterate. In the two riverside communes of Nhang and Ta Lav in Andoung Meas District, illiteracy among both men and women varies from 85 to 90%, in some villages up to 100%. In Ta Veaeng the variation in illiteracy in different villages is from 40 to 98%. Same kind of variation applies to Veun Sai District villages. That kind of great differences can either be caused by great local differences in school infrastructure, local education-focused development projects or an error in the statistics. During this rapid study no reliable causes have been possible to assess. In the downstream Se San District in Stung Treng Province with mainly Lao and Khmer populations illiteracy is in general lower, less than 50%, with the exception of Talat and Rumpoat villages (SEILA 2004).

Due to lack of teachers many schools have only grades 1–2. Added to long distances to school, poor infrastructure and poverty, this situation contributes to the remaining low level of education in the Northeastern areas of Cambodia. Ethnic minority status probably contributes to low priority given to education as well. The local variations in school attendance among the children in school age are enormous in the Se San riverside villages, varying from all children going to school to less than 3% going to school (according to SEILA 2004). It is difficult to find explanations to such great local differences apart from village-level development projects as well as distance to and accessibility of school. Further it can be seen that in the upstream areas (Ou Ya Dav and Andoung Meas) in general few children attend school. Secondary schools are available only in district towns, and there is just one upper secondary school in the provincial capital.

1.5.6 Living and Health Standards

In Ratanakiri 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 the own group. In district centers and along the main roads infrastructure is better, which in general contributes to better living standards, access to education and health care.

The living and health standards in the villages along the Se San River show great local variations. In the uppermost part of the river in Ou Ya Dav less than 3% of the children go to school, families are poor and their assets few. Even in the riverside villages many households do not own boats (SEILA 2004). Along the whole riverside in Ratanakiri, in all villages there seem to be poor families suffering from seasonal lack of food, usually 1–3 months per year. Food insecurity has clearly increased since the late 1990s (see Section 5.5.2 below).

Adequacy of cultivation land varies between different areas along the Se San River. In general, land insecurity has increased during the past 5–10 years. Land Law, the long process to acquire a permit to clear land, private interest and forest companies as well as increased riverbank erosion seem to be among the obstacles for people along the Se San River to obtain sufficient cultivation land. Fishing in the river provides an adequate diet in combination with rice, vegetables and fruit for the riverside population. Fewer children are undernourished than in the highland villages, according to the district health centers. However, this situation has been changing, especially since the year 2000, due to strongly reduced fish populations in the river (see Section 5.5.1 below).

In the riverside villages the Se San 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. Every district has 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 on commune level is under construction in order to bring the basic health care closer to the 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.

There are 66 villages with totally almost 29,000 people (following the SEILA database 2004) living along the Se San River from the Vietnamese border down to its confluence with the Srepok River. This area comprises the Study Area for the present study. The Se San River constitutes an absolute prerequisite for the existence of the riverside population in its present location. People are dependent on the river and its water resources for their daily lives. Their nutrition, economy and culture are built around the river. The recent changes that have taken place in the Se San River have therefore impacted both the food production system, economy and culture of the people residing along the Se San River in Cambodia as explicated in Sections 5.5 and 6.1 below.

1.6 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 operation of Ialy HPP and other projects under development have been considered by superimposing the historical and future project operations onto the relevant environmental, social and cultural conditions along the affected Se San River in Cambodia.

1.6.1 Study Process

The Study process is described in short in Figure 1.4.

Fig. 1.4 The Study process

PROJECT DESCRIPTION
EXISTING BASELINE INFORMATION
FIELD STUDIES
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 Ratanakiri and Stung Treng provinces.

Fieldwork was conducted in the study area. Added to village studies, consultation with provincial, district and commune authorities as well as NGO representatives in Ratanakiri and Stung Treng, 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 parallel, leading to consideration of mitigation needs and measures.

Mitigation measures for the reported impacts from Ialy Hydropower Project as well as potential impacts identified for both the construction and operation phases of new hydropower plants in the Se San River in Vietnam are evaluated and described in general. The mitigation measures are recommended, but should be further elaborated

Finally, a framework for environmental mitigation measures and monitoring is suggested.

1.6.2 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 study method is both to focus on specific 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

In addition water samples were taken from Se San River in Vietnam and also from the Ialy Reservoir.

1.6.3 Methodology for an Integrated Field Study

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 study.

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
- 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
- Water quality (nutrients, minerals, heavy metals, algal toxins, pesticides, eutrophication problems) of the Ialy Reservoir and the Se San River - aquatic.
- 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.

The 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. Two environmentalists from the Client, PECC1 (Vietnam) followed closely the field survey.

Field Work

The fieldwork was covered by three visits to Cambodia and one to Vietnam;

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 and Stung Treng 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 affected villages in each district.
4) The aquatic ecologist visited Vietnam and Ialy Reservoir for collecting water samples after having finished the work in Cambodia.

The 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.

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 collection. 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. The list of persons met and districts, communes and villages visited is enclosed in Appendix 2.

Fig.1.5 Consultation with the Village Chief and villagers at Phum Pir Village.

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 Se San River were also mapped to confirm the configuration provided in the village maps.

Official land use maps were used to delineate the Se San 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 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. Meetings were held with professor Ho Thanh Hai and professor Nguyen Kiem Son at the Institute of Ecology and Bioresources in Hanoi, who have undertaken biological studies in the Vietnamese part of Se San River in connection with the EIA for Plei Krong HPP. 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 were given.

Water samples for standard water chemistry were taken on clean PE-bottles. Water samples for heavy metals were taken on special bottles rinsed with acid. Water samples for pesticide analysis were taken on 2 liters glass bottles washed twice in cyclohexane and burned at 550 degrees Celcius for 12 hours. Water was filtered onto Whatmans GFF filters (0.8 µm mesh size) to retain algae for analysis of algal toxins. The filters were air dried and kept in darkness until analysis in the laboratory of the Norwegian Institute of Water Research. Samples for phytoplankton species composition were taken on glass vials and preserved by Lugols acetic acid solution. Oxygen and temperature were measured by an YSI meter with continuous stirring and 50 m long cable.

Stakeholder Consultation

Stakeholders in this brief study are defined to the following categories:

1) People who are affected by the Ialy HPP and are expected 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 with information 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 downstream impacts in Cambodia from Ialy HPP and from future hydropower plants along the Se San River in Vietnam. It was not possible to arrange consultations within the allocated time frame with all different categories of stakeholders like the specially vulnerable stakeholder groups of fishermen and women. 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.

1.6.4 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 (description of the present situation).

An assessment of the recorded impacts from Ialy HPP and 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 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 mitigation measures and monitoring plan for 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. Such a plan should also closely consider the future mitigative effects of the Se San 4A re-regulation reservoir, which is currently under construction.

The output from the Study is accordingly:

1) Describe the present situation of
   - the river body (physical, chemical (water quality) and biological) of the relevant reach of the Se San River in Cambodia,
   - water quality data of the Ialy Reservoir and the Se San River in Vietnam immediate downstream the Ialy Reservoir.
   - the land areas and settlement affected by the estimated water level fluctuation along the river reach.
   - possible cultural relics along the same reach of the river and in the area affected by the operation of the power stations.
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 monitoring program for the Se San River in Cambodia.

2. HYDROPOWER PROJECTS ON THE VIETNAMESE PART OF SE SAN RIVER

2.1 Overall Aspects of Hydropower Development in Se San River

The hydropower potential in the Se San River Basin is primarily concentrated to the main Se San River and to some extent to its two main sources, Krong Poko and Dak Bla Rivers. However, also the potential for high-head developments in smaller tributaries has been investigated over the years.

Several projects have been identified within the Se San River Basin in Vietnam and one large project, the Ialy Hydropower Project, is in operation.

A Master Plan (General Report) on the Se San River Basin was presented by PIDC1 (now PECC1) in 1992 and reviewed by SWECO in association with Statkraft Engineering in 1997. Further studies of the hydropower resources of the basin were presented in 1999 in the “Se Kong- Se San and Nam Thun River Basins Hydropower Study” by Halcrow/EPDC/MK Centennial.

By the development of the Se San 3, 3A and 4 hydropower projects, the total hydropower potential between the border with Cambodia and the existing Ialy Hydropower Project would be utilized. A considerable advantage with these projects is the possibility to make use of the already regulated outflow from Ialy Reservoir, thus limiting the need for additional large active storages.

2.2 Hydropower Projects in Operation

2.2.1 Ialy Hydropower Project

There is currently one hydropower project in operation in Se San River Basin, Ialy Hydropower Project.

The Project is located just downstream of the confluence between Krong Poko and Dak Bla rivers. The Project features a 70 m high rock fill dam with the spillway located on the left bank. The power facilities are located on the right bank and encompass an intake structure with two headrace tunnels and an underground power station with four 180 MW generating units. Tailrace tunnels convey the turbine flow back to Se San River.

The construction of the Ialy dam started in November 1993, and filling of the reservoir started on May 27, 1998 and was completed in July 1998. The first unit was commissioned June 23, 2000, and final completion of the power plant with all four units in operation, was January 26, 2002.

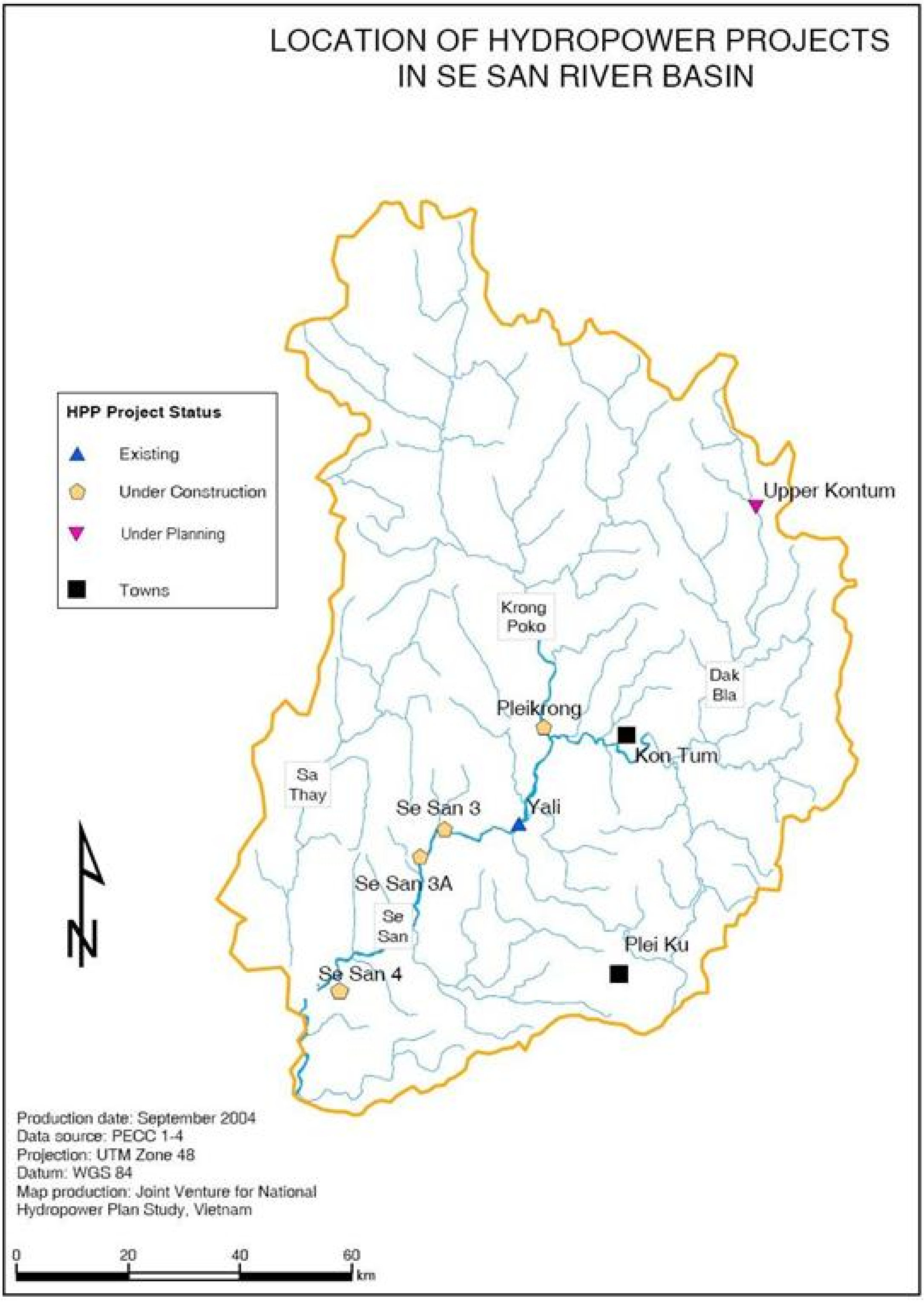


Fig. 2.1 Location of the hydropower projects on the Vietnamese side of the Se San River

Fig. 2.2 Satelite View of the Ialy reservoir (Google Earth)

The main project parameters for Ialy Hydropower Project are as shown in Table 2.1:

Table 2.1 Main parameters of Ialy Hydropower Project

Item	Unit	Ialy
Catchment Area	km^2	7,455
Mean Annual Flow	m^3/s	259
Full Supply Level, FSL	m.a.s.l	515
Reservoir Area at FSL	km^2	65
Minimum Operating Level, MOL	m.a.s.l	490
Reservoir Total Storage	Mm^3	1,037
Reservoir Active Storage	Mm^3	779
Normal Tail Water Level	m.a.s.l	306.5
Turbine Design Discharge	m^3/s	420
Installed Capacity	MW	720
Annual Average Energy Potential	GWh	3,146

Fig 2.3.a Ialy Dam during spillway release *Fig. 2.3.b Ialy Reservoir* *(photo: EVN)*

2.3 Hydropower Projects under Construction

2.3.1 Pleikrong Hydropower Project

Construction of Pleikrong Hydropower Project started during 2003. The Project is located on Krong Poko River some 3 km upstream of the confluence with Dak Bla River, and about 20 km west of the city of Kontum.

The Project features a 71 m high RCC dam, a 100 m long embedded penstock to a surface power station, with 2 units, with an installed capacity of 100 MW providing an average annual generation of 417 GWh. At the FSL of +570 m the reservoir creates an area of 53 km^2 and an active storage of 950 Mm^3, corresponding to some 24% of the average runoff. By providing regulation of Krong Poko River the additional average annual generation will be some 290 GWh for downstream projects.

Table 2.2 Main parameters for Pleikrong Hydropower Project (Technical Design by PECC1)

Item	Unit	Pleikrong
Catchment Area	km^2	3,216
Mean Annual Flow	m^3/s	128
Full Supply Level, FSL	m.a.s.l	570
Reservoir Area at FSL	km^2	53.3
Minimum Operating Level, MOL	m.a.s.l	537
Reservoir Total Storage	Mm^3	1,048.7
Reservoir Active Storage	Mm^3	948
Spillway Design Flood	m^3/s	7,063
Maximum Tail Water Level	m.a.s.l	527.83
Maximum Head	m	57.5
Turbine Design Discharge	m^3/s	367.6
Installed Capacity	MW	100
Annual Average Energy Potential	GWh	417

2.3.2 Se San 3 Hydropower Project

Se San 3 Hydropower Project is located some 15 km downstream of Ialy Dam, and about 40 km from the city of Pleiku.

The Project features a 70 m high concrete gravity dam, two 96 m long concrete penstocks to a surface power station, with 2 units. The installed capacity is 260 MW providing an average annual generation of 1,225 GWh. At the FSL of +304.5 m the reservoir creates an area of 3.4 km^2 and a total storage of 92 Mm^3, and a small active storage for daily regulation of 1.3 m.

Construction of access roads for Se San 3 Hydropower Project started in May 2001, construction of the dam was completed by the end of 2005. First trial run is planned to take place in April 2006, and the plant is expected to be completed by June 2006.

Table 2.3 Main parameters for Se San 3 Hydropower Project (Technical Design by PECC1)

Item	Unit	Se San 3
Catchment Area	km^2	7,788
Mean Annual Flow	m^3/s	274
Full Supply Level, FSL	m.a.s.l	304.5
Reservoir Area at FSL	km^2	3.4
Minimum Operating Level, MOL	m.a.s.l	303.2
Reservoir Total Storage	Mm^3	92
Reservoir Active Storage	Mm^3	Daily regulation
Spillway Design Flood	m^3/s	17,058
Maximum Tail Water Level	m.a.s.l	256
Maximum Head	m	66.5
Turbine Design Discharge	m^3/s	486
Installed Capacity	MW	260
Annual Average Energy Potential	GWh	1,225

2.3.3 Se San 3A Hydropower Project

Se San 3A Hydropower Project is located on the lower Se San River (in Vietnam) some 10 km downstream of Se San 3.

The Project features a 34 m high concrete gravity dam, a surface power station, with 2 units, at the foot of the dam. The installed capacity is 96 MW providing an average annual generation of 475 GWh. At the FSL of +239 m the reservoir creates an area of 8.5 km^2 and an active storage of 4 Mm^3.

Construction of access roads for Se San 3A Hydropower Project started in January 2002, and construction of the dam started in April 2003. By the end of 2005 the dam is finished and erection of electromecanical equipment is going on. First trial run is planned to take place in May 2006, and final completion is expected to be in September 2006.

Table 2.4 Main parameters for Se San 3A Hydropower Project (Technical Design by PECC1)

Item	Unit	Se San 3A
Catchment Area	km^2	8,084
Mean Annual Flow	m^3/s	284
Full Supply Level, FSL	m.a.s.l	239
Reservoir Area at FSL	km^2	8.5
Minimum Operating Level, MOL	m.a.s.l	238.5
Reservoir Total Storage	Mm^3	80.6
Reservoir Active Storage	Mm^3	4.0
Spillway Design Flood	m^3/s	15,200
Maximum Tail Water Level	m.a.s.l	
Maximum Head	m	25
Turbine Design Discharge	m^3/s	500
Installed Capacity	MW	96
Annual Average Energy Potential	GWh	475

2.3.4 Se San 4 Hydropower Project

Se San 4 Hydropower Project is located close to the border between Vietnam and Cambodia, and some 22 km downstream of Se San 3A Hydropower Project.

The Project features a 74 m high rock fill dam, an embedded penstock adjacent to a surface power station with 3 units. The installed capacity is 360 MW providing an average annual generation of 1,402 GWh. At the FSL of +215 m the reservoir creates an area of 58 km^2 and an active storage of 264 Mm^3, corresponding to less than 3% of the annual flow.

Construction of access roads for Se San 4 Hydropower Project started in April 2004.
In December 2005 construction of the dam has not yet started, but excavation for the dam foundation is going on.

Table 2.5 Main parameters for Se San 4 Hydropower Project (Technical Design by PECC1)

Item	Unit	Se San 4
Catchment Area	km^2	9,326
Mean Annual Flow	m^3/s	328.9
Full Supply Level, FSL	m.a.s.l	215
Reservoir Area at FSL	km^2	58.4
Minimum Operating Level, MOL	m.a.s.l	210
Reservoir Total Storage	Mm^3	893.3
Reservoir Active Storage	Mm^3	264.2
Spillway Design Flood	m^3/s	16,570
Maximum Tail Water Level	m.a.s.l	
Maximum Head	m	61.7
Turbine Design Discharge	m^3/s	719

Installed Capacity	MW	360
Annual Average Energy Potential	GWh	1,402

2.4 Committed Hydropower Projects

Apart from the four projects under construction mentioned above there are no committed hydropower projects in Se San River Basin.

2.5 Hydropower Projects under Planning

2.5.1 Upper Kontum Hydropower Project

The location of Upper Kontum Hydropower Project is shown in Figure 2.1, and described in more detail below.

A preliminary optimization study of Upper Kontum Hydropower Project was done in the NHP study and gave the following results:

Table 2.6 Design data for Upper Kontum Hydropower Project.

Parameter	Unit	Value
Full Supply Level, FSL	m.a.s.l.	1,150
Minimum Operating Level, MOL	m.a.s.l.	1,146
Design Discharge	m^3/s	34.4
Installed Capacity	MW	260

The Upper Kontum Hydropower Project will be located on Dak Nghe River some 50 km north north-east of Kontum City in Kon Plong District, Kontum Province.

The Upper Kontum Hydropower Project will be a trans-basin project, and water will be diverted from Dak Nghe River to Dak Lo River in Tra Khuc River Basin of the Quang Ngai Province.

The catchment area of the Upper Kontum Hydropower Project, located in the uppermost part of Se San River Basin, is only 350 km^2, or some 3 % of the total catchment area of the Se San River Basin at the border with Cambodia.

The reservoir regulation of 4 m between the FSL at +1,150m and the MOL at +1,146 m will provide an active storage of 14.5 Mm^3, corresponding to about 3% of the annual average inflow of 15.1 m^3/s.

The Upper Kontum Hydropower Project would reduce the power production for projects located downstream in Se San River. Due to the high head available in the diversion to Tra Khuc River Basin, the total net energy production would be positive, and the Project would supply much needed water for irrigation and industrial use in the receiving catchment.

The hydrological information on Upper Kontum Hydropower Project given below is based on Section 3.2 of Volume VII of the Draft Final Report on NHP Stage 1.

Natural Inflow Series

The natural monthly inflow series for Upper Kontum Hydropower Project derived for the period 1961 to 1996 are given in tables below indicating a mean annual discharge of 15.1 m^3/s. Discharges at various durations, based on monthly data, is given in the table below:

Table 2.7 Natural discharges at various durations at Upper Kontum dam site.

Duration, %	Discharge, m^3/s
5	39.2
10	32.4
90	4.3
95	3.7

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

Table 2.8 Statistical parameters of the natural mean annual inflow series at Upper Kontum 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)
Upper Kontum	350	15.1	470.5	43	8.6	23

The natural average monthly inflows at Upper Kontum dam site is summarized in the table below:

Table 2.9 Natural average monthly inflows at Upper Kontum dam site (m^3/s).

Dam Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper Kontum	8.8	6.3	4.9	4.7	7.1	11.5	14.7	23.8	29.7	29.1	25.7	15.1

Flood Flows

The following design floods were estimated for Upper Kontum Hydropower Project in Stage 1 of the NHP Study:

Table 2.10 Flood peak values for different return periods at Upper Kontum dam site (m^3/s).

Dam Site	Return Period, Years	
	1,000	10,000
Upper Kontum	1,550-1,950	2,100-2,600

2.6 Se San 4A Re-Regulation Reservoir

The site of Se San 4A Re-Regulation Reservoir will be situated approximately 5 km downstream of Se San 4 Power Station, or about 1km from the Cambodian border. See Fig. 2.3.

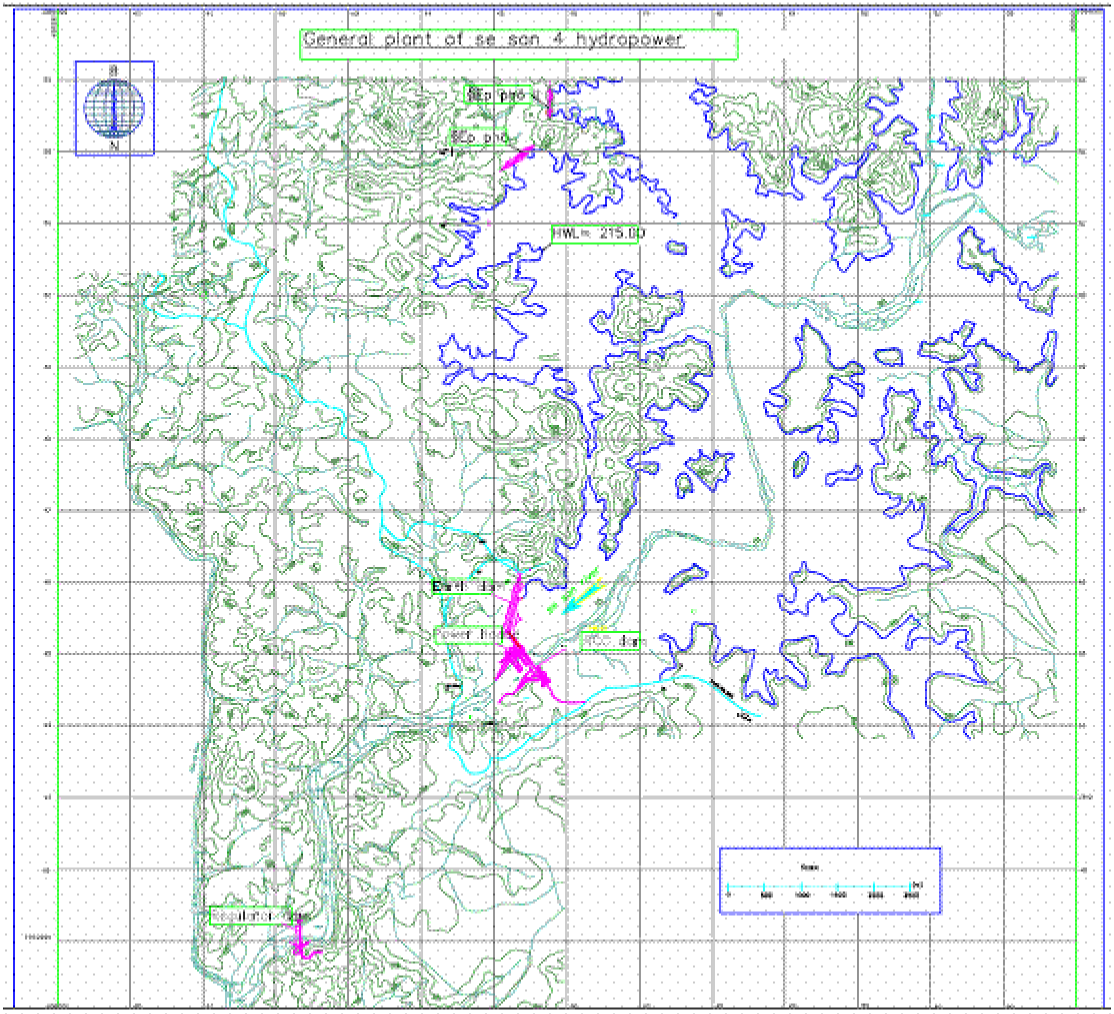


Fig. 2.4 Map of Area around Se San 4 and Se San 4A (PECC1)

The rational of Se San 4A Re-Regulation Reservoir, being the most downstream reservoir in a cascade development of the Se San River, is to provide re-regulation of the intermittent outflow from the upstream Hydropower Projects and thus provide a steady flow without daily variations into Cambodia. According to EVN construction started in November 2004 and will be completed August 2007.

Table 2.11 Main parameters for Se San 4A Re-regulation Reservoir (Technical Design by PECC1)

Item	Unit	Se San 4A
Full Supply Level, FSL	m.a.s.l	155,2
Reservoir Area at FSL	km^2	1.73
Reservoir Total Storage	Mm^3	13.1
Reservoir Active Storage	Mm^3	7.5

3. HYDROLOGY AND FLOW CHARACTERISTICS OF OPERATION

3.1 The Se San River System

The headwaters of the Se San River are situated at elevations exceeding 2,500 m, on the southwestern slopes of the Ngoc Linh massive in Central Vietnam. The river flows in the southwestern direction through the Kontum and the Gia Lai provinces of Vietnam into the Ratanakiri Province in Cambodia. The length of the river is about 462 km, of which 210 km in Vietnam. It joins with Srepok River in Cambodia, 20 km upstream of the confluence with Mekong River near the city of Stung Treng. The total catchment area of Se San River Basin is 18,570 km^2 with nearly 40 % (6,960 km^2) located in Cambodia and some 60 %, or 11,450 km^2, located in Vietnam.

At the border to Cambodia the average flow is about 380 m^3/s. The specific runoff of Se San River Basin varies from around 40 l/s per km^2 in the upper western part of the basin to 30-35 l/s per km^2 in the lower parts.

The Se San River has three main tributaries, the Krong Poko, Dak Bla and Sa Thay rivers, while there are a total of 83 tributaries (more than 10 km long). As the surface of the catchment area is rather homogeneous, the density of rivers and streams is low, about 0.38 km/km^2 in average. The average slope of the basin is about 14 %. In the river, there are numerous steep sections that create many waterfalls and rapids.

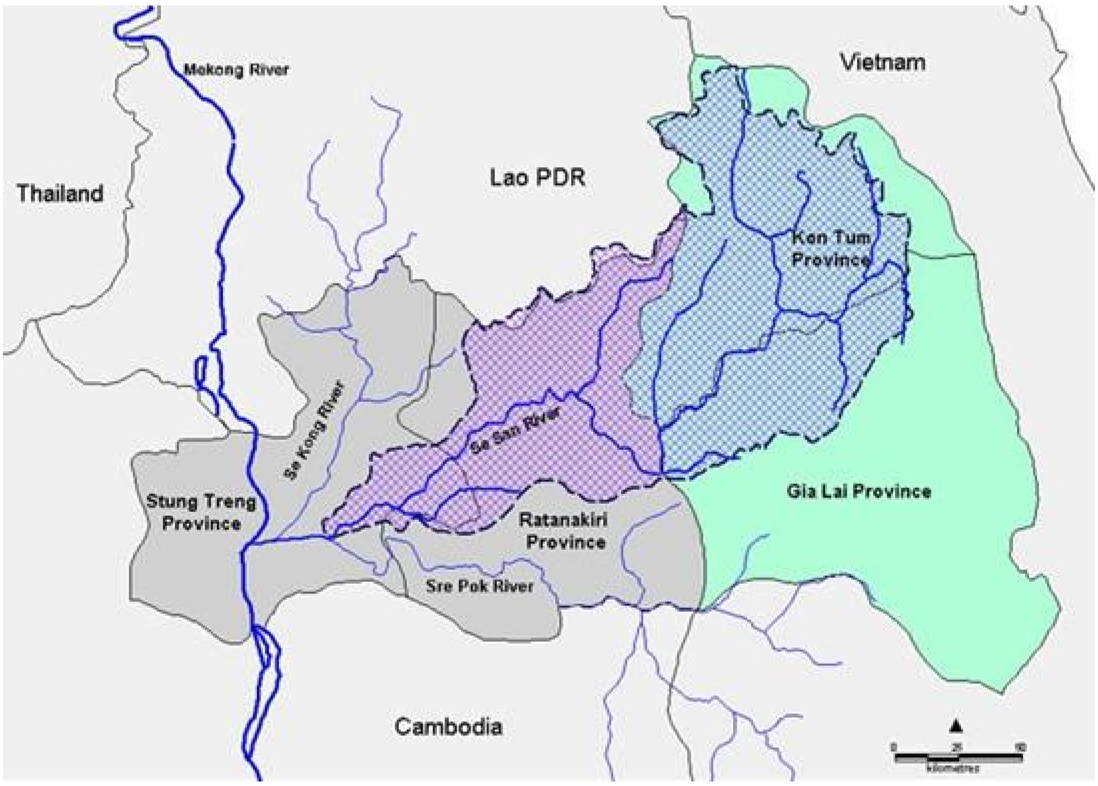


Fig. 3.1 The Se San River Catchment

3.2 Climatic Conditions

A large-scale monsoon circulation influences the climate of the Se San River basin. During the winter, from December to March, the monsoon has a northeast-southwest direction and brings dry air masses over the Se San River Basin. The winter weather is warmer than in the northern Vietnam with little or no rainfall. The circulation has an opposite direction during the summer from May to September. The summer monsoon brings nearly the whole annual rainfall to the basin. During October and November, the basin can be affected by tropical cyclones from the northeastern direction. This circulation may result in extreme flooding. A relatively large size of the basin and varied topography determine the complex spatial distribution of the climatic regime.

3.3 Hydrological and Meteorological Data

The hydrological and meteorological data in the Se San River catchment have been investigated by the Danish Hydraulic Institute and elaborated in a report “Hydrodynamic Modeling of the Se San River” (DHI 2005) with respect to their availability and usability for rainfall runoff modeling.

3.3.1 Meteorological Data

Meteorological data exist at Pleiku, Kontum, Ialy and Dak To. Of the meteorological data, it is only evaporation, which is used by the rainfall-runoff model. Prior to 1990 there are only monthly evaporation data available. Daily as well as monthly data exist from 1990 and onwards. There are no meteorological data available from the Cambodian part of the catchment.

The rainy season over the Se San River Basin is related to the summer southwest monsoon circulation. The spatial distribution of the annual precipitation over the basin is non-uniform, being highly dependent on altitude, position of various mountain ranges with respect to the moisture-laden winds and the small-scale orographic effects.

The average depth of annual precipitation varies within the range from 1,300 mm to more than 2,800 mm. The rainfall generally increases with the elevation and is the highest, probably more than 3,000 mm, on the southwest slopes of the Ngoc Linh mountain range in the northeastern part of the basin.

3.3.2 Hydrological Data

The network of meteorological and hydrometric stations within the basin is sparse, particularly in Cambodia, in combination with a short coverage in time. On the Cambodian part of the catchment there are no rainfall stations available in the mountain areas north of the Se San River.

Discharge and Water Level Data have been observed in Kontum, Konplong, Dak Mot, Dak To, Sa Binh, Trung Nghia, Duong Vong Lu and Ialy stations on the Vietnamese side of the Se San River catchment. Of the stations above, it is only Sa Binh and Ialy that are located on the Se San River. Trung Nghia and Kontum are on the tributaries Krong Poko and Dak Bla, respectively. In Cambodia, discharge has only been observed recently on the Se San River. The numbers of observations are few and only taken in year 2000. Discharge has been observed at Andoung Meas and Veun Sai.

Water levels have been observed at the stations Kontum, Sa Binh, Trung Nghia, Ialy, TV1, TV2, and TV3 on the Vietnamese side. The latter three stations were temporarily set-up in connection with the Ialy Dam construction project. On the Cambodian side of the catchment water levels have been observed at Andoung Meas and at Veun Sai. At Andoung Meas an automatic water level recorder has been set up (with assistance from Mekong River Commission Secretariat), and both manual (daily) and automatic (hourly) data exist.

3.4 Flood Flow Events

The majority of flood events in the Se San River Basin are due to the activity of the summer monsoon. These floods mostly occur during the period from July to October. The extreme floods in the basin are however caused by the typhoons arriving from the N and NE directions. The largest flood at the Kontum station occurred in October 1972. The instantaneous peak flow of this event was estimated at some 4,000 m^3/s. The second largest flood occurred during November 1996. The flood hydrograph of this event has been registered both at the Kontum and at the Trung Nghia gauging stations. The instantaneous peak values at these stations were 3,620 m^3/s and 2,440 m^3/s, respectively.

Inspection of the graph indicates that the rainfall event generating this flood had the torrential character connected to typhoon activity. The rising limb of the hydrograph is very steep and the duration of the main flood wave is short.

3.5 Hydrodynamic Modeling

3.5.1 Introduction

The main reason for the study to be undertaken was the concern regarding adverse impacts on the Se San River in Cambodian territory due to releases of water from Ialy Reservoir in Vietnam. Due to the lack of meteorological and hydrometric data, the Hydrodynamic Modeling report (DHI 2005) has been used to simulate the “Natural Flow Conditions” for the Se San River as well as a number of scenarios with hydropower development.

The study involved the set-up of a mathematical modeling system – MIKE 11 – for the Se San River and catchment. The model system covers the Se San River from Kontum on Dak Bla River, Trung Nghia on Krong Poko and down to the confluence between Se San and Srepok rivers in Cambodia. A separate model has been established to describe the rainfall-runoff from the catchment.

The model study is only dealing with hydrodynamics. The focus has therefore been on the water level and discharge condition along the river and at selected stations to describe the natural, historical and future conditions with operation of hydropower stations. The main objective in this regard has been to test scenarios with the purpose to avoid high flow velocities or sudden changes in the river system. This has been accomplished successfully, and various operation rules for the turbine operation and for spillway operation are provided for all the hydropower stations.

The outcome from the study in relation to the natural flow and historical flow condition is applicable as a basis for the environmental study.

The following scenarios are simulated:

- Historical Flow Condition: The model has been used to compute the historical flow condition from 2000-2003, in which Ialy Hydropower Station has been in operation. The results from this simulation represent the actual flow condition as they were in the period 2000-2003.

- Natural Flow Condition: The model has been used to simulate the river flow and water level condition assuming there were no reservoirs in the river, i.e. in its natural stage. The same hydrology as for the historical flow condition has been used, i.e. 2000-2003. All scenario simulations can be compared to this natural conditions simulation in order to assess their relative impact.
- General Operation of the Hydropower Stations: Overall operation rules for the hydropower stations to be tested in the model have been agreed with the client. Tests have been conducted for Ialy Hydropower Station alone, as well as for Ialy, Se San 3, Se San 3A, and Se San 4 Hydropower Stations in combination. The results from the simulations are used to provide information about the hydraulic impact which the proposed rules have on the river. In this regard comparison with the natural conditions is made. The hydrological period of 2000-2003 has been used in these simulations.
- Intermittent Flow Operation of the Hydropower Stations: The model has been used to determine the effect of specific operation rules during peaking operations, in which flows are intermittently released from the turbines. Operation rules are optimized solely with regards to their hydraulic effect in downstream reaches. Tests have been conducted for Ialy Hydropower Station alone, as well as for Ialy, Se San 3, Se San 3A, and Se San 4 Hydropower Stations in combination. The simulations have been carried out using selected subsets of the hydrological period 2000-2003.
- Spillway Operation of the Hydropower Dams: The model has been used to determine feasible strategies for spillway gate operation during excessive spills. Tests have been conducted for Ialy Dam alone, as well as for Ialy, Se San 3, Se San 3A, and Se San 4 Hydropower Stations in combination. As for the intermittent flow operation tests, the spillway operation rules have been determined solely with regards their hydraulic impact in the river. The simulations have been carried out using selected subsets of the hydrological period 2000-2003.

3.5.2 Historical Flow Condition

The results from the historical simulation is shown in Table 3.1 – 3.3:

Table 3.1 shows annual statistics for the historical simulation. Thus maximum, minimum and average values of discharge at Tailwater of Se San 4, Andoung Meas, Ta Veaeng and Veun Sai are presented.

Table 3.2 shows the Mean Monthly Low flows, which is defined as the month in a given year where the average flow is lowest.
Table 3.3 shows the Monthly 7-day Low Flow, which is the month in a given year with lowest average flow, subsequently divided into weekly average values.

Table 3.1 Annual flow statistics, historical simulation

Historical Simulation, discharges in m3/s						
Year	Tailwater Se San 4			Andoung Meas		
	Max	Min	Mean	Max	Min	Mean
2000	2433	3 *	326	3137	30	528
2001	1890	61	407	2823	126	644
2002	1894	7 *	385	2590	39	664

2003	3225	74	344	3934	89	598
Year	Ta Veaeng			Veun Sai		
	Max	Min	Mean	Max	Min	Mean
2000	4254	58	760	4678	64	872
2001	4001	143	861	4580	150	1017
2002	3295	64	867	3929	79	1029
2003	4709	144	776	5039	147	891

* The values are likely to be too low. According to PECC1 the minimum discharge at Tailwater of Se San 4 in year 2000 is around 19 m^3/s. A revised value for year 2002 has not been provided by PECC1.

Table 3.2 Mean monthly low flows, historical simulation

Historical Simulation				
Year	**Mean Monthly Low Flow, 2000-2004, [m3/s]**			
	Tailwater Sesan4	**Andoung Meas**	**Taveng**	**Voeunsai**
April 2000	5	37	69	77
March 2001	171	212	212	230
April 2002	107	181	165	172
April 2003	106	210	172	194

Table 3.3 Monthly 7-day low flow (m3/s), historical simulation

Historical Simulation	**Tailwater Sesan4**	**Andoung Meas**	**Taveng**	**Voeunsai**
Week 1 April 2000	15	36	66	74
Week 2 April 2000	6	32	61	67
Week 3 April 2000	15	45	76	78
Week 4 April 2000	49	72	117	128
Week 1 March 2001	189	233	229	250
Week 2 March 2001	192	233	232	246
Week 3 March 2001	186	231	221	241
Week 4 March 2001	182	201	212	226
Week 1 April 2002	102	144	151	150
Week 2 April 2002	102	184	169	174
Week 3 April 2002	108	181	163	161
Week 4 April 2002	114	208	175	196
Week 1 April 2003	97	214	176	205
Week 2 April 2003	108	190	167	177
Week 3 April 2003	101	197	163	182
Week 4 April 2003	117	231	180	210

3.5.3 “Natural Flow” Conditions

In order to evaluate the hydraulic changes in the Se San River since the construction of Ialy Hydropower Project, a simulation with no dams included in the model set-up has been made. This simulation is referred to as the ‘Natural conditions simulation’ and covers the period 2000 to 2003. By selecting this period, the results can be compared to the historical simulation for the lower Se San in which Ialy Hydropower project is included, as well as to other application simulations.

The simulated flow statistics for Natural Flow Condition are shown in table 3.4 – 3.6:

- Table 3.4 shows annual statistics for the natural simulation. Thus maximum, minimum and average values of discharge at Tailwater of Se San 4, Andoung Meas, Ta Veaeng and Veun Sai are presented.
- Table 3.5 shows the Mean Monthly Low flows for the natural simulation, which is defined as the month in a given year where the average flow is lowest.
- Table 3.6 shows the Monthly 7-day Low Flow, which is the month in a given year with lowest average flow, subsequently divided into weekly average values.

Table 3.4 Annual flow statistics, natural simulation

Natural Flow condition, discharges in m3/s						
Year	**Tailwater Sesan 4**			**Andoung Meas**		
	Max	Min	Mean	Max	Min	Mean
2000	2866	64	493	4297	86	703
2001	2160	58	404	3332	68	618
2002	2157	33	402	3326	44	617
2003	2619	35	382	3502	48	574
Year	**Taveng**			**Voeunsai**		
	Max	Min	Mean	Max	Min	Mean
2000	5952	112	938	6243	119	1049
2001	4648	80	844	5532	86	1000
2002	4607	55	844	5316	61	1008
2003	4498	61	766	5017	75	891

Table 3.5 Mean monthly low flows, natural simulation

Natural Conditions				
Year	**Mean Monthly Low Flow, 2000-2004, [m3/s]**			
	Tailwater Sesan4	**Andoung Meas**	**Taveng**	**Voeunsai**
April 2000	74	100	132	143
April 2001	76	91	107	116
April 2002	48	65	83	91
April 2003	45	61	76	92

Table 3.6 Monthly 7-day low flow (m3/s), natural simulation

Natural Conditions	**Tailwater Sesan4**	**Andoung Meas**	**Taveng**	**Voeunsai**
Week 1 April 2000	84	109	138	144
Week 2 April 2000	67	90	120	130
Week 3 April 2000	119	144	172	168
Week 4 April 2000	122	164	211	225
Week 1 April 2001	93	115	139	153
Week 2 April 2001	80	96	113	119
Week 3 April 2001	67	81	97	107
Week 4 April 2001	67	77	87	91
Week 1 April 2002	57	78	102	112
Week 2 April 2002	50	66	84	90
Week 3 April 2002	49	62	76	82
Week 4 April 2002	39	55	73	84
Week 1 April 2003	43	63	81	101
Week 2 April 2003	48	64	80	100
Week 3 April 2003	40	52	65	80
Week 4 April 2003	48	63	77	88

The results are shown in Figure 3.2 which shows the simulated water levels at the Tailwater of Se San 4 and at Andoung Meas. In the figures both the simulated natural flow condition and the historical condition are presented. This is done in order to compare the two situations.

The main conclusion to draw from the plots is

- the reduced peaks in the beginning of the monsoon due to the operation of Ialy hydropower station
- the increased water levels/discharges in the dry season due to the operation of Ialy hydropower station

The water level peaks in the beginning of the monsoon are being reduced by 1.0-1.5 m, whereas the dry season water levels increase by 0.5 – 1.0 m. The reduction of daily peak discharge in the monsoon is of the order 500-1000 m^3/s, whereas the dry season flow increase is about 100-300 m^3/s.

The findings above are based on the results being saved on a daily basis.

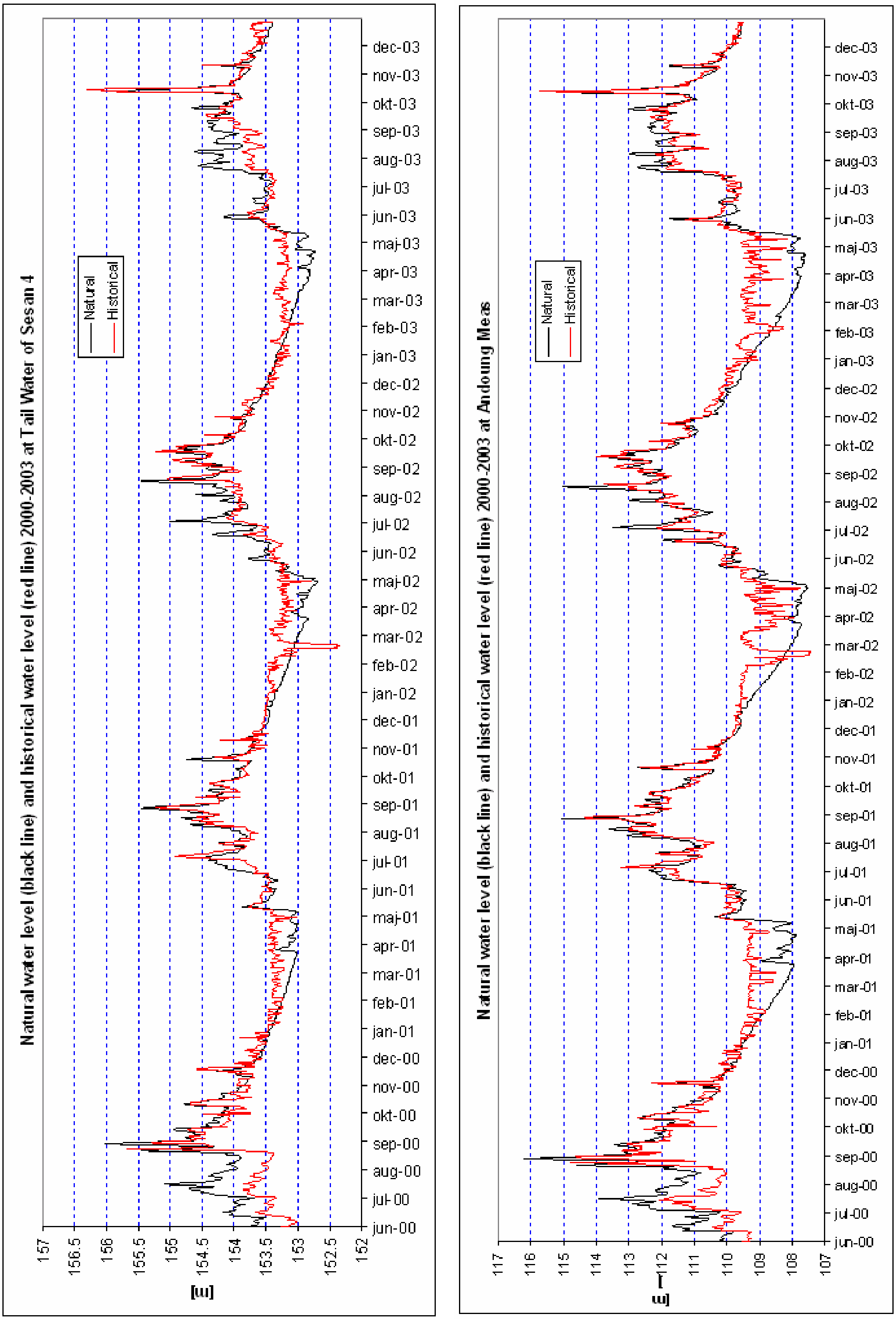


Fig. 3.2 Simulated water levels at tail water of the Se San 4HPP (left) and Andoung Meas (right). Natural simulation (black line) and Historical simulation (red line)

3.5.4 Some of the Main Simulation Results

Intermittent flow operation (cyclic operation of turbines from zero to their full capacity) has been simulated for Ialy alone and for Ialy, Se San 3, Se San 3A, and Se San 4 in combination. The following are some of the findings from the simulation tests.

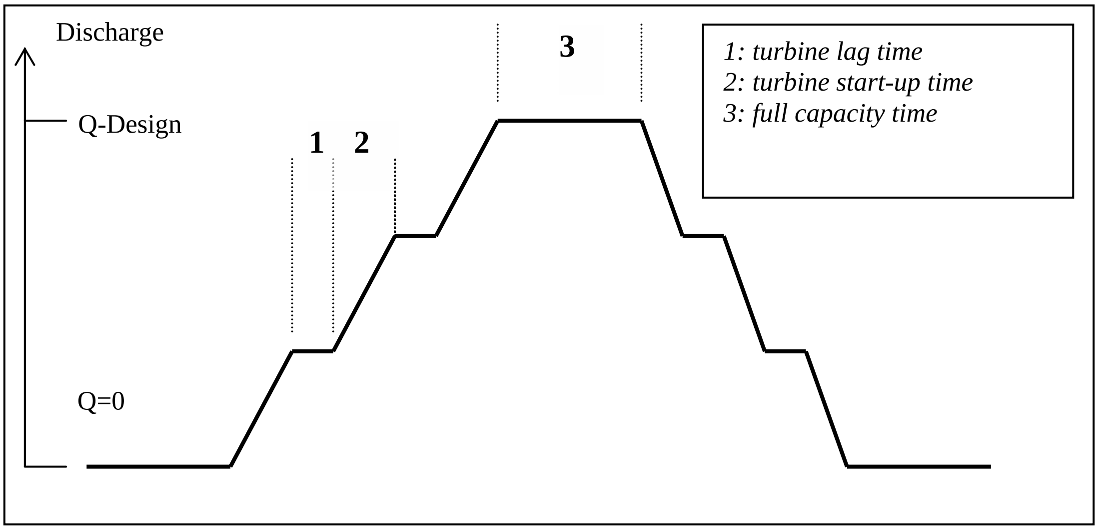


Fig. 3.3 Time definitions of an intermittent flow cycle

The main factor controlling the water level amplitude downstream of the hydropower stations is the time period for which the turbines are kept at their maximum and minimum capacity during intermittent flow operation.

The simulations show that if the time period described above is less than or equal to 3 hours, then the downstream water level amplitudes will be of an acceptable magnitude from a hydraulic point of view.

If the turbine start-up time and lag-time periods are increased, then the maximum flow velocities in the vicinity of the hydropower dams will decrease.

The simulation tests carried out have not been able to confirm the occurrence of shock-waves or waves with growing amplitude for turbine-start-up and turbine-lag times larger than 1 minute. Turbine start-up and –lag times less than 1 minute is not practically possible and is therefore not considered.

Figure 3.4 (DHI 2005), shows the water level variations at Andoung Meas in Cambodia, some 30 km from the border to Vietnam in Nov/Dec 2003 with only Ialy Power Station in operation.

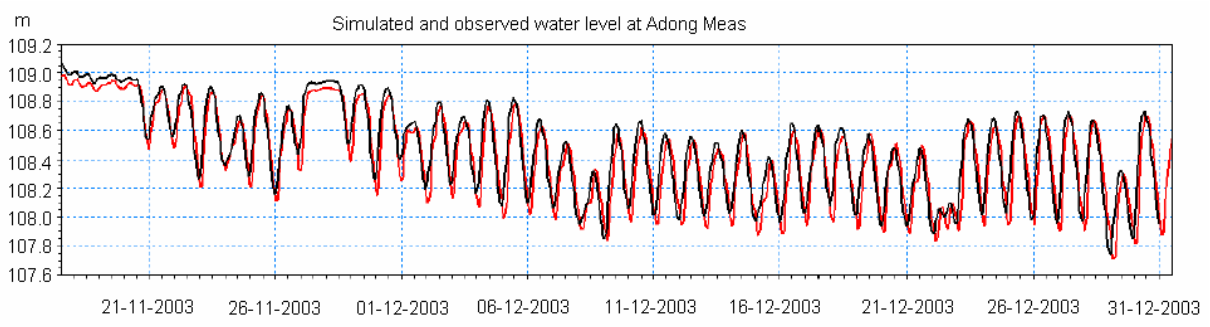


Fig. 3.4 Daily variations in water level due to intermittent operation of the Ialy Hydropower Plant. Observed (black) and simulated (red) water levels in Se San River in Cambodia at Andoung Meas. (after DHI 2005).

Figure 3.5 shows the daily water level variations at Adond Meas for different modes of operation of the Ialy Power Plant. The operation mode in the simulation is full turbine capacity and 1 hour on and off, 3 hours on and off, and 6 hours on and of respectively. It can be read from the y-axis that the 6 hours on and off gives a water level fluctuation of 0.6 m at the Andoung Meas.

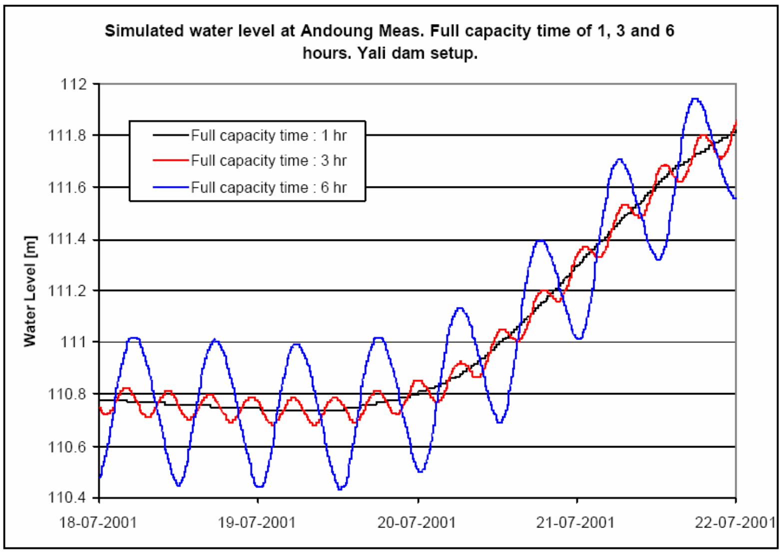


Fig. 3.5 Simulated daily water level variations during high flow in Se San at Andoung Meas at different running periods of the Ialy Power Plant (after DHI 2005)

Figure 3.6 shows the water level variations when all the power plants are run in an intermittent manner, Ialy, Se San 3, Se San 3a, and Se San 4. The daily water level variations will be larger when all the power plants are operating, than when only Ialy is operating. (0.6 m and 1.1 m respectively). The water level fluctuations will be much less as you go downstream the river. In Ta Veaeng the fluctuation will be approximately 20-30 cm, and only 5 cm in Veun Sai according to the DHI (2005).

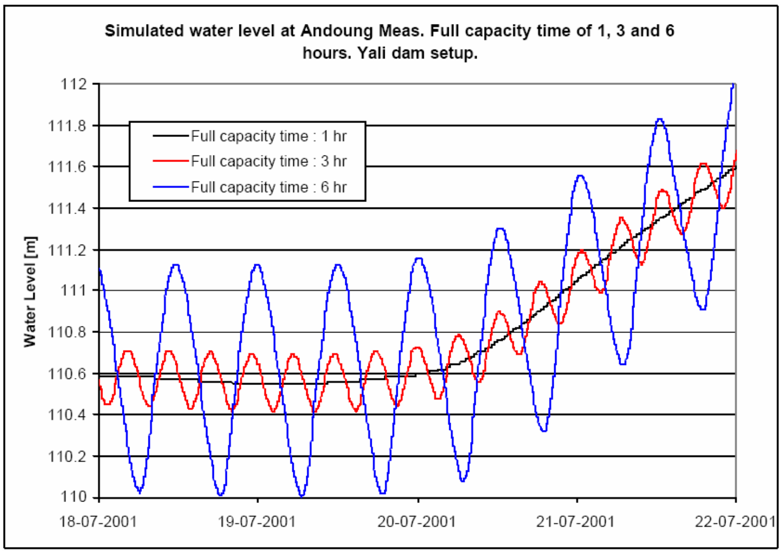


Fig. 3.6 Simulated daily water level variations during high flow in Se San at Andoung Meas at different intermittent running periods of the Ialy Power Plant, Se San 3, Se San 3a, and Se San 4 (after DHI 2005)

It should be noted that the Figures are representing the high flow situation when the power plants are run at full capacity. The water level fluctuations will be greater during the low flow situation if the power stations then are run at full capacity.

Conclusions

On this basis the following is recommended by DHI as a rule for operating the turbines intermittently:

It is recommended that the turbines are kept at their maximum capacity for a period of maximum 3 hours during intermittent flow operation.
The turbine lag-time, i.e. the time passed before a new turbine is switched on, should be kept at approximately 5 minutes to avoid too high flow velocities downstream of the hydropower plants.
If the turbine start-up time, i.e. the time it takes for a turbine to reach its full capacity, can be controlled, then it should be kept at approximately 3 minutes.

3.5.5 River Modeling – Spillway Operation Rules for the Dams

Various spillway operation rules have been tested, and the most feasible in terms of minimizing the fluctuations in the water levels and the flow velocities, to keep the maximum water levels low, and in general to follow the natural runoff pattern, are summarized below.

Table 3.7 Spillway rule for Ialy Dam

Reservoir level [m]	Ialy Spillway discharge [m3/s]
WL < 515.0	No spill
515.0 < WL < 516.0	0 < Qspill < 1000
516.0 < WL < 516.5	1000 < Qspill< 2000
516.5 < WL < 517.5	2000 < Qspill < 2500

WL > 517.5	Not considered in the simulations, but a gradual increase of Qspill up to Qdesign (14552 m3/s) is proposed for water levels increasing from 517.5 m and up to the dam crest level minus the freeboard this is

Table 3.8 Spillway rule for Se San 3

Reservoir level [m]	Se San 3 Spillway discharge [m3/s]
WL < 305.0	No spill
305.0 < WL < 310.0	0 < Qspill < 6000
WL > 310.0	Not considered

Table 3.9 Spillway rule for Se San 3A

Reservoir level [m]	Se San 3A Spillway discharge [m3/s]
WL < 239.0	No spill
239.0 < WL < 242.0	0 < Qspill < 8000
WL > 242	Not considered

Table 3.10 Spillway rule for Se San 4

Reservoir level [m]	Se San 4 Spillway discharge [m3/s]
WL < 215.5	No spill
215.5 < WL < 516.5	0 < Qspill < 2000
216.5 < WL < 218.3	2000 < Qspill< 10000
WL > 218.3	Not considered in the simulations, but a gradual increase of Qspill up to Qdesign (17500 m3/s) is proposed for water levels increasing from 218.3 m and up to the dam crest level minus the freeboard.

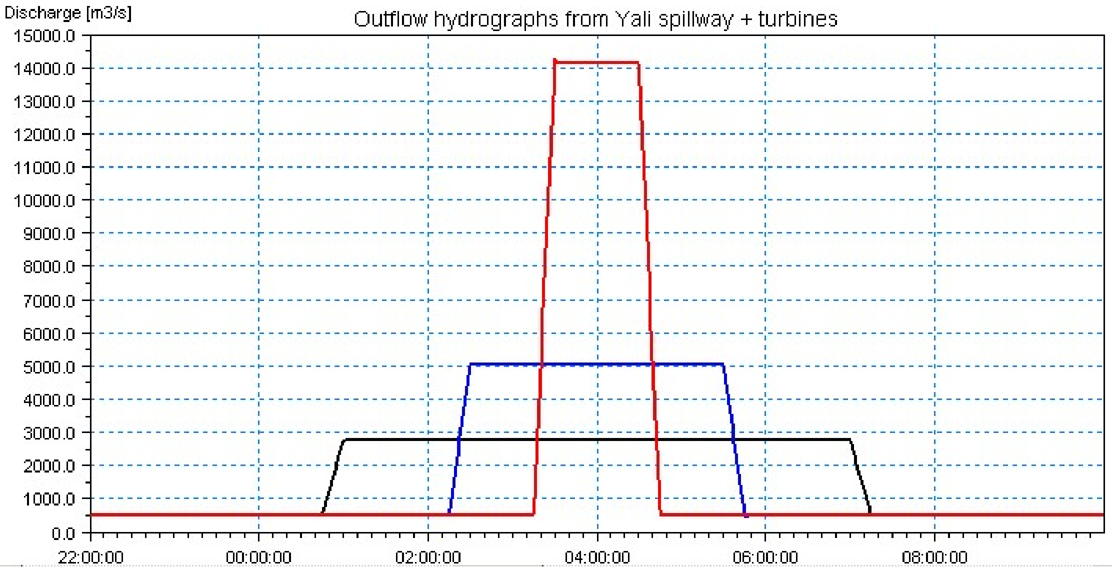


Fig. 3.7 Spill discharge examples

3.5.6 Variation in spill discharge and time period

The following combinations of spill discharge and periods have been used as outflow from Ialy reservoir in the simulations:

- Discharge of 2275 m^3/s with duration of 6 hours
- Discharge of 4550 m^3/s with duration of 3 hours
- Discharge of 13650 m^3/s with duration of 1 hour

The flow volumes of the above tests are the same. Figure 3.7 shows the outflow hydrographs from Ialy reservoir as described above. In addition to the spillway releases, the turbines deliver a constant flow of 400 m^3/s. The discharge value of 2275 m^3/s and the turbine release of 400 m^3/s are close to the observations made at Ialy HP station on 18th October 2003. The simulations assume a 15 minutes start-up time, i.e. the time for the spillway flows to reach the maximum discharge. A test has also been made with 30-minute start-up time.

The simulated water level at Andoung Meas for the three discharges is seen in Figure 3.8. It is observed that the hydrograph is being distorted implying that a ‘tail’ is created after passing of the flood wave. This is due to storage effects in the river and flood plain system.

There is roughly one meter difference in the predicted water levels at Andoung Meas between the three different discharges. Still the maximum water level (app. 117 m) is lower than the river bank at this location, hence overbank flooding does not occur. The discharge release from the Ialy spillway of about 14000 m^3/s gives a corresponding maximum flow at Andoung Meas of about 6500 m^3/s.

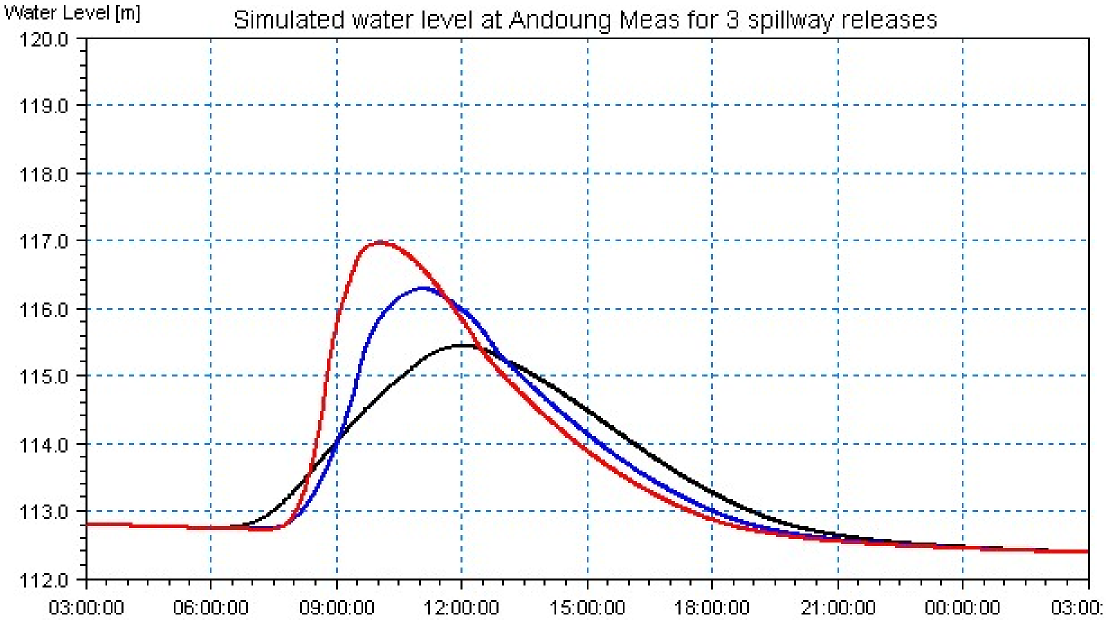


Fig. 3.8 Simulated water level at Andoung Meas for the three outflow hydrographs from Ialy (at top) used in the initial tests with varying spillway discharge and period. Sudden Opening of Spillway Gates at Ialy

A simulation has been made in which the Ialy reservoir opens all spillway gates instantaneously in a series of accidents. The gates are kept open for one hour.

The opening of the spillway gates creates a high discharge on the spillway, and a corresponding drawdown of the water level in the reservoir. The spill has immense effect in the river just downstream of the dam.

At Andoung Meas the maximum level is app. 117 m, a rise of more than 4 meters. This occurs over a 3-hour period. The maximum discharge is 6500 m^3/s (Fig. 3.9). This simulation is comparable to the spillway release test where an inflow discharge of 13650 m^3/s was applied for one hour. The water levels at Veun Sai are seen in Figure 3.10.

None of the stations Andoung Meas and Veun Sai have overtopped riverbanks in the simulation. For this to occur, the high spillway release must be held for a longer period, say about 3 hours. Overtopping will, however, also occur if the 1-hour spill is released at a high river discharge.

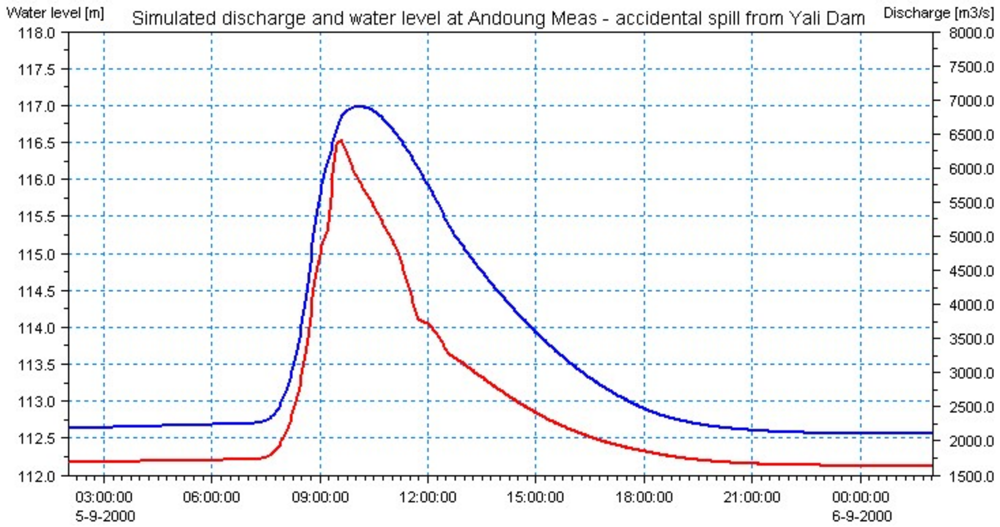


Fig. 3.9 Simulated discharge (red line) and water level (blue line) at Andoung Meas from accidental spill form Ialy Dam

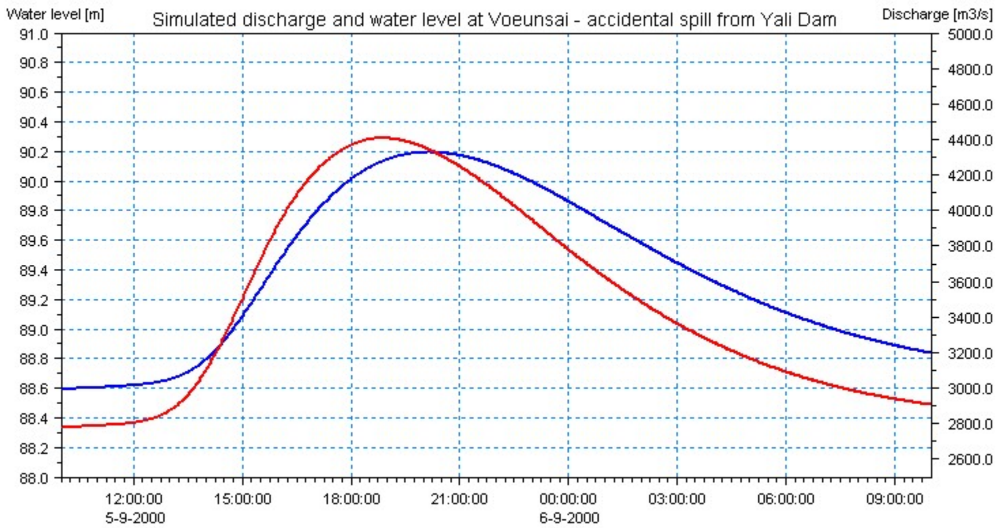


Fig. 3.10 Simulated discharge and water level at Veun Sai resulting from an accidental spill from Ialy Dam. Red line: Discharge, Blue line: Water level.

4. IMPACTS FROM THE THE IALY HYDROPOWER PROJECT REPORTED BY OTHER STUDIES

This chapter presents impacts alleged by other studies to be caused by the Ialy hydropower project. In the current study the available information has been assessed and critically reflected upon, comparing with the information from and discussions with the people met during the field study. It should be emphasized that the field study is a rapid assessment and the purpose of the present study is to assess the impacts and recommend mitigation of the present and expected future impacts from new hydropower plants under construction and planning. In several reports (Fisheries Office 2000, Baird et al. 2002, Mc Kenney 2001) a detailed listing is made of the losses of lives, animals and assets reported to have taken place along the Se San River. In the current study the amount of losses is not considered in such a detail. Due to the limitation of time for the field data collection, the consultant has not been able to follow up all the details and confirm the occurrence of all the reported developments given in previous reports and NGO sources.

4.1 Reports evaluated

Reports of negative impacts first from the construction and then the operation of Ialy Hydropower Plant on the Se San River downstream villages in Cambodia have been released by NGOs[3] and Cambodian officials[4] since late 1990s.[5] The most comprehensive study was made by Ratanakiri Fisheries Office in cooperation with NTFP Project in April-May 2000 with a survey on 59 villages located along the Se San River in Ratanakiri Province (Fisheries Office 2000). Most of the subsequent reports are based on the information in this study. Another village study in 29 villages in Stung Treng Province of the Se San, Srepok and Se Kong rivers was conducted in December 2001 to January 2002 by a group of NGOs in cooperation with the Fisheries Office in Se San District (Baird et al. 2002). A rough estimate of the economic losses caused by impacts from Ialy in the years 1996 to 1999 in the villagers' lives in the Cambodian part of the Se San River has been made in an Oxfam America report (McKenney 2001). The downstream area of Ialy HPP in Vietnam was studied by CRES of Vietnam National University in January 2001, funded by Oxfam America (CRES 2001). The reported negative impacts are mostly the same in the Vietnamese and Cambodian side of the border, and the same in all reports. The Ratanakiri Fisheries Office study (2000) is the most comprehensive study so far, and all the later reports, newsletters and press releases are mainly based on the data found in this report. All the available information from the Ialy HPP effects on the socio-economic and cultural lives of the people living along the Se San River are initiated by NGOs working in the area. No government reports apart from provincial Fisheries Office studies ([Ratanakiri] Fisheries Office 2000, Baird et al. 2002) made in cooperation with NGOs have been available so far.

4.2 Change in Rainy Season Flooding

The natural rainy season flooding is reported to have changed considerably in the Se San River (field data, Fisheries Office 2000, Baird et al. 2002). These changes are assumed to have been caused at least partly by water releases from Ialy Hydropower Plant. The timing of flooding no longer coincides with heavy rains in the upper parts of the river basin. Since the late 1990s the floods have been higher and lasted longer than before. The extended floods have not been beneficial for the rice crops in the way the natural short-time floods are, and have therefore resulted in losses of crops. Floods have moreover occurred in the end of the rainy season, when

[3] like Oxfam America, Se San Protection Network, NTFP Project
[4] Ratanakiri Fisheries Office; Stung Treng Agriculture, Fisheries and Forestry Office
[5] See the List of References

flooding is not taking place naturally, and villagers have experienced very rapid rising water levels. The rainy season flooding has hit the downstream parts of the Se San River in Cambodia much harder and more times a year than the upper parts. Normally the rainy season floods have been occurring every 5-8 years, but since 1996 they are reported to have taken place almost every year (field data, Fisheries Office 2000). On the other hand, the rainy season over-flooding which is decisive for the rice cultivation is reported not to have occurred regularly in the lower parts of the watershed during the late 1990s (Fisheries Office 2000).

The Fisheries Office report (2000) blames the strong rainy season floods occurrence on the large water releases done by the dam operation staff in response to rapid changes in water levels in Ialy reservoir due to heavy rainfall in the Central Highlands of Vietnam.

<u>Consultant's Comments:</u>
Floods in the period before 1999 and the Ialy Reservoir was not filled, likely were not caused by the operation of the Ialy Power Plant, since the reservoir was not in operation at that time. Lack of hydrological data from this period makes it difficult to make further comments for this period.

Simulations presented in the Hydrodynamic Modeling Report for the period 2000 - 2003, concludes that the peak flow in the beginning of the monsoon season is reduced by 1.0 – 1.5 meters, and the reduction of daily peak discharge in the monsoon is in the order of 500 – 1000 m^3/sec. The conclusion is that the reservoir will reduce the flood peak, but the flood period will last longer compared with the period before commissioning of the Ialy Reservoir. The DHI Hydrodynamic Modeling Report deals particularly with rules for spillway operations in order to reduce downstream effects.

4.2.1 Extreme Flood in 1996

In 1996 there was a huge natural flood during the rainy season, probably caused by a tropical storm in the upstream parts of the watershed. However, according to Fisheries Office (2000) a long time after the effects from the storm had settled, there were even more intense floods in the Se San River in the end of the rainy season (in October and November). Especially the villages in the downstream parts were impacted hard with flooding of fields and houses that lasted several days. The water level is said to have risen several meters in just a few hours' time. During the field study people in Andoung Meas, Ta Veaeng, Veun Sai and Se San showed markings of the water level, at that time up to almost 2 meters high at a considerable distance from the river (estimate 150m). The Fisheries Office (2000) report suggests that the huge water release was caused by an accident in the Ialy diversion dam during the construction of the main dam. ,

<u>Consultant's Comments:</u>
No information on such an incident has been available, and it is also not likely, as the coffer dam only diverts the water in the river while the main dam is being built, and is not building up a reservoir. Meteorological and hydrological data from 1996 show that there was high flood this year, and most likely the flood reported in 1996 was an extreme natural flood.

4.3 Rapidly Rising Water Level

People living along the Se San River have experienced several serious incidents of floods and rapidly rising water levels. According to reports (Fisheries Office 2000, Baird et al. 2002, Mc Kenney 2001) both animals and people have drowned during high floods and accidents caused by riverbank erosion. Many people, especially women, are now afraid to go down to the river because they never know when the next flood will take place. Riverside residents in Cambodia have neither received any warnings for coming occurrences of water releases from Ialy, nor any disaster preparedness training. Changes in the river appear irregular and uncontrolled for them. Experienced insecurity among the local people is reported to have increased domestic conflicts and problems in the villages (Fisheries Office 2000).

Consultant's Comments:
Rapidly rising water level in the rainy season has been most likely caused by spillway releases from the Ialy reservoir. Historical records from Ialy (2000 – 2004) show that during rainy season spillway releases have occurred. This might have resulted in more rapidly changes than what is experienced during a natural flood. Spillway releases will from time to time be necessary, however, with an effective early warning system, downstream effects should be able to be considerably reduced. See Chapter 7.1.3. To reduce the insecurity experienced by people it is important to properly inform the local population about the warning system.

4.4 Dry Season Water Level Fluctuations

Exceptional low dry season water levels in the river since 1997 are reported as well. On the other hand, for some years like 2000 and 2001 the dry season water levels are mentioned to have been higher than normal, presumably due to increased water releases from Ialy (Fisheries Office 2000). When the Ialy Reservoir was being filled in 2001 the river was dry in the lowland parts.

People living along the Se San River are moreover experiencing rapid daily changes in water levels caused by the operation regime of Ialy Hydropower Plant. The rapid rising and then declining of water level takes place at different times of the day and night, in different parts along the river. Villagers are unable to provide a precise pattern for the water level changes, but in some parts of the river they report that in general the water level rises every 7 to 10 days, in some parts as often as every 3 days. Most often the water level rising has taken place during the night or just before dawn, when people are asleep. This has very much frightened people living along the river. (Field data, Fisheries Office 2000, Baird et al. 2002).

Consultant's Comments:
These water level changes are most likely caused by the operation of the Ialy reservoir. Hydrodynamic model simulation show that daily water level variations due to intermittent operation may be up to 1.1 meter at Andoung Meas, and correspondingly 0.3 meters at Ta Veaeng.

The daily fluctuations will be mitigated when the Se san 4A Regulating Reservoir will be commissioned in August 2007.

4.5 Water Quality Problems

The water quality in the Se San River is reported to have seriously deteriorated since the construction of the Ialy Power Plant started. The river has become more turbid than before, and the water smells bad.

Local people have reported that serious health problems have resulted from the changes in water quality in the Se San River, in which local people bath and drink. In the Fisheries Office Report (2000) it is reported that people got sick and many died from drinking the water, e.g. that 952 persons have perished during the period 1996 – 2000, and that water quality has been the cause of all or most of the death cases. Added to the deaths, many people have suffered from river associated ailments, which include itchiness, bumps and eye irritation after bathing in the water, as well as stomach problems, respiratory problems, throat and nostril irritation, dizziness and vomiting after ingesting the water. A great number of domestic animals have also died since the water quality problems first appeared, but it is difficult to determine to what extent animal deaths have resulted from deteriorated water quality. However, wild animals have also been found dead near the Se San River, and villagers are convinced that most domestic animal deaths are associated with bad water quality in the river. (Fisheries Office 2000)

Consultant's Comments:
The first years after the construction of the dam breakdown of terrestrial vegetation will take place in the reservoir. This will release nutrient to the deep water of the reservoir. This may produce toxic algae in as well as downstream the reservoir. Toxic algae are the only water quality problem that can have potential of killing large animals and people. Nutrient releases from the workers camp can also produce increase in the algal growth in the river, but it is not likely that this will be enough to produce the necessary amount of algae. Before the filling of the dam, it is not likely that toxic algae have had the necessary concentration to create death of large animals.

It has not been possible to confirm the supposed death cases, as the district and provincial authorities have no data on increasing death rates among the local population during the reported period. There seems to have been many periodic water-related health problems in the area, but the magnitude of these is not possible assess due to lack of proper data. District and provincial health authorities confirm that the problems with itching skin are prevalent in all areas, not only along the Se San River, and related to rainy season water parasites. Respiratory and stomach problems are likewise prevalent in all areas of the province, related to poor living standards connected to poor clean water access and poor hygienic and health standards. Epidemic animal diseases have been occurring throughout the province, not only along the Se San River. However, some sudden animal deaths along the river might have been caused by toxic algae in the water. No proper investigation concerning the reported wild animal deaths has been made so far, and the magnitude and occurrence are therefore not possible to assess.
To conclude: During construction of Ialy Reservoir – not likely algae as a result form the construction work.
After Construction period and when dam is filled – there could have been algae growth in or downstream the reservoir due to nutrients released from the reservoir.
Otherwise data is not available

4.6 Impacts on Riverine vegetation

It is reported that irregular fluctuations in the Se san River have seriously affected riverine vegetation, birds, reptiles and various aquatic life from whose lifecycles are dependent on the natural rhythm of the River. (Fisheries Office 2000)

Consultant's Comments:
These water level changes are most likely caused by the operation of the Ialy reservoir. Hydrodynamic model simulation show that daily water level variations due to intermittent operation may be up to 1.1 meter at Andoung Meas, and correspondingly 0.3 meters at Ta Veaeng.

Vegetation on the river banks and in the water can be easily impacted due to wet and dry events, particularly reeds, algae and leafy aquatic plants. During the field survey of this study it was apparent that many parts of the river banks (approximately 1-2 meters above the water level) were eroded and weakened due to water level changes. These river banks areas were not eroding due to removal of vegetation by local communities. The fact that the lower parts of the river banks become unstable also renders the use of the river bank for agriculture difficult and not possible in many areas (see details in baseline and impact chapters in this report). In the dry season water level fluctuations can have significant impact on aquatic life, like crustaceans which are unable to reach water rapidly thus experiencing desiccation. Animals relying on little change and inhabiting sand banks and river banks are particularly vulnerable. In the case of birds there is good documentation (Claassen 2004) that water fluctuations impacted bird nesting sites and feeding areas by inundation - having also impacts on eggs.

The daily fluctuations will be mitigated when the Se San 4A Regulating Reservoir will be commissioned in August 2007.

4.7 Impacts on Fish, Fish Habitat, and Fisheries

It is reported that native fish, fish habitat and riverine fisheries have been severely impacted by changes in the hydrological regime and water quality. Fish catches have reportedly declined drastically, which has badly affected villagers, who are highly dependent on fishing for food and income. Although all fish species have apparently been impacted, large fish species may have been affected more. Fish diseases have also increased. The rapidly rising waters, which occur without warning, have washed away large numbers of fishing gears and boats. (Fisheries Office 2000)

Consultant's Comments:
The rapid rise of waters can destroy boats and fishing gear. With respect to the reduction of fish stocks, the most critical is if the river has been rendered dry or almost dry in the initial filling of the dam. Deviation of natural flow patterns will in the long run reduce fish stocks due to less spawning success. Increased erosion and diurnal water level fluctuation will reduce the production of fish food items in the river, and thereby reduce the fish productivity.
Based on studies of fish species and historical reports of fish, and interviews it is very likely that fish numbers and species in the Se San River have been reduced. What this reduction is due to is unclear, although the filling of the Ialy dam and erosion related impacts on water quality could certainly have contributed to the reduction. The reduction in fisheries has also adversely impacted the livelihoods of local people who have had fish as the main protein source.

4.8 Impacts on Human Livelihood Systems

According to the Fisheries Office Report (2000), the overall impacts of the Ialy Hydroelectric Power Plant have severely disrupted human livelihoods system along the Se San River. Local people have had to increase wildlife trading, collection of non-timber forest products, and general forest exploitation because of problems with cultivation close to the river due to flooding and rapid water level changes and unreliable over flooding of the river irrigating the fields. The imbalance caused by the power plant impacts have negatively affected terrestrial resources, since local people have few alternatives.

Consultant's Comments:
These water level changes/sudden floods could be caused either by natural floods or by operation of the Ialy Reservoir.

Vegetation on the river banks and the availability of water can be easily impacted due to wet and dry events. During the field survey of this study it was apparent that many parts of the river banks (approximately 1-2 meters above the water level) were eroded and weakened due to water level changes. These river banks areas were not eroding due to removal of vegetation by local communities. The fact that the lower parts of the river banks become unstable also rendered the use of many river banks for agriculture difficult and not possible in many areas (see details in baseline and impact chapters in this report). The decline in use of the rivers for agriculture was apparent during our field survey. The increase in wildlife hunting, use of forest products, and encroachment had also increased and was attributed to the lack of river bank use and reduction in river fish. For the poorest families and those with small pieces of land the impact on their lives is regarded to be significant.

Local people also depend on the river water levels reaching a certain level to allow for flooding of paddy fields. This was hindered or exceeded levels necessary for flooding as mentioned by villagers interviewed.

5. DESCRIPTION OF THE PRESENT SITUATION

The environmental evaluation along Se San 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 research literature and reports, new field studies, public consultation and the project outlines and operation.

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

5.1 Water Quality

5.1.1 Sampling sites and parameters

It has been anticipated in several NGO reports that water of poor quality is coming from the Ialy Reservoir (Fisheries Office 2000, IRN 2002). On some occasions the first years after the dam was built, people and animals along the Se San River got sick from drinking water from the river. It was suspected that the water could contain toxic blue-green algae, pesticides, arsenic and heavy metals which aroused in the Ialy Reservoir.

To check the water quality of the water coming from the Ialy Reservoir today, a sampling program was included in the field survey of November/December 2005. The water samples were analyzed for relevant water quality parameters. These included:

- Standard water quality parameters
- Nutrients (N and P fractions)
- Heavy metals including arsenic
- Pesticides (55 compounds)
- Algal species composition (looking for toxin producing species)
- Algal toxins

The testing included surface water (0-10 m) and deep water (50 m) in the Ialy Reservoir, the water coming out of Ialy Reservoir (tailrace water), and samples taken in the Se San River at Phum Pir Village (Near the Vietnamese Border) and from the ferry crossing at Veun Sai District.

In addition the following data are compiled and analyzed

- Water quality data from the Cambodian part of the river in 2001 (the year after the impacts were identified).
- Water quality data (Cambodian part) from one year of monitoring (May 2004-April 2005).
- Vietnamese monitoring data from Ialy Reservoir from 2004 and 2006 (received at the review meeting in Hanoi May 2006).

The Ialy Reservoir is located on the top of the Ialy Falls. To day the reservoir forms a lake of 64.5 km^2, see Figure 5.1. For more information about the hydrological and morphometrical features of the dam, see Chapter 3. Figure 5.1 shows the areas of the watercourse where the water quality was studied.

Fig 5.1.a Location of Ialy Reservoir and the other water sampling stations in the Se San River

Fig. 5.1.b Satellite image of the reservoir

Fig. 5.1.c Photo from the road entrance to the Ialy Dam Site (photo EVN)

Fig. 5.1.d Water sampling in the Ialy Reservoir

Fig. 5.1.e On top of the Ialy Dam

Fig. 5.1.f The former mighty Ialy Falls

Fig. 5.1.a - 5.1.f show photos from the water quality study sites. Reservoir at full supply level 515 m.a.s.l.

Fig. 5.1.g The Ialy spillway

Fig. 5.1.h The Ialy spillway during water release (photo EVN)

Fig. 5.1.i 1 km downstream after the entrance of a small tributary

Fig. 5.1.j The tailrace outlet from the Ialy Power Station, where the downstream water samples were taken

Fig. 5.1.k Water sampling site at Phum Phi

5.1.l Water sampling site at Veun Sai

Fig. 5.1.g – 5.1.l Water quality study sites - continued

5.1.2 Temperature and oxygen stratification in the Ialy Reservoir

The Ialy Reservoir is approximately 60 m deep at full supply level 515 m.a.s.l. The reservoir was at FSL at the time of observation. The results are given in Figure 5.2.

From the temperature curve it is seen that the lake has already stratified, despite it was just after the rainy season when the reservoir fills and the water normally circulates. The thermocline is as deep as 30 m. The reason for this deep thermocline is because of strong northern wind on the day of observation, and the samples were taken only some 500m – 1 km upstream the dam. The warm surface water will then be stowed up in the southern end of the lake, while the cold bottom water will be closer to the surface in the northern end. Most likely, in average, the thermocline in Ialy Reservoir lies at a depth between 10 and 15 m. When a lake stratifies warm (and light) surface water will be lying on top of cold (and heavy) bottom water, and preventing the bottom water from getting supply of the life-important oxygen until the next circulation period. When oxygen is consumed in the deep water due to decomposition of organic matter, different chemicals tends to accumulate in the deep water, some from leaking out of the sediments, others from anaerobic decomposition of organic material sinking from above (dead algae, terrestrial detritus, etc). The outlet from the reservoir to the power plant (below 490 m.a.s.l.) will in Ialy more or less always withdraw water from the hypolimnion (deep water). In the first years after an inundation the water in the hypolimnion of reservoirs can therefore contain nutrient rich water. This can create algal growth problems both in the reservoir (after partial circulations) and in the downstream river (particularly towards the end of the dry season, April, May, June).

The oxygen content (Figure 5.2) was approximately 95 % saturation throughout the epilimnion (surface waters), whereas it declined to approximately 50 % at 50 m depth. As this was at the start of the dry season it is likely that the oxygen content will be much lower at the end of the stagnation period, e.g. in May – June.

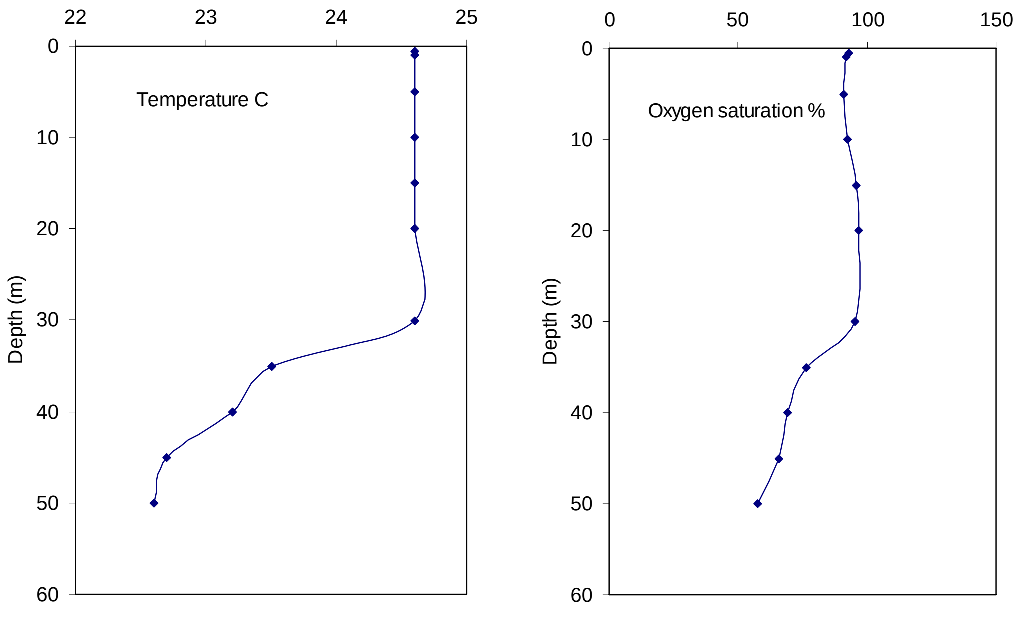


Fig. 5.2 Temperature and oxygen in Ialy Reservoir 06.12.2005

5.1.3 General water quality and nutrients

The results of the water analyses with respect to general water quality and nutrients are given in Table 5.1. The conductivity is low showing that the water has low content of dissolved ions. The turbidity is low to moderate, showing that the content of erosion material is relatively low, which means that the erosion activity in the catchment has been low the days before the sampling. The content of erosion material can be much higher during the rainy season, and after sudden hard rainfalls. It was dry weather during the sampling days and the days before. The content of nutrient and organic material is also low. This indicates that the river is little impacted by human discharges like sewage and from agricultural areas runoff.

Table 5.1 General water quality parameters and nutrients at locations from Ialy in Vietnam to Vuon Say in Cambodia (Nov/Dec 2005)

	pH	Conductivity mS/cm	Turbidity FNU	Tot-P µg P/l	PO4-P µgP/l	Tot-N µg N/l	NH4-N µg N/l	TOC mg C/l
Yali 0-10m	7.31	4.82	6.6	8	2	205	6	1.1
Yali 50 m	7.3	3.67	7.24	10	2	190	7	1.2
Outlet Yali	7.33	3.66	12	11	2	210	5	1.1
Phum Phi	7.26	3.18	20.7	15	4	170	4	1.2
Vuon Say	7.24	3.21	27.6	18	5	185	4	1.1

Phosphorus (P) is the nutrient that almost always determines how much algae there is in freshwaters, and when a water body receives too much of P, it will become eutrophic. This is a situation that is characterized by too much algae, too little oxygen in the deepwater, etc. It can frequently occur algal blooms with toxic strains of blue green algae in eutrophic reservoirs. In such periods the water can be dangerous to drink and it can give skin irritations like itchiness, with symptoms very similar to those described in the NGO reports (e.g. Fishery Office 2000).

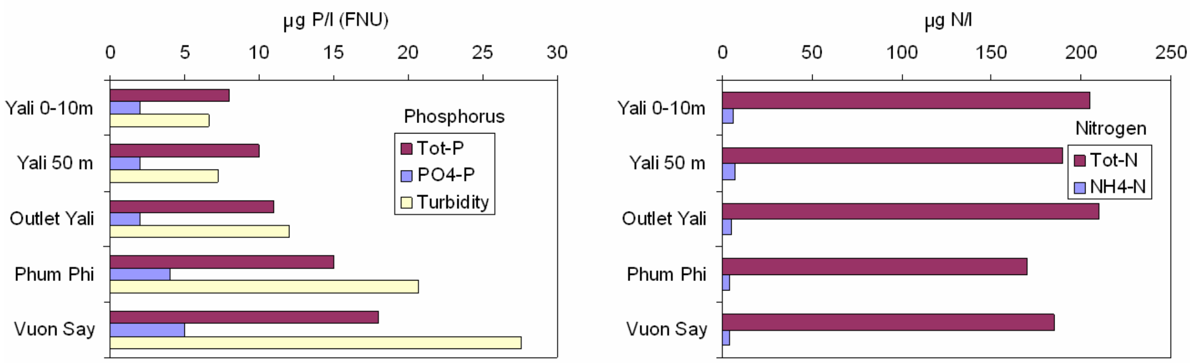


Fig. 5.3 Concentrations of phosphorus fractions and turbidity (left panel) and nitrogen fractions (right panel) at different locations in the Se San River, December 2005

Figure 5.3 shows an increase in the concentration of phosphorus down the river. This can be due to either P in discharges from human activity, or particulate P bound to erosion material. The latter is little bioavailable and not dangerous with respect to eutrophication. If it had been the result of human discharges, one should also expect the similar increase in the concentration of nitrogen (N), as both sewage and agricultural runoff contain both N and P. There is however no increase in the N concentration downstream (Figure 5.3 right panel), rather the opposite. There is however a downstream increase in the turbidity which corresponds very well with the increase in P. A statistical regression analysis showed that this correlation was highly significant ($r^2 = 0.98$, $p = 0.0015$) while there was no statistical correlation between N and P concentrations ($p = 0.21$). This shows that the downstream increase in P concentration is due to P bound to particulate erosion matter and not due to discharges or run off from human activity.

The concentrations of P and N in both Ialy and the downstream river were low during the field work in Nov/Dec 2005, and too low to sustain blooms of toxic algae of any concern.

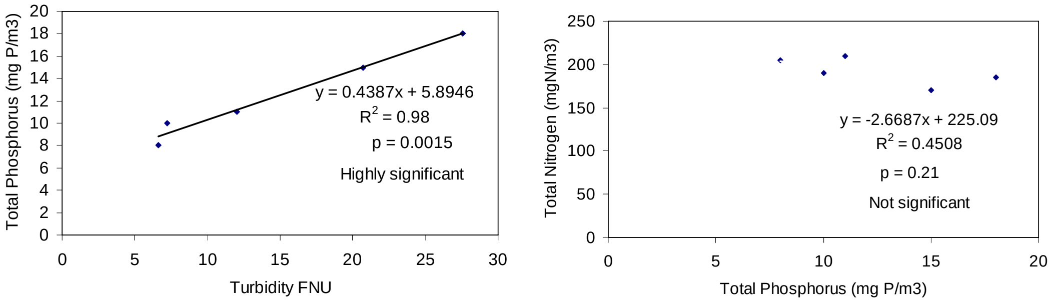


Fig. 5.4 Regression analyses. Highly significant correlation between turbidity and P concentration, but no inter-correlation between N and P concentrations

5.1.4 Water quality data from 2001 provided by MOWRAM

After the water quality problems had occurred in the dry season 2000, MOWRAM took a set with water samples in May 2001 to see if some of the same problems were occurring this year. The results are given in Table 5.2, 5.3, and 5.4.

Table 5.2 Water quality data from the Se San River in May 2001 at Phum Phi close to the Vietnamese border

Nº	Item	Unit	Phum Pi Village, Oyada District			
			Right site	Left site	Middle	Mix together
1	Sampling date		22.05.2001	22.05.2002	22.05.2003	22.05.2004
2	Temperature	ºC	28.7	28.7	28.7	28.7
3	pH		7.39	7.34	7.39	7.44
4	Conductivity	ms/m	3.90	3.80	3.90	3.90
5	TSS	mg/l	35.00	35.00	33.50	32.50
6	Alk.	mg/l as CaCO3	16.85	16.05	17.05	16.65
7	NO3+N	mg/l	0.170	0.160	0.170	0.170
8	NO2+N	mg/l	0.005	0.004	0.004	0.004
9	Tot.N	mg/l	0.240	0.190	0.240	0.240
10	NH4-N	mg/l	0.070	0.050	0.060	0.060
11	PO4-P	mg/l	0.002	0.002	0.002	0.008
12	Tot.P	mg/l	0.010	0.006	0.007	0.010
13	DO	mg/l	7.569	7.722	6.670	X

Table 5.3 Water quality data from the Se San River in May 2001 at Andoung Meas (MOWRAM)

Nº	Item	Unit	Angdong Meas District Center			
			Right site	Left site	Middle	Mix together
1	Sampling date		22.05.2001	22.05.2002	22.05.2003	22.05.2004
2	Temperature	ºC	28.6	28.6	28.6	28.6
3	pH		7.30	7.31	7.26	7.34
4	Conductivity	ms/m	3.90	3.90	3.90	3.90
5	TSS	mg/l	30.50	34.50	29.50	32.00
6	Alk.	mg/l as CaCO3	17.20	16.85	16.25	17.80
7	NO3+N	mg/l	0.150	0.150	0.150	0.160
8	NO2+N	mg/l	0.003	0.003	0.003	0.004
9	Tot.N	mg/l	0.220	0.190	0.220	0.240
10	NH4-N	mg/l	0.050	0.050	0.050	0.050
11	PO4-P	mg/l	0.001	0.001	0.002	0.002
12	Tot.P	mg/l	0.005	0.006	0.007	0.005
13	DO	mg/l	7.722	7.342	7.366	X

Table 5.4 Water quality data from the Se San River in May 2001 at Veun Sai(MOWRAM)

Nº	Item	Unit	Veun Sai District center			
			Right site	Left site	Middle	Mix together
1	Sampling date		22.05.2001	22.05.2002	22.05.2003	22.05.2004
2	Temperature	ºC	30.6	30.6	30.6	30.6
3	pH		7.14	7.06	7.20	7.15
4	Conductivity	ms/m	3.30	3.70	3.60	3.40
5	TSS	mg/l	26.50	25.00	33.50	31.00
6	Alk.	mg/l as CaCO3	13.10	15.25	14.85	14.70
7	NO3+N	mg/l	0.160	0.170	0.180	0.160
8	NO2+N	mg/l	0.000	0.000	0.000	0.000
9	Tot.N	mg/l	0.210	0.230	0.220	0.200
10	NH4-N	mg/l	0.040	0.050	0.050	0.050
11	PO4-P	mg/l	0.004	0.007	0.002	0.001
12	Tot.P	mg/l	0.005	0.009	0.005	0.005
13	DO	mg/l	7.560	7.228	7.326	X

The data reflect a rather oligotrophic water quality with low concentrations of the plant nutrients phosphorus and nitrogen. The levels are so low that they cannot sustain such a high algal biomass that it is likely to produce toxic blue green algae. The content of suspended solids is moderate, and not so high that they are supposed to create problems for fish or other aquatic organisms. It should be noted, however, that this only represent one single day in the dry season, and as a river is a dynamic system, the water quality values can shift rapidly. However, if the water coming out of the Ialy Reservoir had been eutrophic, the concentrations of nutrient should have been higher in the collected samples.

5.1.5 Water Quality Results from Monitoring in 2004/2005 provided by MOWRAM

MOWRAM has monitored the water quality from May 2004 to April 2005 at four stations; Pleiku in Vietnam (downstream Ialy), Phum Pi at the border, Andoung Meas and at Vuon Sai. There have been relatively few parameters included in this monitoring, pH, Dissolved oxygen, Turbidity, Temperature, Conductivity and Total Coliform bacteria (37 ^{o}C). The results are given in Table 5.5.

The pH are slightly above neutrality, and the water is well oxygenized. The oxygen does not show super saturation, nor is there any observation of high pH values, which was shown in Srepok at Lumphat (Srepok EIA, SWECO-Grøner 2006). This indicates lower algal biomass than in Srepok. The chlorophyll analyses (see chapter 5.1.6) confirmed this. There was only low algal activity in the Se San River during the monitoring, and no signs of algal bloom are observed.

With respect to bacteriological contamination the two stations in Cambodia show the highest content of Coliform bacteria. It is particularly in the rainy season that the values are high. As it is total coliform bacteria (37 ^{o}C) that is analyzed, it also comprise the so-called “soil coliform bacteria”. This means that the high values in the beginning of the flooding season is likely a result of old animal wastes from the top-soil litter along the river. This has been washed into the river during high water level.

Table 5.5 Water quality results from the monitoring performed by MOWRAM in 2004/2005

Pleiku

Date	T^{o}C	pH	Cond mS/m	Turbidity NTU	DO mg/L	Coliform bact(37^{o})
22.05.2004	27.8	7.4	4.0		6.9	9073
20.07.2004	27.8	6.9	3.5	195.0	7.7	2633
20.09.2004	25.6	6.6	2.9	165.0	8.5	703
27.11.2004	24.8	7.1	4.1	26.3	8.7	2840
05.01.2005	22.4	7.2	4.1	15.3	8.7	770
31.01.2005	24.2	7.5	4.3	12.0	8.3	340
26.02.2005	24.7	7.4	4.4	10.0	8.5	1050
01.04.2005	27.1	7.3	4.9	16.0	8.0	753
27.04.2005	27.3	7.3	5.0	24.0	7.6	690
18.05.2005	28.6	7.8	5.0	64.0	7.4	433
Average	26.0	7.2	4.2	58.6	8.0	1929

Phum Pi

Date	T^{o}C	pH	Cond mS/m	Turbidity NTU	DO mg/L	Coliform bact(37^{o})
25.05.2004	28.3	7.5	4.5		6.6	11147
23.07.2004	26.3	2.4		8.0		
24.09.2004	26.0	6.8	2.9		8.6	2073
23.11.2004	24.4	6.8	3.7		8.2	80
27.12.2005	21.8	7.6	3.5	10.9	7.5	33
29.01.2005	26.0	7.5	4.0	24.3	8.4	567
24.02.2005	25.3	7.5	5.3	3.4	9.4	2650
31.03.2005	27.9	7.6	4.3	5.1		467
26.04.2005	28.5	7.5	5.1	17.8	7.4	1917
17.05.2005	29.6	7.6	5.0	12.3	8.1	900
Average	26.4	6.9	4.2	11.7	8.0	2204

Adong Meas

Date	T^{o}C	pH	Cond mS/m	Turbidity NTU	DO mg/L	Coliform bact(37^{o})
25.05.2004	28.7	7.4	4.0		6.5	683
23.07.2004	27.0	6.5	2.6		7.4	243333
24.09.2004	27.4	6.3	2.9		8.3	1047
23.11.2004	25.4	7.1	3.7		8.1	133
27.12.2004	23.6	6.7	3.5	5.6		52
29.01.2005	24.5	7.4	4.2	13.2	7.4	907
24.02.2005	27.9	7.6	5.2	3.2	9.4	2650
31.03.2005	30.9	7.8	4.2	3.4	7.0	620
28.04.2005	28.9	7.6	5.1	5.4	6.8	860
17.05.2005	30.1	7.5	5.0	4.2	6.9	403
Average	27.4	7.2	4.0	5.8	7.5	25069

Table 5.5 continue

Vuon Sai

Date	T°C	pH	Cond mS/m	Turbidity NTU	DO mg/L	Coliform bact(37°)
26.05.2004	29.4	7.3	3.7		6.2	377
24.07.2004	26.5	6.6	2.6		7.3	226667
25.09.2004	26.5	7.0	2.7		7.8	2983
22.11.2004	26.2	7.3	3.5		7.3	120
26.12.2005	24.4	7.0	3.4	6.3	7.6	25
29.01.2005	26.7	7.7	3.9	13.7	7.7	3060
23.02.2005	29.6	7.9	4.4	3.0	9.3	1525
30.03.2005	31.4	7.8	4.5	3.7	6.4	2433
25.04.2005	31.8	7.8	5.1	4.4	7.6	2033
16.05.2005	32.9	7.9	5.4	3.6	7.9	117
Average	28.5	7.4	3.9	5.8	7.5	23934

Figure 5.6 shows the turbidity results from the four stations. One can get the impression that there is much more erosion material in the river close to the dam, and that it settles out further down in the river. However, it is only Pleiku station that has data from the rainy season. The results from July and September 2004 from Pleiku show, however, very high erosion activity with turbidity values close to 200 FNU. Converted into suspended solids via regression found by Berge et al (1995) from Theun Hinboun in Laos, Figure 5.5, it gives a concentration of suspended sediments of 270 mg/l. This is very high values which will give considerably stress to all aquatic life, and give reduced productivity on all ecological levels including fish. According to EIFAC (European Commission for Inland Fisheries, see Alabaster & Lloyd 1980) it is impossible to keep up high fish productivity in water with suspended sediment above 100 mg/l.

Most of the year, the turbidity of Se San River is not high enough to be a constraint to in-river primary productivity. But incidents of that high turbidity as observed here in the rainy season, result in sedimentation and siltation problems which effects persist throughout the year. The sediments in slow flowing reaches become inorganic and have reduced nutritional value for the digging bottom animals, periphyton may be intermingled by sediments and receives less light for efficient photosynthesis, and cannot be as easily digested by periphyton grazers as before. In chapter 6 on the impact descriptions, more details are given on how erosion material impacts the river ecology and productivity.

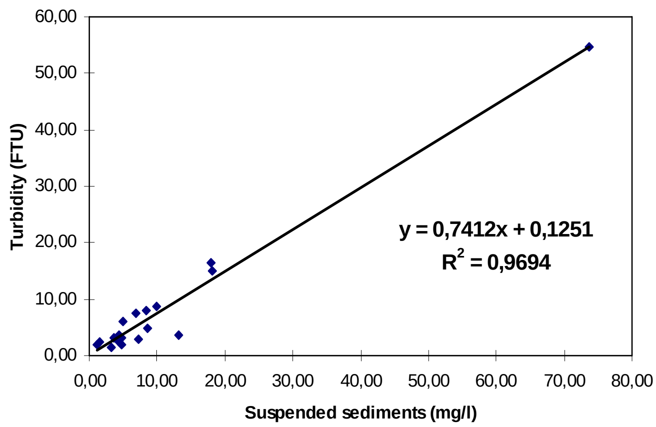


Fig. 5.5 Relationship between turbidity measurements and the concentration of suspended sediments. (from Nam Theun River in Laos, Berge et al 1995)

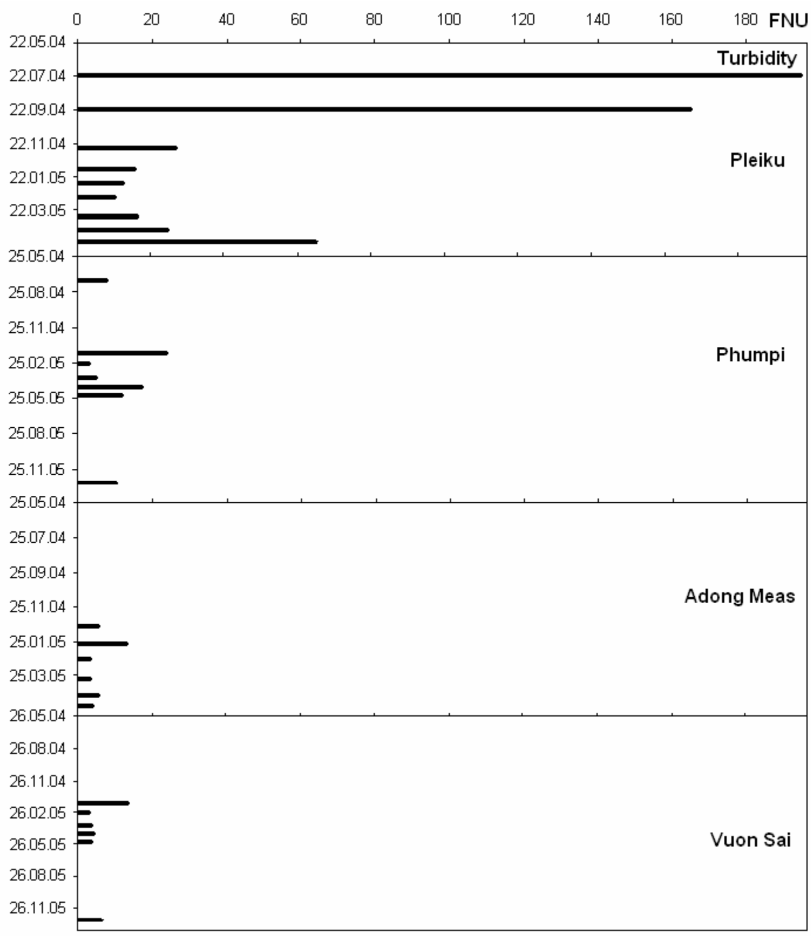


Fig. 5.6 Turbidity measurements in Se San River 2005/2005

5.1.6 Water quality analyses from 2004 and 2006 provided by PECC1

In table 5.6 and 5.7 are listed water quality data from Vietnamese monitoring of the Ialy Reservoir and the Tailwater from the Ialy Power Plant. The data was provided by PECC1 in May 2006. Data was also given from several tributaries to the Ialy Reservoir and Se San River, but presented here is only the data from Ialy Reservoir and from the tailwater of the power plant.

The data is limited:

1) They are only from 2 dates 15.11.2004 (at the end of the rainy season) and 20.02.2006, (the beginning of the dry season).
2) From Ialy there is no data from the deep water. In the dry season the deepest samples was take from 10 m depth.
3) Phosphorus is not analysed on samples taken inside the reservoir. This means that the samples do not give any information of the possibilities for phosphor accumulation in the deep water at the end of the dry season.

In the samples from downstream the tailrace outlet (See Table 5.7) there are 2 analysis of total phosphorus with the very high values of 2.38 and 2.8 mg P/l respectively. Such high concentration of phosphorus, combined with low content of particulate matter of 13 and 7 mg/l respectively (see Table 5.7), will clearly create algal growth problems downstream. As the tailwater from the power station is taken from the deep water of the reservoir, this may indicate that there takes place up-concentration of P in the hypolimnion of the reservoir.

However, there are only 2 analyses of total P from the Vietnamese downstream data, and as they are much higher than what was measured by NIVA in Dec 2005, as well as what MOWRAM has found in 2001 and 2005, the Vietnamese data from 2004 may be of questionable value. They can not be used to “prove” that it happens P-enrichment in the deep water of the reservoir (which is claimed in several NGO reports), only some indicative value. The question of P-enrichment in the deep water of the reservoir should be clarified by future monitoring.

Most other data from the Vietnamese monitoring is in good correspondence with the data found during the field survey in November/December 2005. The values are low and for most parameters inside the best water quality category of the Vietnamese water quality criteria (Class A – Water for life).

It is noted that bacterial contamination in Ialy is much higher in November than in February. This idicates that washout of animal and human wastes during high water levels and swelled tributaries in the rainy season are the sources, and not piped effluents from human activites. (See discussion of the MOWRAM data).

Tabl 5.6 Water quality analysis from Ialy Reservoir provided by PECC1 May 2006

	Date	15.11.2004								20.02.2006			
	Location	100 m from the intake		Middle of the reservoir			Right bank of reservoir			Middle of the reservoir		Close to intake	
Parameter	Unit/Depth	0.5m	10m?	0.5m	10m	20m	0.5m	10m	20m	0.5m	10m	0.5m	10 m
pH		7.5	6.9	7.2	7.1	6.9	7.2	7.2	6.9	7.2	7.3	7.3	6.4
BOD_5	mg/l	3	4	1	1	2	1	1	2	3	4	2	4
COD	mg/l	4	5	2	2	3	2	2	3	6	8	3	6
DO	mg/l	6.1	4.3	6	5.4	3.1	6	4.5	3.1	6.4	5.3	4	4.4
TSS	mg/l	3	3	4	5	4	5	5	6	8	11	8	8
PCR	mg/l	0.015	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.				
As	mg/l	0.02	0.03	0.002	0.004	0.004	0.002	0.003	0.003	0.003	0.002	0.002	0.002
Cd	mg/l	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.
Pb	mg/l	0.004	0.003	0.003	0.005	0.006	0.002	0.004	0.005	0.0007	<det. lim.	<det. lim.	0.0013
Cr^3	mg/l	<det. lim.	0.008	0.007	0.005	0.001	0.005	0.006	0.006	0.005	0.003	<det. lim.	<det. lim.
Cr^6	mg/l	0.01	0.016	0.014	0.013	0.01	0.016	0.013	0.011	0.013	0.012	<det. lim.	0.011
Hg	µg/l	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.001	<det. lim.
Cu	mg/l	0.006	0.004	0.004	0.003	0.005	0.004	0.003	0.004	0.002	0.0017	0.0038	0.0054
Zn	mg/l	0.014	0.016	0.01	0.016	0.02	0.01	0.015	0.02	0.0084	0.0063	0.0078	0.012
Mn	mg/l	0.011	0.015	<det. lim.	<det. lim.	0.001	<det. lim.	<det. lim.	0.001	0.017	0.022	0.033	0.013
Fe	mg/l	0.11	0.13	0.21	0.22	0.26	0.02	0.022	0.021	0.44	0.26	0.19	0.13
Sn	mg/l	0.002	0.001	<det. lim.	0.001	0.001	<det. lim.	0.001	0.001			0.005	0.003
NH_4	mg/l	0.02	0.04	0.03	0.05	0.05	0.05	0.06	0.05	0.23	0.27	0.06	0.12
NO_2	mg/l	<det. lim.	0.003	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	0.012	0.015	0.017	0.019
NO_3	mg/l	1.5	1.8	1.4	1.3	1	1.5	1.4	1.4	20.9	23	19.2	20.1
Oil	mg/l	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.	<det. lim.
CN	mg/l	0.002	0.002	0.002	0.002	0.003	0.001	0.002	0.002	<det. lim.	<det. lim.	<det. lim.	<det. lim.
Coliform	CFU/100m	30000	31000	14000	13000	10000	15000	14000	12000	900	310	95	13

Table 5.7 Water quality analysis from Se San River just downstream Ialy Power Plant provided by PECC1 May 2006

	Date	15.11.2004		20.02.2006	
	Location	40 m downstream tailrace		Outlet tailrace	500m downstr tailrace
Parameter	Unit/Depth	Right bank	Left bank		
Temp	degr. C	24.8	24.3	7.2	7.2
pH		7.2	6.9		
BOD_5	mg/l	2	2	<det. lim.	<det. lim.
COD	mg/l	3	3	2	3
DO	mg/l			4.9	4.7
TSS	mg/l	13	7	11	13
PCR	mg/l		<det. lim.		
As	mg/l	0.002	0.003	0.003	0.001
Cd	mg/l	<det. lim.	<det. lim.	0.002	0.0008
Pb	mg/l			0.0025	0.0017
Cr^3	mg/l	0.004	0.002	0.005	0.003
Cr^6	mg/l	0.028	0.019	0.012	0.011
Hg	µg/l	0.002	0.004	0.002	0.001
Cu	mg/l	0.004	0.006	0.0068	0.0053
Zn	mg/l	0.017	0.022	0.017	0.0093
Mn	mg/l	0.016	0.012	0.012	0.052
Fe	mg/l	0.23	0.3	0.19	0.46
Sn	mg/l	0.002	0.004	0.007	0.004
NH4	mg/l	0.008	0.005	0.25	0.25
P organic	mg/l	0.06	0.07		
P total	mg/l	2.38	2.8		
N total	mg/l				
NO_2	mg/l			0.025	0.063
NO_3	mg/l			20.6	5.8
Oil	mg/l	0.1	<det. lim.	0.2	0.15
CN	mg/l	0.002	0.001	<det. lim.	<det. lim.
Coliform	CFU/100m	11000	16000	153	150

5.1.7 Algal analysis

Samples for Chlorophyll-a analysis, for analysis of algal species composition as well as samples for analysis of algal toxins were taken from Ialy Reservoir, just downstream the border to Vietnam, at Phum Phi, and at Vuon Say, midway down to Stung Treng. See Figure 5.1 for location of the sampling stations

The results from the chlorophyll measurements, which is a relative measure of algal biomass, are given in Figure 5.7, whereas the biomass of the different species is given in Table 5.8.

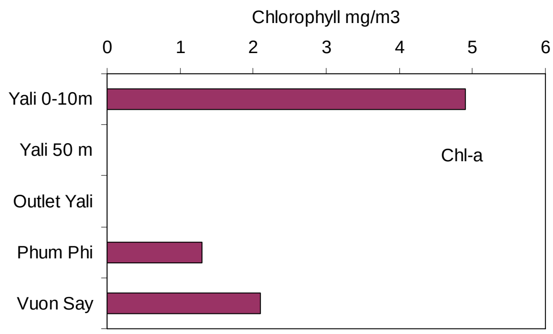


Fig. 5.7 Chlorophyll a concentrations in Ialy Reser-voir and downstream in Se San River in Dec 2005

The concentrations of algae is low and in the range of oligotrophic (nutrient poor) lakes. At Phum Phi there were too little algae in the sample for microscopic analysis. The content of blue green algae was very low, almost not existing. The genus observed, the *Microcystis spp* can under certain conditions occur with toxic strains. However, it is not normal to observe problems with blue green algae in lakes before the algal biomass exceeds 15-20 mg Chl-a/m^3. The low algal content is in good correspondence to the low content of the plant nutrient phosphorus and nitrogen that was observed. It should be noted that most likely the algal amount will increase towards the spring and reach its maximum in May/June.

Figure 5.8 shows the values from the monitoring of chlorophyll in Se San River by MOWRAM in 2004. The total chlorophyll values (algal biomass) are between 1 and 2.5 mg/m^3, which are very similar to what was found in 2005. The measurements are made by a flouroprobe which allow for separation of algal groups based on the differences in pigmentation of the different groups. The differentiation between algal groups is, however, easily determined in-accurate with such an instrument. Compared to the microscope analyses, the instrument gave too high values of bluegreen- and green algae. These algal groups play normally a minor role at the oligotrophic level of biomass which is observed in Se San River and Ialy Reservoir.

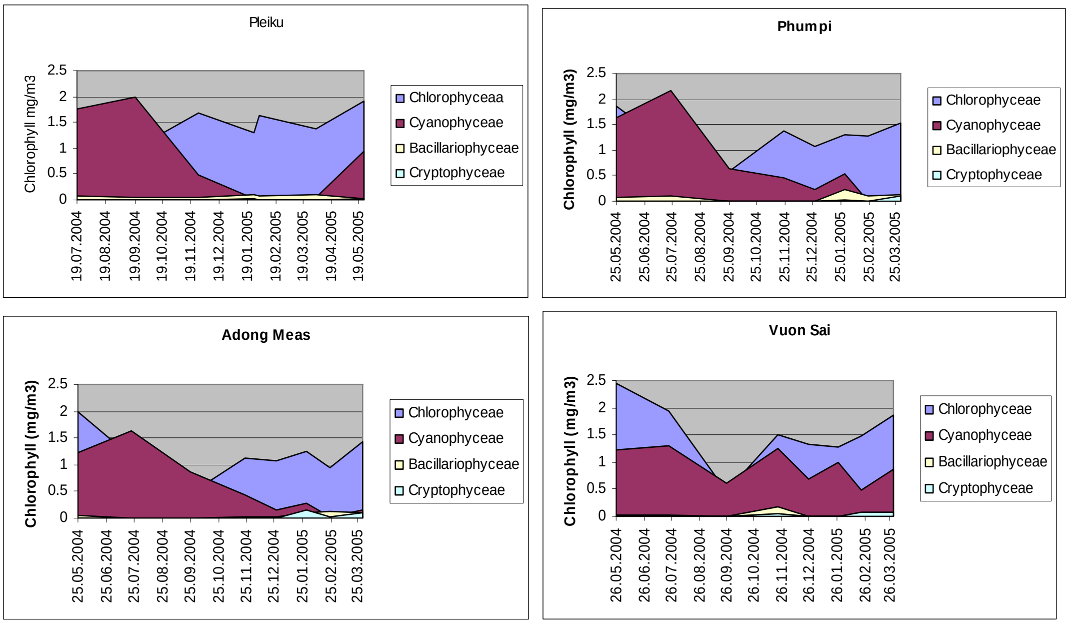


Fig. 5.8 Algal biomass monitored by MOWRAM with flouroprobe technique in 2004/2005 in 4 sites in Se San River

Table 5.8 Algae species composition from Ialy Reservoir 0-10 m depth mixed sample, and from Veun Sai (0.5 m depth). From Phum Phi the water did not contain any algae

Values given as mm³/m³ (=mg/m³ wet weight)

Yali Reservoir	
Year	2005
Month	12
Day	6
Depth	0-10m
	mm3/m3
Cyanophyceae (blue-green algae, cyanobacteria)	
Microcystis sp.	1.5
Planktolyngbya subtilis	0.7
Sum - Blue-green algae, cyanobacteria	2.2
Chlorophyceae (green algae)	
Ankistrodesmus falcatus	0.2
Closterium acutum v.variabile	2.9
Dictyosphaerium subsolitarium	1.0
Koliella sp.	0.4
Monoraphidium contortum	0.3
Monoraphidium minutum	1.1
Nephrocytium lunatum	0.2
Pediastrum duplex	1.0
Ubest. kuleformet gr.alge (d=5)	1.6
Sum - Green algae	8.6
Chrysophyceae (Golden algae)	
Chrysococcus cordiformis	0.3
Cyster av Dinobryon spp.	1.3
Dinobryon bavaricum	3.4
Mallomonas akrokomos (v.parvula)	0.5
Mallomonas elongata	1.5
Mallomonas spp.	10.6
Ochromonas sp. (d=3.5-4)	1.6
Små chrysomonader (<7)	11.4
Store chrysomonader (>7)	15.5
Sum - Golden algae	46.1
Bacillariophyceae (diatoms)	
Fragilaria sp. (l=40-70)	0.1
Rhizosolenia longiseta	30.2
Stephanodiscus hantzschii	2.1
Sum - Diatoms	32.4
Cryptophyceae (cryptomonads)	
Cryptomonas cf.erosa	19.7
Cryptomonas erosa v.reflexa (Cr.refl.?)	4.4
Cryptomonas pyrenoidifera	4.5
Cryptomonas sp. (l=15-18)	27.4
Cryptomonas spp. (l=24-30)	3.2
Ubest.cryptomonade (Chroomonas sp.?)	23.2
Sum - Cryptomonads	82.4
Dinophyceae (dinoflagellates)	
Ceratium brachyceros	58.5
Ceratium hirundinella	52.0
Peridinium pusillum	1.1
Sum - Dinoflagellates	111.6
Euglenophyceae (euglenoids)	
Euglena sp. (l=40)	0.6
Sum - Euglenoids	0.6
µ-algae	
My-alger	15.1
Sum - µ-algae	15.1
Total biomass of phytoplankton	298.9

Values given as mm³/m³ (=mg/m³ wet weight)

Vuon Say	
Year	2005
Month	11
Day	27
Depth	1
Chlorophyceae (green algae)	
Ankistrodesmus falcatus	3.2
Gloeotila sp.	0.4
Monoraphidium contortum	1.8
Scenedesmus acuminatus	0.3
Sum - Green algae	5.7
Chrysophyceae (golden algae)	
Mallomonas spp.	0.7
Ochromonas sp. (d=3.5-4)	1.1
Små chrysomonader (<7)	9.1
Store chrysomonader (>7)	14.2
Sum - Golden algae	25.2
Bacillariophyceae (diatoms)	
Fragilaria sp. (l=40-70)	1.0
Fragilaria ulna (morfotyp"ulna")	3.2
Navicula spp.	4.5
Rhizosolenia longiseta	0.2
Stephanodiscus hantzschii	0.5
Sum - Diatoms	9.4
Cryptophyceae (cryptomonads)	
Cryptomonas sp. (l=15-18)	11.9
Cryptomonas sp. (l=20-22)	4.8
Indet.cryptomonad	2.3
Ubest.cryptomonade (Chroomonas sp.?)	7.8
Sum - Cryptomonads	26.7
Dinophyceae (dinoflagellates)	
Gymnodinium cf.lacustre	1.8
Peridinium pusillum	1.8
Sum - Dinoflagellates	3.5
µ-algae	
µ-algae	27.7
Sum - µ-algae	27.7
Total biomass of phytoplankton	98.1

5.1.8 Analysis of algal toxins

The most frequently occurring algal toxin is a compound called microcystin (hepatotoxin), named after the organism it was originally detected from, the blue-green algae *Microcystis aeruginosa*. Some times one or more neurotoxins occur together with the microcystins. The symptoms described in the report from the Fisheries Office and NTFP (2000) is most likely a neurotoxin.

Two parallel samples were taken from the surface water of Ialy Reservoir, from the outlet of Ialy Reservoir, from Se San River at Phum Pi and at Vuon Sai. Samples were collected on 48 mm GF/C filters that were air dried in darkness. The samples were extracted three times with water with a freezing/melting technique. The microcystin concentration in the extracts was determined using an anti-adda ELISA kit distributed by Biosense (Bergen, Norway). The detection limit is in the range of 0.003 µg/l. The results are given in Table 5.9.

Table 5.9 Content of the algal toxin "microcystin" in the water of Ialy Reservoir and Se San River in Nov/Dec 2005

Location	Microcystin µg/l
Yali Reservoir 1	0.073
Yali Reservoir 2	0.067
Outlet Yali Resererservoir 1	0.044
Outlet Yali Resererservoir 2	0.044
Phum Pi 1	0.001
Phum Pi 2	0.001
Vuon Sai 1	0.003
Vuon Sai 2	0.002

The samples from both the Ialy Reservoir and the outlet of the reservoir gave positive significant detection of microcystin, whereas the values at Phum Pi and Vuon Sai were at the detection limit and thus are regarded as negative detections. The concentrations are, however, low. WHO sets a guideline of 1 µg/l of microcystin as upper limit for safe drinking water, which means that there is not dangerous to drink from Ialy Reservoir with the observed concentrations. To be acute toxic the concentration of microcystin need to be above 1 mg/l, which occurs frequently in eutrophic lakes during algal blooms.

The analyses confirm that there are strains of toxin producing blue green algae present in Ialy Reservoir. Most likely it is the Microcystis species observed in the microscopic analysis. This means that there might well have been incidents of toxic blue green algae that caused, or contributed to, the health problems for animals and people described during 2000.

Even though the concentrations were negligible during the investigation in Nov/Dec 2005, the concentration can be higher at the end of the dry season (April to June). The concentration of microcystin should be monitored throughout one complete dry season (Nov-June) with sampling every 14 days. This is necessary to draw a secure conclusion about algal toxins.

The algal toxins are thermo-stabile, which means that they are not destroyed by cooking the water. They are confined inside the algal cells, and are most effectively removed by filtering the water.

5.1.9 Heavy metals

Another group of pollutants which has been mentioned in the NGO reports, and which can give health effects, are the heavy metals. Particularly Arsenic has been in focus since this element has been shown to create problems in well water from floodplains of several Vietnamese rivers (Berg et al 2001). High Arsenic levels were reported observed in floodplain wells in Stung Treng (Ian Baird 3 S River Network, pers. comm., and Willi Kohlmus, Welt Hunger Hilfe, Ban Lung, pers. comm.) It was therefore taken samples of the most probable heavy metals, from Ialy Reservoir (surface and deep water) as well as from Phum Phi (Border) and Vuon Say. The results are given in Table 5.10.

Table 5.10 Concentrations of heavy metals in Ialy Reservoir and downstream in Se San River, samples from November and December 2005

	Arsenic As µg/l	Cadmium Cd µg/l	Chromium Cr µg/l	Copper Cu µg/l	Iron Fe µg/l	Manganese Mn µg/l	Nickel Ni µg/l	Lead Pb µg/l	Zink Zn µg/l
Yali 0-10 m	0.38	0.093	0.44	5.66	250	4.2	1.5	1.11	8.3
Yali 50 m	0.29	0.008	0.38	5.77	260	11.2	0.34	0.406	2.23
Outlet Yali	0.24	0.041	0.4	4.69	280	6.83	1.4	0.803	10.5
Phum Pi	0.2	0.004	0.43	5.88	348	10	0.2	0.395	0.63
Vuon Say	0.2	0.008	0.49	6.46	432	14.6	0.2	0.549	1

The concentrations of all the elements are very low, and far below the water quality criteria for any human use category. The concentrations are in the same levels as are found in remote, unpolluted, Scandinavian lakes (Skjelkvåle et al 2001). They are all well below for example the US EPA guidelines for drinking water (cfr. http://www.epa.gov/safewater/arsenic/index.html), which are among the most strict water quality criteria in the world to day.

The conclusion is that heavy metals do not constitute any pollution problem in Se San River. Even though the water quality impacts from the Ialy Reservoir can be a little larger in May, particularly with respect to iron and manganese, this conclusion will persist.

However, all wells in the area should be analyzed for arsenic, as this may be a problem in this area. The reason for the arsenic content in the wells has, however, nothing to do with the regulation scheme of Se San River. Its presence is due to natural geological accumulation processes.

5.1.10 Pesticides

In the catchment of the Vietnamese part of Se San there is considerable agricultural activity. Particularly there are large areas with coffee plantations in the Pleiku area. This is fairly close to the Ialy Reservoir. The agriculture is run after modern techniques which imply the use of a large number of pesticides. Pesticides from the Vietnamese agriculture have also been mentioned in the NGO reports as a potential threat to the local people living along the Cambodian part of the Se San River. To elucidate the probability of occurrence of such compounds, water samples from Ialy Reservoir, from Phum Phi and from Vuon Say were analyzed for 55 commonly used pesticides, see Table 5.11.

Pesticides were not detected in any of the samples. Detection limits for the Gas Chromatographic methods used, were for most compounds at 0.01 ppb. This is lower than the quality guidelines for drinking water set by US EPA, which is among the strict drinking water standards in the world.

The conclusion of this pesticide screening is that there is very unlikely that pesticides occur, or have occurred, and will occur in concentrations that will give any health problems from drinking the water from the Se San River. From monitoring of pesticides in Europe and in the USA it is shown that it is more or less only brooks and small streams within agricultural areas that have concentrations of pesticides that give health hazards, as well as ground water in agricultural areas.

Table 5.11 Analysis of pesticides in water from Ialy Reservoir, Se San at Phum Phi and at Vuon Say.

Pesticide	Group	Detection limit	Result of analysis
Aklonifen	Herbicide	0.01 ppb	Not detected
Aldrin	Insecticide	0.01 ppb	Not detected
Alfacypermetrin	Insecticide	0.01 ppb	Not detected
Atrazin	Herbicide	0.01 ppb	Not detected
Atrazin-desetyl	Metabolite	0.01 ppb	Not detected
Atrazin-desisopropyl	Metabolite	0.02 ppb	Not detected
Azinfosmetyl	Insecticide	0.01 ppb	Not detected
Azoksystrobin	Fungicide	0.02 ppb	Not detected
Cyprodinil	Fungicide	0.01 ppb	Not detected
Cyprokonazol	Fungicide	0.01 ppb	Not detected
DDD-o,p’	Metabolite	0.01 ppb	Not detected
DDD-p,p’	Metabolite	0.01 ppb	Not detected
DDE-o,p’	Metabolite	0.01 ppb	Not detected
DDE-p,p’	Metabolite	0.01 ppb	Not detected
DDT-o,p’	Insecticide	0.01 ppb	Not detected
DDT-p,p’	Insecticide	0.01 ppb	Not detected
Diazinon	Insecticide	0.01 ppb	Not detected
Dieldrin	Insecticide	0.01 ppb	Not detected
2,6-diklorbezamid	Metabolite	0.01 ppb	Not detected
Dimetoate	Insecticide	0.01 ppb	Not detected
Endosulfan sulphate	Metabolite	0.01 ppb	Not detected
Endosulfan-alfa	Insecticide	0.01 ppb	Not detected
Endosulfan-beta	Insecticide	0.01 ppb	Not detected
Esfenvalerat	Insecticide	0.02 ppb	Not detected
Fenitrotion	Insecticide	0.01 ppb	Not detected
Fenpropimorf	Fungicide	0.01 ppb	Not detected
Fenvalerat	Insecticide	0.02 ppb	Not detected
Fluazinam	Fungicide	0.02 ppb	Not detected
Hexachlorbenzen (HCB)	Fungicide	0.01 ppb	Not detected
Heptaklor	Insecticide	0.01 ppb	Not detected
Heptaklor epoksid	Metabolite	0.01 ppb	Not detected
Imazalil	Fungicide	0.01 ppb	Not detected
Iprodion	Fungicide	0.02 ppb	Not detected
Isoproturon	Herbicide	0.01 ppb	Not detected
Klorfenvinfos	Insecticide	0.01 ppb	Not detected
Klorprofam	Herbicide	0.01 ppb	Not detected
Lamdacyhalotrin	Insecticide	0.01 ppb	Not detected
Lindan	Insecticide	0.01 ppb	Not detected
Linurod	Herbicide	0.02 ppb	Not detected
Metalaksyl	Fungicide	0.01 ppb	Not detected
Metamitron	Herbicide	0.1 ppb	Not detected
Metribuzin	Herbicide	0.01 ppb	Not detected
Penkonazol	Fungicide	0.01 ppb	Not detected
Permetrin	Insecticide	0.01 ppb	Not detected
Pirimikarb	Insecticide	0.01 ppb	Not detected
Prokloraz	Fungicide	0.02 ppb	Not detected
Propaklor	Herbicide	0.01 ppb	Not detected
Propikonazol	Fungicide	0.01 ppb	Not detected
Pyrimetanil	Fungicide	0.01 ppb	Not detected
Simazin	Herbicide	0.01 ppb	Not detected
Tebukonazol	Fungicide	0.02 ppb	Not detected
Terbutylazin	Insecticide	0.01 ppb	Not detected
Tiabendazol	Fungiside	0.05 ppb	Not detected
Trifloksystrobin	Fungicide	0.01 ppb	Not detected
Vinklozolin	Fungicide	0.01 ppb	Not detected
Bentazon	Herbicide	0.02 ppb	Not detected
2,4-D	Herbicide	0.02 ppb	Not detected
Dikamba	Herbicide	0.02 ppb	Not detected
Diklorprop	Herbicide	0.02 ppb	Not detected
Flamprop	Herbicide	0.1 ppb	Not detected
Fluroksypyr	Herbicide	0.1 ppb	Not detected

Klopyralid	Herbicide	0.1 ppb	Not detected
Kresoksim	Metabolite	0.05 ppb	Not detected
MCPA	Herbicide	0.02 ppb	Not detected
Mekoprop	Herbicide	0.02 ppb	Not detected

5.1.11 Conclusions on the present water quality situation in the Se San River

The study has comprised

- Compilation and analysis of water quality data from 2001 provided by MOWRAM
- Compilation and analysis of one year of water quality monitoring 2004/2005 provided by MOWRAM
- Water quality data from Vietnamese monitoring of Ialy Reservoir and Sesan River just downstream the Ialy Power Plant (2004 and 2006)
- New study of WQ in November/December 2005 in both the Se San River itself and in the Ialy Reservoir, including algal species composition, algal toxins, heavy metals and pesticides, in addition to standard water quality parameters.

The present situation can be described as:

- The water is soft with low content of dissolved ions with conductivity 3-4 mS/cm
- The water has weakly alkaline reaction with typical pH of 7.0-7.5
- Most of the year the turbidity is moderate (5-15 FNU), but in the rainy season turbidity can very be high (200 FNU corresponding to 250-300 mg SS per liter). This high particle content causes problems for the river ecology and for human use.
- The content of the plant nutrient phosphorus and nitrogen is low, and is not high enough to produce eutrophication problems.
- The algal biomass is low, and the species composition is normal.
- No content of algal toxins has been observed, but this is not studied in the most intensive algal producing period (April-June).
- The concentrations of heavy metals, including arsenic, are low and reflect unpolluted water in this respect. Concentrations are below standards for drinking water including US EPA, which has the strictest regulations.
- It has been analyzed for 55 pesticides with detection limit of 0.01 ppb, but no compound is detected. The conclusion is that pesticides are not a problem in Se San River.
- The content of coliform bacteria is periodically high, particularly in the rainy season. Drinking water should be boiled, or filtered, before consumption.
- It is not likely that the water coming out of Ialy Reservoir will contain enough nutrients to create any algal problems in Se San River in the future. However, Vietnamese monitoring data from 2004 found very high phosphorus content in samples taken just downstream the outlet from Yali Power Plant.

It should be noted that the present study was done just after the rainy season, when the reservoir was recently filled, and when the deep water still contained water of 50 % oxygen saturation or more. At the end of the dry season (April-June) the oxygen may be very low in the deep water, giving rice to release of bioavailable nutrients. The water quality, with analysis of algal species composition, and algal toxins, should be monitored through a whole dry season, to verify the conclusion given above.

5.2 Aquatic Life

5.2.1 Periphyton and bottom dwelling animals

There is no available data on this important organism groups from the Cambodian part of Se San River. It should be noted that 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, and are easily affected negatively by hydropower regulations i.a. Proper abatement measures can reduce the negative impact considerably.

5.2.2 Fish

The 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, 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

In the Mekong River system between 5- and 600 species of fish are described scientifically (Rainboth 1996). It is however, mainly the fishes used for food that 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 the Se San River based on the catch of fishermen, and came up with 120 distinct species. In addition, he had a long list of un-confirmed species, which was not included. He anticipated that the real number of fishes in the Se San River in Ratanakiri is 2-300 species. Baird (pers. Comm.) is now working with the finalization of a new assessment of fish stock, fish catch and species diversity in the Se San River. Baird's new report was available when this EIA report was written, and this report therefore base the species list on Baird (1995) from the Se San River.

It is believed (Rainboth 1996, Baird 2000) that the three rivers Se Kong, Se San and Srepok have much the same species of fishes, and contains the most the same species as the main Mekong River. It seems that the Srepok River has higher diversity, and contain larger specimen of the different species compared to the Se San River (Baird 1995). This may be because the Srepok River generally has greater depth, 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 Se San River. According to professor Ho Thanh Hai, and professor Nguyen Kiem Son, at the Institute of Ecology and Bioresources in Hanoi, which have undertaken biological studies in the Vietnamese part of Se San River in connection with the Plei Krong EIA, told that more than 30 species of fish migrate into Vietnam from Mekong River.

Table 5.12 List of fish species in the Se San River given by Baird 1995

Family: Dasyatidae	Family: Notopteridae
Dasyatis laonsensis	Chitala blanci

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

Changes in fish diversity

People in the villages along the Se San River told that several species that were frequently caught prior to the Ialy-dam now have declined seriously and some have more or less disappeared. Species that for all practical reasons has disappeared (extinct) were told to be *Cirrhinus microlepis, Wallago leeri, and Pangasianodon gigas*. Other species have become very rare, but not extinct.

In several villages along the Srepok River people told that new fish species had entered the river the last years. The number of newcomers varied from 2-4 species. One of the new comers was Thilapia, the others were looking like marine fish. In the Se San villages new fish species were not mentioned at all.

Fish Migrations

It is not performed any fish migration studies in the Se San River, and all is based on information gained from fishermen. According to professor Ho Thanh Hai, and professor Nguyen Kiem Son, at the Institute of Ecology and Bioresources in Hanoi, which has undertaken biological studies in the Vietnamese part of Se San River in connection with the Plei Krong EIA, more than 30 species of fish migrate all the way into Vietnam from the Mekong River. Baird (1995) gives a description of the fish migrations in the 3 rivers, which will be shortly summarized in the following:

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 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 river begin to swell, a number of species of fish migrate up the rivers from the Mekong River. 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. (herafter 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 (herafter 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 in this period when the river flow increases. 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. 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 probably 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 of fish ponds (Chann Soupheap, Dept. of Fishery, pers. Comm.).

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 up and down the three rivers.

As the monsoon ends, and water levels begin to drop, many species of fish begin retreating 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 of the three rivers during the dry season.

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

Group A, the cyprinids also descend streams and enters the three rivers. They begin a long migration that takes them back to the Mekong River and upstream to Laos and Thailand where they feed until the monsoon begins again. At that time they migrate back to the three rivers for spawning. As the streams and wetlands begin to dry out, the group B, black fishes, also return 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 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 is 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 other small species of which the migratory behavior are not known, because they are not caught frequently enough by the fishermen.

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

Fishing activity and the most common methods used
More or less all families living along the river fish for daily food, and those who do not fish, buy fish from the fishermen. Fish is the main protein source for the residents in all areas along the rivers (80 % according to Baird et al 2002). They keep household animals like buffalos, cows, pigs, geese and chicken, but they sell these animals to provide cash. There are also problems for single families of efficiently utilizing the meat from such big animals like buffaloes, cows and pigs in warm areas without the possibility of deep-freezing. Fish has more suitable size of a “one meal portion”.

The fishing methods used in the Se San River are mainly

- Gillnet
- Castnet
- Baited long-line
- Cylinder trap

The 3 first methods were 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 took place during nighttime. They deployed the equipment at 10-11 pm and took it up again at 04-05 am. They fishermen claimed that the fish was only moving during the hours when the moon was up.

Only a few persons in each village were professional fishermen. They sold their catch to those who did not fish in the village and in the surroundings. Some of the fish they sold to traders bringing the fish to the fish market in Ban Lung or Stung Treng. However, the fish market in Ban Lung was increasingly being supplied with fish from Kratie, brought in by car every morning. It was a problem for the professional fishermen that the traders didn't come to their village as often as before. When we visited the fish market in Ban Lung (December 2005) more than 90 % of the fish was from Kratie, and the fish from Ratanakiri was mainly *Channa striata*, and *Clarius sp*, caught in the rice fields and not from the Se San River.

Fish catch
In all villages along the Se San River they claimed that the fish stock had declined after the Ialy Dam was constructed. Fish yield were now about 10-30 % of what it was before. In Sre Kor Village in Stung Treng, villagers said that before 2000 a typical catch was 15-20 kg fish per boat per night, but now the catch is only 2-5 kg per boat per night. The size of the fish has also decreased. Before 2000 it was normal to catch single fishes up to 15 kg, but now the biggest fish reportedly is 1-1.5 kg. In Phum Pi close to the Vietnamese border a typical catch before Ialy was built was said to be 10-20 kg per boat per night, but now it was 1-2 kg per boat per night. The biggest fish specimen they caught today is from 0.5 – 1 kg, while before they got fishes up to 20 kg. Some species had declined more than others, and some had disappeared from the river. The same development was reported in all the villages visited along the Se San River. The same kind of interviews was done along the Srepok River, and it was a great difference in the answers. In Srepok there were also some complains about reduced fish yield, but several places they said it was still good fishery. The interview answers in the Se San Villages were a unanimous story about a dramatic decline in the fish yield. Based on the information from the interviews with village chiefs (cross checked and confirmed by asking people along the river) gave us an estimate that the fish yield today was from 10-30 % of what it was before the Ialy Dam was implemented.

It should be noted that it was observed a decline in fishery yield even before the Ialy Dam was constructed (Baird 1995), and that this decline is likely included in the fishermen's decline estimates in recent years given to us in the interviews. A small decline (10-30%) in fishery yield was also reported in the same type of interviews from Srepok (SWECO 2006), where there has not been any hydropower regulations yet. In Sesan. However, in Sesan, the reductions were told to be between 70-90% of earlier catches. As the population along Sesan is much bigger than along Srepok, the fishing pressure has also been higher in the former. The decline in fishery yield in Sesan is therefore also partly a function of high fishing pressure, and not only caused by impacts from the hydropower regulations. Based on 100 years experience of hydropower regulations in Scandinavia and the reductions they give to downstream fish stocks, also in rivers with no fishing pressure, the EIA team is convinced that the Ialy Regulation iosa main cause of the decline in fishery yield in Sesan.

Illegal fishing
Baird (2002), reports that the use of explosives for fishing has been a problem in Se San River. He also reports that electro shock fishing had become popular, and that those two illegal methods might have had negative impacts on the fish stock. Our impression from the interview with village chiefs and fishermen along the river was that these activities have declined to levels that they no longer thought was a threat to the fish population. The use of poison was also said to have declined to low levels which they did not believe had any effect on the fish population in Se San River.

Over-fishing
There was a growing concern over the increase in the use of highly efficient synthetic monofil gillnets, which had become very cheap over the last 10 years. Over-fishing by gillnets is a growing concern among fishermen and the head of commune fisheries.

Fish diseases
The EUS (Epizooic Ulcerative Syndrome) disease has been in Se San River for 10 years (Fisheries Office Report 2000). The disease spread from Thailand 25 years ago, and are now present in most rivers in SE-Asia today. It is the wetland species like Channa striata and Clarius sp that are mostly affected, but also fish from the main the Se San River is affected. The disease is also present in the Srepok and Se Kong rivers, where the fishermen have not experienced the dramatic decline in fish yield as they have in the Se San River. Fish diseases are often specific, i.e. some fish species are more impacted by the disease than other species. It is very seldom that a disease reduce all kind of fish types to low biomass levels like what has happened in the Se San River.

5.2.3 Fish market survey in Ban Lung

The fish market in Ban Lung was visited in the morning 29.11.2005. The market was well equipped with fresh fish (30-40 species), smoked fish, salted fish, fermented fish (prohok and others), dried fish, shrimps, frogs, and snakes. Fig 5.9 shows a selection of what were available at the market.

The sellers and the traders (middlemen) told that more than 90 % of the fish was from Kratie at the Mekong River, brought to Ban Lung every morning by car. Only the wetland fishes (Channa sp and Clarius sp), and some of the shrimps, were from local fishermen. The traders said it was much easier to have a secure delivery of fish from Kratie than from the Se San and Srepok rivers.

Fig 5.9 A selection of what was available at the fish market in Ban Lung 29.11.2005. Most fishes are from Kratie at the Mekong River

The Cambodian team member and fish expert Chann Sopheap, which had visited the fish market in Ban Lung several times some years ago, said that there had been a great change compared to the 1990ies. At that time most of the fish came from the Se San and Srepok rivers, and the size of the fishes was much larger than they were to day. You could always find real big fishes on the market at that time, some more than 20 kilos. During this visit to the market there were no big fish at all.

5.3 Land Use

5.3.1 Land: The present situation and the Ialy Hydropower Plant

Agriculture is the main source of food and the reliance on river water and banks, predictable regimes in water fluctuations and floods, and water related produce are vital and integral to the local livelihoods of people by the Se San River. The construction of the Ialy Hydropower Plant and the events around it are said to have influenced agriculture in profound ways – by reducing rice production, almost eliminating river bank gardening, reducing river bank and water related vegetables and animals (also other than fish) used for food, increasing vulnerability of river banks to slippage and thus increasing erosion. Since there are no baseline conditions recorded prior to Ialy Hydropower Plant it is hard to make any comparisons. The information given here is based on what is observed at present (based on field interviews and observations). Conditions said to occur prior to the Ialy Hydropower plant are considered and shed light on changes that have occurred and those that may be addressed in mitigation: where considered these are mentioned clearly so as to distinguish these from observations done during this study The aim of the present study is to consider the reported and observed impacts on land use and particularly agriculture, objectively.

5.3.2 Agriculture.

Along the Se San River, where this study is focused on, villagers utilize land for a range of agricultural activities, namely; rice paddies, fruit orchards, secondary crops (seasonal mostly), and home gardens. Field observations showed some general but clear distribution of crops across the landscape in relation to the Se San River. Paddies and fruit orchards were furthest from the river while homesteads surrounded by home gardens and secondary crops were closest. Although small patches of fruit trees (similar species) were also on occasion 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 more common among villages near the Se San River than along the Srepok River, and 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. Land area for rice per household varies from 0.5 ha to 2 ha, although 5 ha are allowed by regulations. 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 further away from the river to start permanent paddy fields or cashew orchards. Rainfed paddy is grown furthest from the river. The riverside is used for other crops; secondary, cash and also those which fetch more income.

Fig. 5.10 Rice field at Sre Kor commune, Stung Treng province

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, it can be divided into three zones in relation to the position of the house and the river:

1) *home gardens (around and closest to the house);*
2) *backyard gardens/crop fields; and*
3) *river bank gardens.*

These zones have also been used to describe the homesteads by the Srepok River, where these zones are more demarcated, and used and maintained actively. Note that there are also homesteads placed right next to the river.

Home gardens are found associated with the immediate surroundings of almost 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 5.13). Annual plants commonly comprise spice plants (e.g. coriander, spring onions, Chinese chives), vegetables (e.g., long beans, greens of mustard family (Brassicaceae), gourds) and ornamental plants) (Table 5.13). 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 can 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 5.13). Villagers used these extensively before the floods they said. It was noted in the field that today not all homes utilized the backyards in this way, and in fact this practice was noticeably less here than along the Srepok River. In many cases, the home gardens (just around the house) simply gave way to the river bank, and backyard areas 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. The presence of shrubs (not of usable species) and wild grasses indicated an abandoning of these areas by many farmers. Due to the unpredictable water levels in the river and floods, many farmers put in less effort into maintaining gardens in general, and many areas are simply abandoned. The current vegetation points to their abandoned nature.

Fig. 5.11 River bank garden limited to one terrace used as a nursery. See plants on high ridge - comprising an example of the backyard gardening

River bank gardening was once practiced by most homes during the dry season, low flow period of the river, when drawing water from the river is easy and there is no risk of flooding. At present the experienced unpredictable fluctuations of the Se San River during the dry season have almost ceased all river bank agriculture. The very few who try to practice it are very poor and have little other available land. The river bank gardening, which exists, has progressively moved to higher levels and has impacted the type of plants that can be grown and significantly increased the labor required to maintain these higher placed plots. Many villagers (particularly older) expressed their dismay in not being able to put in so much labor for the river bank gardening due to weak river bank slopes, increasing in proneness to erosion, and further away watering needs due to unpredictable water level fluctuations. Many vegetables (like most seedlings, coriander, spring onions and basil) require two watering doses per day, especially on hot sunny days.

For river bank agriculture the sand banks and slopes of the river bank were once used extensively, elaborated upon by most elders and young farmers during interviews. The rich and fertile river banks were cleared and terraced for planting of seasonal vegetables (Table 5.13). This was usually done just as harvesting of rice is coming to an end and as the dry season begins. The planted river bank plants serve as significant contributions to daily meals. The availability and accessibility to use the river bank 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 for domestic needs.

River banks 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 5.13; see also NGO Forum 2005a and 2005b; Dy Phon 2000). Many of these species are rich in minerals and iron, and are liked by the villagers due to their 'delicious' taste. In some areas these species have much lower occurrence and in fact some have disappeared. Many villages expressed their dismay over the fact that they could not rely on river based vegetables and river bank slopes for gardening. Some species occur in higher levels along the river bank and can thus be harvested. The use of the river bank, its importance and maintenance, was described in many ways as the situation is by Srepok River where river bank agriculture is commonly practiced and relied upon heavily.


Fig. 5.12 Poorly kept backyard gardenparts were abandoned. This is a common sight in many village backyard gardens along the Se san River

Animals in the agricultural landscape

The area (land) mentioned in the sections above is 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 the cows and buffalo using the river for water.

Crabs, frogs, snails, insects, lizards, and earthworms (for fishing) are collected from and by the river for food. Some families said that they started eating frogs only after the fish levels became very low. Villagers noticed a drop in crustaceans in some areas. The water level fluctuations were blamed for impacting the river and river edge/bank based catches of animals other than fish. 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. The number of deer animals has however gone down considerable, compared to the wild boar.

Fig. 5.11 Feeding pigs at Phum Phi village, Oy Ya Dav district, Ratanakiri province

Table 5.13. List of Food and Crop Plants in Se San River homesteads. (source: interviews and field observations)

Food and Crop plants					
Plants grown in the home gardens (immediate surroundings)		**Crop/food plants in the backyards of homes, those said to be once grown and those observed**		**Plants that used to be cultivated along river bank 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	Mtesh	Chili (hot pepper)
Tralach*	Long gourd - 1 (hairy)	L'ngo*	Sesam	Mnaos	Pineapple
Nonong*	Long gourd - 2 (smooth surface)	Thnaim Chok*	Tobacco	Trab Kdak	Aubergine
Kh'toem	Spring onion				
Chi Kraham	Basil				
Chi Krahorm	Chinese Chives				
Trab Kdako	Aubergine				
Rumchek	Pandan				
Kh'toem Sor*	Garlic			Plants that could be once collected by the river bank (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	# these occur now on higher parts of the river banks and can still be collected in many areas	
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				
Different Species	Flowers (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 or pumps in some areas. 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 get 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.

The villages said that irregularities in water levels (e.g., at the onset on the growing/wet season) have led to the loss of paddies and lower productivity.
The higher and unpredictable flood water coming before the rice is mature is also a problem as leaves can remain submerged in water and the rice does not ripen. In addition access water/moisture increases vulnerability to diseases. Vegetables and cash crop areas can get inundated and most plants can easily die.

Rain and river water is used for watering the home gardens, backyard gardens and river bank 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 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.

5.3.3 Forest.

The most common forest type in the Se San Basin in Cambodia is the deciduous and mixed forest types, 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). There are large areas of bamboos and different succesional stages of secondary forest, and abandoned shrubby areas. An estimation of vegetation in a 100 m belt along the north and south river banks of Se San River in Cambodia to the confluence with Srepok River revealed the following land use types and cover (Table 5.14) base on the Land use Map of Cambodia (2003). In addition land use along the river beyond the Srepok River and the Se San River confluence to Strung Treng comprises of predominantly paddy fields, and home and backyard gardens (Land use Map of Cambodia. 2003). Cropped areas may be underestimated due to the seasonality and the resolution of the maps used.

Fig. 5.13 Deciduous dipterocarp forest with old stumps near Ban Hvang Village

Bare Slopes

Although it is not possible to provide an estimate of barren river banks, we noticed many areas with bare river banks and dangerous edges at the verge of slipping. Although some of the barren banks may be due to natural conditions, the majority of what we saw in the field where due to the river water fluctuations which were slowly eroding away the base of the banks (characteristic of water fluctuation), often a concaved area up to a meter high, and exposing the higher ridges to slipping into the river. Many areas with tree, shrub or bamboo cover (usually mixed) were also experiencing slippage suggesting that tree vegetated sites are also highly vulnerable to fluctuations (Figure 7.1). The magnitude of such bare slopes is expected to be significant.

Forest Use

Villages by the Se San River have contiguous areas with forests of different qualities (much of it is secondary, and thus of poor quality) and shrubland, and local people have traditional associations with the forest. In this section the focus is the use of the forested areas for NTFPs. The forest are more under scrutiny now than before due to the presence of Virachey National Park to the north of the Se San River, and areas between the Se San and Virachey National Park is regarded as a buffer zone. Villagers do however occasionally go hunting, and many mentioned hunting at least once a month. Local people enjoy eating wild boar, and deer (barking and sambar), 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 monitor lizards and turtles were also said to be killed.

Table 5.14. Proportion (%, numbers rounded) of land use or vegetation type along the north and south Se San River banks. Measured along the Se San River bank in Cambodia until its confluence with the Srepok 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 Se San River (Estimated Percentage of length)**	**Land use/Vegetation Type**	**South Bank of Se San River (Estimated Percentage of length)**
Paddy Fields	2.8	Paddy Fields	4
Swidden agriculture	16	Swidden Agriculture	11
Village Garden Crops	4	Village Garden Crops	6.4
Deciduous forest	17	Deciduous forest	14
Evergreen Broadleafed forest	3.5	Evergreen Broadleafed forest	9.5
Riparian Forest	0.6	Riparian Forest	0.6
Bamboo and Secondary forest	14	Bamboo and Secondary forest	9
Mixed forest of evergreen and deciduous species	15	Mixed forest of evergreen and deciduous species	18
Abandoned field covered by shrub	25	Abandoned field covered by shrub	22
Woodland and scattered tree (canopy<10%)	2	Woodland and scattered tree (canopy<10%)	3
Shrubland (undifferentiated)	1.3	Abandoned fields covered by grass	>0.1
		Sand Bar	2

The forested areas also are an important source of plant based non-timber forest products (Table 5.15). Resin collection is the most important source 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 Srepok River the problems mentioned above are more severe along the Se San River. This is partly due to the denser population and no formally protected areas in the direct vicinity. The area technically lies in the buffer zone of the Virachey National Park and thus there is growing concern related to illegal activities, and the need to set-up viable community forest management practices. Generally there 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[6]) which

[6] 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*

recognizes 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[7]. Therefore community management of forests is still in its infancy, although some villagers and provincial officials mentioned its potential.

Table 5.15. List of forest products collected or hunted reported by villagers living along the Se San River. (Source: interviews and field observations)

Plants			**Animals**		
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 (many species)	Rattan	Stem	Trey (not from the 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 5 ha of cultivation land, although in practice most people had much less land (up to 2 ha). According to the village interviews, the land acquisition process is long from

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.

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

the village chief through the central government approval. Several young villagers who required extra land for paddy or orchards expressed dismay and frustration. 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 indifferently by the government regulations.

5.4 Biodiversity

5.4.1 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. 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[8] 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[9], 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 be 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 biodiversity rich areas are in the northern part of the Ratanakiri Province. MAFF is also responsible for the CITES convention which Cambodia ratified in 1997. In essence, at present

[8] 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.

[9] 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.

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 25 protected areas[10] or areas of conservation importance[11] 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. Multiple Use Areas include the Dangpeng, Samlot and Boeng Tonle Sap. For details see www.wildaid.org, 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. At present 18.5% of the land area is nationally protected (World Bank 2004).

The Se San Basin (specifically to the north of the Se San River) in Cambodia has one protected area (Table 5.16). In addition the national park area and in fact the whole area in the Se San Basin has 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).

[10] 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.).

[11] The list is not complete for all areas of conservation concern as some are not official or recognized by MoE or MAFF. The area of concern to this Report (Virachey National Park) on the Se San River is listed.

Fig. 5.14 Ranger Station of Virachey national Park in Ta Veaeng District – stations of this sort is set up to conduct wildlife surveys, monitor illegal activities, and advise on sound forest use

The WWF has classified the area around the Se San River (specific to the area studied in this report) 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 Cambodia/Laos/Vietnam Tri-border Forests (Priority Landscape DF5 in Baltzer et al. 2001) bordering in the south the Eastern Plains Dry Forests (DF4), and its biological importance is rated as Acute to Critical by WWF.

The areas next to the Se San River are rated as Critical. This priority area spans essentially two quite different ecological communities: a part of the western portion of the Central Annamites and the northeastern areas of the northern Cambodian band of dry, lowland dry deciduous forests and semi-evergreen forests. Classifying broadly, the main forest types[12] of this ecoregion also fall in similar categories as reported in the Land use Map of Cambodia (2003): Deciduous Forest, Semi-evergreen forest and deciduous forest (Mixed forest) and shrubland. The area that we are directly concerned with in this report is the area by the Se Sean River, and this supports a mosaic of Dry Deciduous Forest and Semi-evergreen forest (with transitional forest types such as mixed deciduous forest). The Virachey National Park (e.g., located in the northern part of Ratanakiri Province) has large spans of semi-evergreen forest also. The areas by the Se San River have much cultivation and shrubland (See Table 5.14)

[12] 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).

Table 5.16. Protection area (PA) in the Se San Basin of Cambodia (Source: literature, MoE 2003; MoE, interviews)

Type of PA	Name of PA	Management Responsibility and formal establishment	Location of PA	Size (ha)
1. National Park	Virachey	MoE. Royal Degree of 01 Nov 1993.	Ratanakiri	332,500

This section will not cover fish diversity (see Chapter 5.2). Since the precise biological diversity status of all the areas by the Se San River are not known this report draws on records from surveys done by Forest Management and Virachey National Park Rangers. We do not focus on Virachey National Park (VNP) *per se* due to its location being away from the Se San River, but draw on the experiences and observations of the park management and rangers. Since the area between Se San River and VNP is considered the buffer zone of VNP, the management of VNP has vested interest in the areas, especially in terms of illegal logging, hunting, trade, land encroachment, and plausibility of instilling community based management regime.

VNP is the largest of seven national parks in Cambodia. It extends into two districts in Ratanakiri Province (Ta Veaeng and Veun Sai) and one district in Stung Treng Province (Siem Pang). Most of the park lies in Ratanakiri Province. VNP borders Lao P.D.R. in the north, and Vietnam in the east. The terrain is fairly mountainous with mountain ranges and plateaus from 4000 – 1,000 m ASL. Two major rivers (the Se Kong and Se San) run along the eastern and southern edges of the park's buffer zone, fed by permanent streams originating in the highlands. Nationally it borders the Nam Ghong Provincial Protected Area. Internationally VNP borders with Chu Mom Ray Nature Reserve in Vietnam, and Xe Pian and Doong Ampham conservation areas in Lao P.D.R. VNP is of major importance as a watershed and catchment area. The water from the park flows into the Se San and Se Kong Rivers, and together with the Srepok River make up approximately 20% of the Mekong River flow. In addition it has immense value to local communities both for agriculture and fish (protein), as well as for the wildlife that it and its buffer zone sustains.

Local communities (of 60 villages, given in MOE 2003) rely on the natural resources of VNP and the land use can be categorized into the following large categories: village settlements, swidden agriculture (slash and burn), forest product gathering (main examples include rattan, bamboo, malva nuts (*Sterculia lychnophora*), eaglewood (pieces of *Aquilaria crasna*) and resin) and hunting (rabbits, forest rats, turtles, deer, wild boar), rain-fed (wet) rice agriculture, and spirit forests. Although the park management has been able to reduce illegal hunting and logging, there are reports that indicate that the tiger, Himalayan black bear, Malayan sun bear, guar, sambar deer, muntjac, and civet are still hunted. Illegal trade is significant and largely involves turtles, monitor lizards, pangolins and certain birds.

The buffer zone is more populated and has more agricultural cover than the area in the park, and thus has less wildlife and intact vegetative communities. It also serves as a route of entry into the park for illegal activities. The recent involvement of park management and NGOs in creating and testing out community management regimes is seen as an important step towards taking sound conservation measures, increasing awareness and most importantly providing recognition to local forest rights.

5.4.2 Vegetation and Wildlife

Ashwell (1998) recognized two board vegetation formations in the Park – humid medium elevations formations (above 600 meters) and Humid low elevation formations – and presented a description of the fauna based on literature. Dense semi-evergreen forest, upland savannah, bamboo thickets and occasional patches of deciduous forest form the majority of the vegetation of the VNP. Although no systematic surveys are available, Ashwell (1998) reported 156 vertebrate species of which 43 are of international significance. Of these bovids, small carnivores and primates are threatened.

Wildlife in the area that is reported to have global significance is, but not limited to, the following highly threatened species: Slow Loris, Pygmy Loris, Pig-tail Macaque, Long tailed Macaque, Douc Langur, Yellow-cheeked Crested Gibbon, elephant, tiger, gaur, banteng, other gibbons and langurs (Hout et al. 2003: Baltzer et al. 2001; WWF-Cambodia interviews; field interviews). The Siamese Crocodile has also been said to be sighted in tributaries close to the Se San River. Going southwards (i.e., the next vegetation zone to the south of the Se San River) is the Eastern Plains Dry Forests (DF4 in Baltzer et al. 2001) also has many threatened species which may be vulnerable. For more additional 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 problem especially in VNP. Larger animals like the tiger and bears are also targeted and are seriously threatened. Illegal logging also occurs and is serious in some areas. The presence of abundant and diverse wildlife with little protection allows for poaching, often reportedly steered from across the border in Vietnam (interviews with rangers and WWF-Cambodia). It is not known if any animals have migratory paths that cross the Se San River.

The river bank of Se San River has reportedly served as habitat for a number of animals, although at the present time there are few observations of wildlife other than the more commonly seen birds, boars, deer, lizards, otters and turtles. Many bird species use the river area for nesting and breeding during the dry season in particular (Table 4.15). Claassen (2004) conducted surveys and nest monitoring in 2003 on the Se San River (and Srepok River, not the focus in this report) and compared it to surveys conducted in 1998. She reported that the Se San River had 'extensive' sandbar habitat which served, other than the river banks and vegetation, as important nesting sites. This was confirmed also by wildlife rangers and villagers during our interviews. Major threats to sandbar nesting birds were reported as being inundations of nests and chicks, reduction in breeding and foraging habitat, and reduction in food sources as a result of irregular water fluctuating levels and floods. Egg collection by villagers and predation by animals (including domestic) also ranked high on the disturbance list. In particular numbers of River Lapwings and Small Pratincoles were significantly lower than the counts in 1998. The water rise due to the Ialy Hydropower Project has led to a large percentage of nest failures (Claassen, 2004). Up to 13.5% of total nest failures were also reported for a selected number (seven) of focal species.

Claassen (2004) also reported seeing on two occasions the Long-Tailed Macaque (*Macaca fascicularis*) and Otter sp. Soft-shelled turtles (*Amyda cartilaginea* and *Pelochelys cantorii*) populations and water monitor lizard (*Varanus salvator*) have also been reportedly impacted by water level fluctuations as they lay eggs on sand banks (eggs become rotten when in water for too long). Some iguanas lay eggs on the river banks, and these can be impacted by the changing water levels and also by the erosion prone bare river banks.

Local people reported several crustaceans (shellfish, snails), earthworms and insects as 'difficult to find'. Villagers said that they frequently find dead animals on the river bed and bank during water fluctuations due to the operation of the Ialy Hydropower Station.

Table 5.17.

A. Birds inhabiting along Se San River (see more details in Hout et al. 2003; Hourt 2005; Setha and Poole 2003; Timmins and Soriyun 1998 (one of the main source for the list below); Timmins and Rattanak 2001; Claassen's 2004 (one of the main source for the list below); Neath et al. 2001; van Zalinger et al. 2002; Interviews in the field and with WWF-Cambodia). C: Common; P: present, abundance unknown; LC: Locally common.

B. Mammals inhabiting along Se San River and near the mouths of tributaries

Local name	Common name	Scientific name	Status
Staing Kh'mao-sar Slap Chhaek	Black Baza	Aviceda leuphotes	P
Rompeh Poh Khmao	Black-bellied Tern	Sterna acuticauda	P
Kroling Krolong	Black-collared Starling	Sturnus nigriscollis	C
Khlaeng Chhapleung Kramao	Brahminy Kite	Haliastur indus	P
Kok Ko	Cattle Egret	Bubulcus ibis	P
Totea	Chinese Francolin	Francolinus pintadeanus	C
Kokkrork Kbal Tnoat Chais	Chinese Pond-Heron	Ardeola bacchus	C
Ckor Lor Cheung L'miet	Common Greenshank	Tringa nebularia	P
Unknown	Common Koel	Eudynamys scolopacea	C
Pravek	Cotton Pygmy-goose	Nettapus coromandelianus	P
Unknown	Crested Honey-buzzard	Pernis ptilorhyncus	P
Tracheak Kaim Prey	Crested Treeswift	Hemiprocne coronata	C
Chaptet Prey	Dark-necked Tailorbird	Orthotomus atrogularis	C
Teav Prey	Dollarbird	Eurystomus orientalis	P
Tavao Prey	Drongo Cuckoo	Surniculus lugubris	C
Sarekarkev Kballeung	Golden-crested Myna	Ampeliceps coronatus	P
Poplak Thom	Great Eared Nightjar	Eurostopodus mocrotis	C
Chongkong Krais Champoush Kh'mao	Great Thick-knee	Esacus recurvirostris	LC
La-ot Thom	Greater Coucal	Centropus sinensis	C
Tradev Tauch	Green Bee-eater	Merops orientalis	C
Preap Prey	Green Imperial Pigeon	Ducula aenea	C
Unknown	Green pigeon spp.	Treron	p
Krasar Praphesh	Grey Heron	Ardea cinerea	P
Orktrey Kbal Praphesh	Grey-head fish Eagle	Ichthyophaga ichthyaetus	P

Sarrekakev Vong	Hill Myna	Gracula religiosa	C
Teav Kheav	Indian Roller	Coracias benghalensis	C
Chork Vork Tauch	Large Scimitar-Babbler	Pomatorhinus hypoleucos	C
Ka-aek	Large-billed Crow	Corvus macrorhynchos	C
Pravoek	Lesser Whistling-Duck	Dendrocygna javanica	P
Sat Kbalthom Vointroung Phleung Champosh Veng	Lesser/Greater sand-plover	Charadrisus mongolus/leschenaultii	P
Poaltoak Kbal Prolet	Lineated Barbet	Megalaima lineate	C
Kok Krong Tauch	Little Egret	Egretta garzetta	C
Kra Aich/Krasar Svay	Little Heron	Butorides striatus	P
Sat K'barl Thom Voin Trong Khmao	Little Ringed Plover	Charadrius dubius	C
Kh'tob Dei Mekong Leu	Makong Wagtail	Motacilla samveasnae	
Unknown	Needletail spp.	Hirumdapus	C
Kengkang Tauch	Oriental Pied Hornbill	Anthracoceros albirostris	P
Tontrit Thom	Oriental Pratincole	Glareola maldivarum	P
Unknown	Parakeet spp.	Psittacula	C
Prohit Sor	Pheasant-tailed Jacana	Hydrophasianus chirugus	P
Kordorb Kbal Sor	Pied Kingfisher	Ceryle rudis	C
Chap Daunta Bampongkor Poang	Puff-throated Babbler	Pellorneum ruficeps	C
Krasar Thnong	Purple Heron	Ardea purpurea	P
Tramaik Kh'la	Racquet-tailed Treepie	Crypsirina temia	P
Maon Prey	Red Junglefowl	Gallus gallus	C
Seksork	Red-breasted Parakeet	Psittacula alexandri	P
Tradev Vech Tuol	Red-wattled Lapwing	Vanellus indicus	LC
Prapech Tracheak Krahorm Sor	Red-whiskered Bulbul	Pycnonotus jocosus	P
Tradevech Tonle	River Lapwing	Vanellus duvaucelii	C
Tradevech Tonle	River Lapwing	Vanellus duvaucelii	C
Rompeh Tonle	River Tern	Sterna aurantia	C
Tracheak Kaim Tonle Void Voin	Sand Martin	Riparia riparia	P
Tontrid Tonle	Small Pratincole	Glareola lactea	C
Lolok Bay	Spotted dove	Streptopelia chinensis	C
Ngeav Kork	Stork-billed Kingfisher	Halcyon capensis	C
Popech Tracheak Chhnot	Streak-eared Bulbul	Pycnonotus blanfordis	P
Chap Daunta Tourasaip	Striped Tit-Babbler	Macronous gularis	C
Kh'tob Dei Khmao-Sor	White Wagtail	Motacilla alba	LC
Tmart Phesh	White-rumped vulture	Gyps bengalensis	P

Kordorb Troung Sor	White-throated Kingfisher	Halcyon smyrnensis	P
Sarekakaev Krabei	White-vented Myna	Acridotheres javanicus	C
Sareka Kaev Krabei	White-vented Needletail	Hirundapus cochinchinensis	C

B. Mammals inhabiting along Se San River and near the mouths of tributaries		
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 (Phay)	Smooth Otter	Lutrogale perspicillata
Krapeu Trei	Siamese Crocodile	Crocodylus siamensis
Phay	Otter sp.	

Box 1 below provides descriptions on the characteristic vegetation types in the Ratanakiri and Stung Treng Provinces which local communities use, those that comprise habitats for wildlife and form land cover in protected areas. It includes descriptions of deciduous dipterocarp forest, mixed deciduous forest, semi-evergreen forest, wetland and aquatic flora (riparian vegetation along streams and around ponds or lakes), grassland, and bamboo groves. On the basis of forest cover map, semi-evergreen forest is only present in isolated patches by the Se San River. The main vegetation types associated with the river is presented in Table 5.14. 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; Ashwell 1998; Champion and Seth 1968; Santisok 1988; MoE 2003).

The area consists of many diverse forest habitats ranging from wetland to hill semi-evergreen or evergreen forest, although the dominating forest is the deciduous forest type and shrubland (abandoned land now covered by shrub and grassland). 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 are found throughout the forest. Mixed deciduous and semi-evergreen forests are rich in valuable trees and most of which are members of *Dipterocarpaceae* and *Fabaceae*. Many hard wood 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 river bank animals like crustaceans, reptiles, amphibians and insects) are extremely poorly known – highlighting the need for thorough surveys.

BOX 1. Brief description of the selected vegetation types associated with Se San River (Table 4.12) and those 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. The canopy trees are generally between 15-17m high, but on rich soil trees are up to 25m high. The definition of DDF is drawn from the dominance of members of *Dipterocarpaceae*, most of which are *Dipterocarpus tuberculatus, Shorea obtusa* and S*horea siamensis*. *D. obtusifolius* and *D. intricatus* are, sometimes, also in association within this forest types but not significantly dominant in both wildlife sanctuaries. The associated deciduous tall 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 were also associated in this forest type. These species are *Memecylon scutellatum* (Lour.) Naud, *Mammea siamensis* (Miq.) T. And., and *Irvingia malayana* Oliv. ex Benn. Ground species composition include *Phoenix loureiri* Kurth, *Cycase siamensis* Miq., *Dillenia hookeri* Pierre, *Arundinaria pusilla*, and certain species of *Fabaceae*, *Zingiberceae* and *Poaceae* families. All species in this forest type are fire-prone. Epiphytic orchids and ferns are fairly abundant on upper part or canopy trees, and hemi-epiphytic plant like *Huya* spp. is often found in this forest type. Forest fires, which are caused by human beings, usually occur between December and early April (dry season), and are considered a general phenomenon. Most of plants start to produce new shoots and flowers after the first rain, especially in the middle of March and April.

Many termite hills reaching up to 3m high and 4m in diameter can be found scattered across DDF. A number of particular vegetation assemblages 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 seem to be confined in this ecological zone.

Mixed Deciduous Forest (MDF). MDF is referred to a forest type, dominated by deciduous tree species which lack of or mix with few trees of *Dipterocarpaceae*. Tree and ground plant compositions are more diverse in MDF than in DDF. Species diversity and dominant species are variable within MDF. MDF can occur in narrow strips occurring between DDF and other forest types or as isolated patches inside DDF or nearby semi-evergreen forest. Dominant species at studied sites are *Lagerstroemia* sp., *Cratoxylon prunifolium* Dyer, *Terminalia mucronata* Craib et Hutch, *Dalbergia nigrescens* Kurz, *Xylia xylicarpa* TAUB and *Adina sessilifolia* Hk.f., and associated species include *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 usually a mixture of seedlings, very short treelets, subshrubs and grasses. Forest fire usually occurs in this forest type, as result of spreading from DDF.

Semi-evergreen Forest (SEF). SEF is also termed dry evergreen forest or forêts dense. This forest type is 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, Zingiberaceae*, ground fern (*Pteris venusta* O.K, *Tectaria impressa* (Fee) Holtt), and certain evergreen treelets which prefer shade are abundant. Lianas, rattans and strangler trees are frequently found in this forest type. In general, tree species can incude *Hopea odorata* Roxb, *Dipterocarpus alatus* Roxb., and *Ficus* spp. (strangler trees), *Tetrameles nudiflora*, *Irvingia malayana* and *Lagerstoemia* spp. These canopy trees can reach 25-30m high and have a 110-125cm dbh. *Lagerstroemia* spp. in SEF, different from the ones in MDF or DDF, as some never shed their leaves entirely in the dry season. Epiphytic orchids and ferns especially nest ferns inhabit on the canopy of big trees. Due to the valuable timber species in SEF (used for construction and furniture) this forest types has experience much exploitation. Many areas are covered by spiny and useless climbers. Forest fire usually spreads from MDF or DDF to the ground of this forest margin and stops because of high humidity on the ground.

Riparian Vegetation (Wetland) and Aquatic Flora. The Se San River banks vegetation that falls in the following categories include: gallery forest, riparian, riverine forest or wetland forest, ponds or small lakes that support aquatic and inundated herbaceous plant, and swamps which are dominated by stilt root trees or shrubs. Riparian forests found along the Se San River and its tributaries. 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 DDF appear as ribbon-like green feature. However, this type of forest is sometimes discontinued and replaced by DDF or bamboo forest. The change of forest features along the streams may be a result of forest fire, land clearance for cultivation or timber extraction, although this is 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 plant in the families of *Zingiberaceae* and *Araceae* are abundant in this forest type.
Ponds and small lakes occur in the area (filling up in the wet season), and most of them are dry in dry season. Characterisitc 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*).

Grassland. Grassy glades dotted with trees (on occasion) may be the result of clearing DDF for farming and eventual abandonment. The characteristic 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. Some dwarf trees of found in DDF are, e.g. *Terminalia alata*, *Antidesma* sp., *Phyllantus emblica* L., *Zysygium* sp. and *Cratoxylon prunifolium* DYER.

Bamboo Forest (BF). BF is also termed as Bamboo Grove when it is not larger than 5 hectares. It is defined by means of the dominance of bamboos in particular area. All bamboo species in this forest type comprise *Bambusa multiflex, Bambusa bambos*, *Dendrocalamus nudus* and *Arundinaria pusilla* (pygmy bamboo). Forest fire usually occurs in this forest type.
(text adapted from Hourt 2005, for more details, Maxwell undated; Rundel 1999; Hourt 2005; Mosaic 2003; Baltzer et al. 2001; Ashwell 1998; Champion and Seth 1968; Santisok 1988; MoE 2003)

5.4.3 Use of Forest and Wildlife by local people

Local communities reported collecting NTFPs from the forested areas, including protected areas. Local rangers expressed the view that as long as the local people collected NTFPs for subsistence the damage is minimal but 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 poaching. 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 protected 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 5.3)

5.4.4 Dependency on Se San River – animals and vegetation

Animals depend on the Se San 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, like at the end of the dry season, function to facilitate migration (particularly of fish) 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. Erosion which leads to suspended soil particles in the water is also detrimental to river dwelling animals (especially crustaceans).

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 river bank dropping leaves, flowers and fruit into the river for dispersal and which can be consumed by fish and other animals.

5.4.5 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, removal of bird eggs and young species by villagers, irregular water level fluctuations, sudden floods, forest clearance for agriculture, unsustainable collection of certain NTFPs, and forest fires.

5.5 Socio-Economic and Cultural Situation

Lives of the people residing along the Se San River in Cambodia are based on rice cultivation and fishery, and other natural resources utilization. The Se San River constitutes a prerequisite for the existing lifestyle in the riverside villages. Inhabitants in the villages along the river say that great changes in their resource base have taken place since the construction of Ialy Hydopower Project started. However, there are no baseline studies of the socio-economic situation of the riverside population prior to the HPP construction. It is therefore not possible to compare the present situation with a pre-Ialy situation. The present situation can no longer be considered as a “baseline” one, but a situation impacted by the hydropower plant. The situation preceding Ialy can only be envisioned by what people tell about their lives in the past. The same applies to the impacts: Many people tell about the same kind of incidents and changes that have taken place in their environment, and they compare the present situation to the past one. People tell about rapid daily changes in water levels, flash floods, drying of the river, deterioration of water quality, and riverbank erosion. Some of the recent developments like the reduced fish populations seem to have taken place partly due to overfishing and to the use of advanced fishing equipment (what can also be seen in the nearby the Srepok River), but many of the observed and reported changes in the river and its the nearby environment can be dated back to the implementation of the Ialy Hydropower Project.

The description of the socio-economic conditions along the Se San River in Cambodia below aims at creating a picture of the villages prior to the reported problems from the hydropower development in Vietnam and at reviewing the reported impacts on human lives by operation of the Ialy Hydropower Plant. The previous and present socio-economic situation along the Se San River is assessed through information from both the riverside inhabitants in the visited villages and from the district and provincial authorities met during the field study. Previous studies made in the area and the negative impacts from Ialy reported in them are accounted for in Chapter 4 above. The aim of the present study is to consider the reported and found impacts on the lives of the Se San riverside people-in as an objective and impartial manner as possible.[13]

5.5.1 Livelihoods and Subsistence Economy

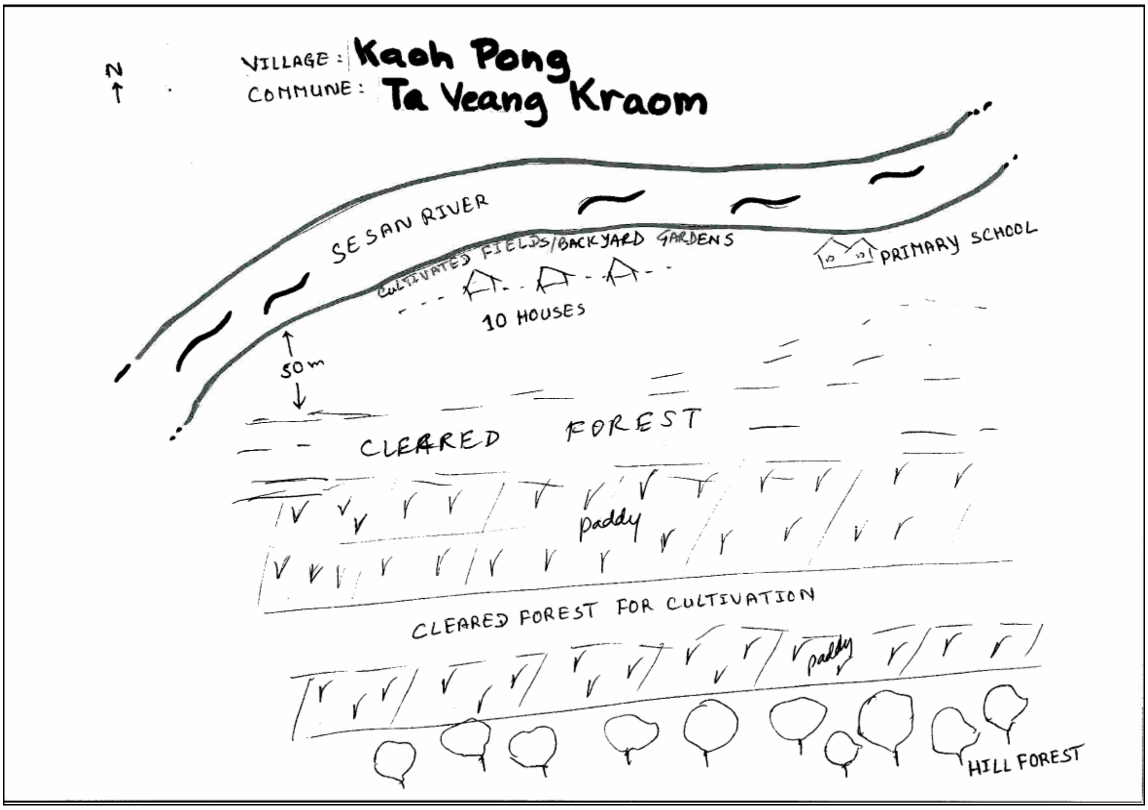
Village Setting

Livelihoods in all the villages along the Se San River are based on rice cultivation and fishery. Complementary activities like raising animals, collection of forest products and hunting contribute to nutrition and also bring some extra income. Gold panning in the river has traditionally been an important dry season activity, ensuring financial resources for buying a buffalo or a cow when needed, or rice in occurrence of a bad harvest. However, gold panning has according to a village study done in 2000 (Fisheries Office 2000) almost entirely ceased due to fear for irregular flooding and rapid water level fluctuations in the river, which the local inhabitants have experienced occurring since 1996.

In a characteristic riverside village, the wooden houses on poles of more than 2m in height are located parallel with the river along the village road; vegetables are grown close to the river, and fruit trees are grown both on the riverbank and around the houses. Rice fields are found further away from the river 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 and swidden fields further away from the village. Between the rice fields and the forest further up from the river, many villages have plantations with species like corn, watermelon and cassava.

In a typical village there is a small shop in the center of the village by the village road. The shop is a natural point for meeting and exchanging information. All the shops in the villages visited during the field study are run by women. Most households keep pigs, cows, buffaloes and chickens that roam freely in the village. See Figure 5.15 for a typical village maps.

[13] Information is based on field interviews and observations when the source of information is not given.



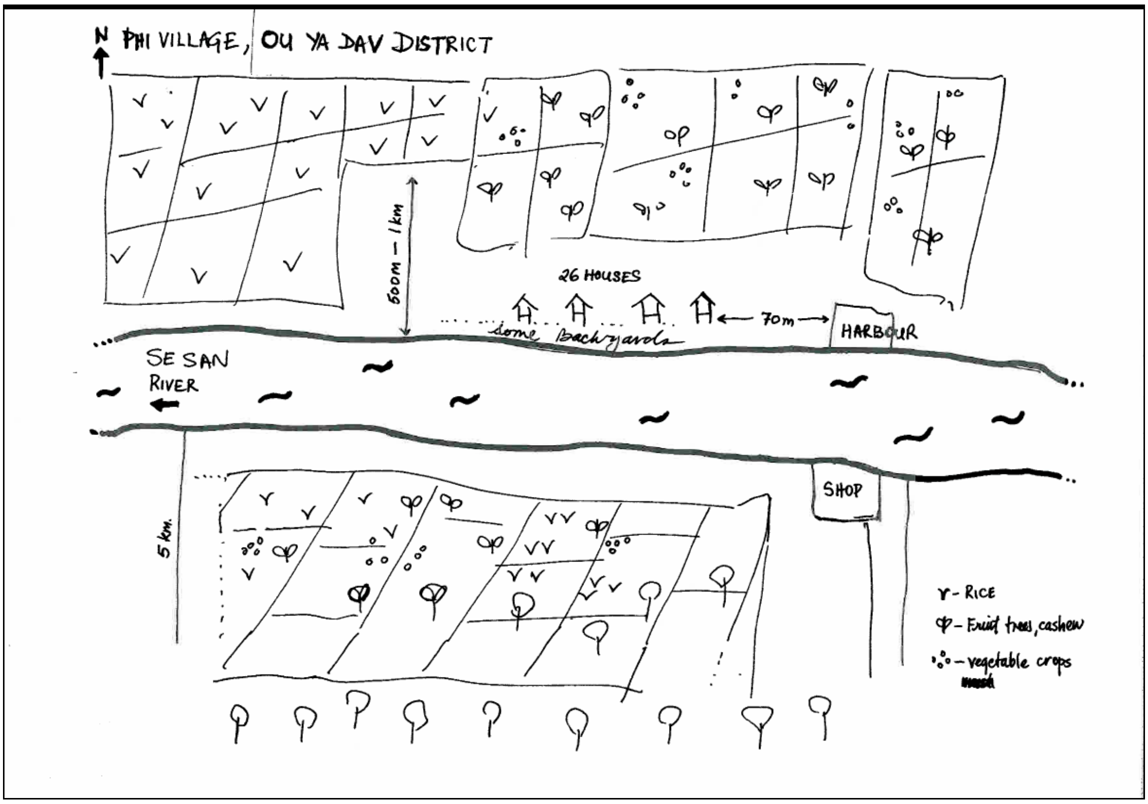


Fig 5.15Typical village maps drawn during consultation with villagers. Kaoh Pong Village in Ta veang District and Phum Phir Village in Ou Ya Dav District

Agriculture
In all the studied villages paddy is grown for one crop per year. 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 or pumps in some areas. After the rice harvest, vegetables are grown during the dry season. Irrigation water is carried or pumped up to the gardens from the Se San River, or lead to the fields from contributory streams, ponds and lakes. All cultivation is based on manual labor and neither pesticides nor fertilizers are used. A rice field size per household in general varies from less than 0.5 to 2 ha; some households have up to 5 ha of land. 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. According to the province and district authorities a permit to clear land is easy to obtain by declaring the need through the commune authority to the district government. However, in several villages people expressed difficulties and a time-consuming process in obtaining this permit.

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 below). In some villages along the Se San River cultivation land is not sufficient for food production, according to the villagers, and they are not allowed to clear more land in the forest. The forest close to the fields of one visited village seemed to be utilized by a private company or by other private interest owners: the villagers were afraid of these “powerful men”. In another village the village community expressed difficulties in obtaining rights to land clearing from authorities that requested payments the villagers could not afford (see also Section 5.3.3 above).

Households along the Se San River traditionally have dry-season gardens on the riverbanks with fast growing vegetables and corn. Main cultivation season takes place from November to April when there normally is no more risk of flooding from the river. Corn, pumpkin and onion are grown right along the river together with vegetables like morning glory, beans, salad and lettuce. Wild growing vegetables on the riverbank and in the water are also utilized for food. However, a decline in the availability of the wild growing vegetables is reported by the villagers along the river, due to high surges of water and following riverbank erosion, which also has degraded riverbank vegetation and reduced gardening areas.

Close to the river and around the houses families grow fruit trees like banana, coconut, mango, papaya and milk fruit as well as vegetables and spices. In some villages also cassava plants are located next to the houses. Beyond the rice fields away from the river many villages have plantation fields with species like beans, cassava, sweet potato, sugar cane and watermelon.

Among some ethnic minority groups like the Jarai, smoking is common (both men, women and children were seen smoking during the field survey) and tobacco plants are grown on the riverbank as well as further away from the river. In some areas like in Andoung Meas many households have started small-scale cultivation of cash crops like soybeans at a distance from the river. Cash-generating cashew nut cultivation has also been growing in importance for villagers in Ta Veaeng and Veun Sai. There are private commercial cashew nut and coffee plantations in the inner parts of Ratanakiri Province, but no ethnic minority people are growing coffee so far. Rubber Plantations are under the Ministry of Agriculture, Forestry and Fishery in Phnom Penh (ADB 2000).

Some families nowadays temporarily move up to do swidden cultivation higher up from the river during the rainy season. This is due to their fear for the irregular flooding of the river destroying rice fields close to the river. Majority of the riverside residents belong to ethnic minority groups, which originally have resided in the mountains and practiced swidden agriculture. Especially during the Khmer Rouge rule, people were relocated along the riversides and forced to cultivate wet rice. It is therefore natural for the ethnic minority people like the Brau and the Kavet to return to their old cultivation methods if life by the riverside becomes insecure. But also people who are not used to swidden agriculture are reported to have begun clearing slash-and-burn fields higher up in the forests (Fisheries Office 2000, McKenney 2001).

The food and crop plants are listed in Table 5.13 in Section 5.3.2 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 Se San River. Traditionally all households are fishing, and there are several households in each village that are specialized in year-round fishing and selling fish. A decline in fish population has been reported, both in reports by the Fisheries Office (2000) and Baird (1995, 2002), and through the interviews with local population made by the Consultant in 2005. The decline is reported to have been especially dramatic since the year 2000. Villagers along different parts of the river report the same kind of a situation; see section 5.2.2 above.

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 households specialized in fishing. 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 capital of Ratanakiri through middle traders traveling by boat, jeep or motorbike. Fish therefore constitutes both the main diet and a considerable income source for the riverside people.

However, fish in the Se San River has been significantly reduced during the past ten-fifteen years according to reports and interviews. The deep-water pools in the river that are important for fish reproduction are reported to have become very shallow. Traditionally the Lao people were rarely fishing in the deep pools of the river because they were afraid of the spirits, serpents and crocodiles believed to dwell there. 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 may offer home-made rice or cigarettes to the water spirits in order to secure the catch on a specific gear, tradition has since many years no more been strong enough to protect the dry season refuges for fish, and apparently increased fishing already prior to the construction of the Ialy Dam has affected the fish stocks in the river.

Today many people have stopped fishing due to poor catches. Fish at the provincial Ban Lung market comes mainly from Kratie along the main Mekong River. Some fishermen have moved to work along the Srepok River in Southern Ratanakiri, increasing the pressure on this river, where also a decline in fish population has been reported during the past decade[14]. According to different district officials, people also clear more land in the forests, at a distance from the Se San River, in order to compensate the reduced fish in their diets by growing more rice and vegetables. Pressure on collecting forest products as well as wild animal hunting for income and food has also increased, due to less fish in the river.

[14] The decline of fish populations in the Srepok River is reported to have taken place probably due to over-fishing, illegal fishing with explosives and poisons and due to modern gillnets.

The cultural habits connected to fishing and people's relation to the river have also been affected by irregular water levels and floods. Traditionally men used to do fishing trips of several days and sleep on the sand banks in the river. The sand banks were also used for dry season cultivation. Fear for floods has changed these habits, as people no more feel that sand banks are safe due to the experienced rapid water level changes in the Se San River.

In many villages people 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. The notion from the field study is that collecting frogs for food is more common along the Se San River than along the neighboring Srepok River where the fish resources are still rather abundant. At the Veun Sai ferry port, local women were selling roasted frogs together with roasted corn and bananas. Flawn frogs were also for sale at the Ban Lung market. However, it is not possible to assess if the habit and magnitude of eating supplementary aquatic species has to do with the reduced access to fish or not.

Fish species and fishing practices are discussed in detail in Section 5.2 above.

River transportation

Both rowboats and motorboats are utilized for fishery as well as for traveling. In the upstream villages of Ou Ya Dav District approx. 43% of the families have a rowboat but only 1% owns a motorboat. Coming downstream to Andoung Meas District, in the riverside villages only some 5% of the families have a rowboat and 3.4% a motorboat. In Ta Veaeng some 26% of the families in the riverside villages in Ta Veaeng Leu Commune and 8.5% in Ta Veaeng Kraom have a rowboat; the respective figures for motorboats are 11% and 4%. In some villages people have no boats at all. In Veun Sai District approximately 14% of the families have a rowboat and 9% a motorboat. In the Lao dominated riverside villages in Ta Lat, respective Srae Kor Commune in Se San District 83%, respectively 55% of the families have a rowboat, and 7%, respectively 20% have a motorboat. (SEILA 2004). Traditionally people without boats can borrow boats for fishing or follow neighbors on the fishing trips. During the dry season men often stay away fishing over several days and nights in places with fish and fish buyers. Women rarely accompany on these fishing trips.

All along the Se San River since 1996 people have experienced irregular water levels throughout the year and unnatural strong rainy season floods. Many villages, especially along the stretch from Andoung Meas to Veun Sai, have reported lost boats, fishing equipment and other property when sudden rising waterflow have flushed away their assets (See below in Section 6.1 and 6.3).

Fig. 5.16 Boats are used for fishing as well as traveling across and along the river. Phum Pir Village, Ou Ya Dav District

Forest and Wildlife Utilization

People living in the riverside villages have a long tradition and knowledge in utilizing many types of forest products for food, medicine, shelter, household utensils, and for generating 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.

According to a study in 1997 (Bann, quoted in ADB 2000) the estimated net present value of NTFPs per ha in Ratanakiri Province far exceeded the value of timber logging (USD 3,922 compared to USD 1,697). NTFPs definitely have a high economic and cultural value for the ethnic minority households, even though the value is not exchanged into money and consequently not shown in any statistics.

Wildlife hunting has been a very important activity for food and income for generations in Ratanakiri Province. Elephant trapping was in the past a major activity. In the 1990s, wildlife trade was expanded with more species being traded through expansive networks in the area.

However, during the past few years, wildlife collection has decreased, due to both law enforcement and increasing control and to the establishment of environmental and wildlife protection areas. The villagers met during the field study say they nowadays 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, which definitely is larger than the villagers admit. Wildlife collection of turtles, lizards, pangolins, deers, wild boars, etc. certainly still is an important activity and income source for the local people, and there are many wildlife traders in the area (Fisheries Office 2000, NGO Froum 2005b). Deer meat is also sold at the provincial market in Ban Lung and along the roads in Ratanakiri.

Forest products collected and hunted are listed in Table 5.14 in Section 5.3.3 above, where also more information is found on forest products utilization.

Domestic Animals

In a typical village domestic animals move around freely. They are kept both for food and for income. Pigs and dogs take care of the household waste. Chickens and ducks are raised both for family food and for selling. Practically all households along the Se San River own poultry. Buffaloes are mainly draught animals and also used in religious ceremonies. Cows are mostly sold in order to generate cash. In the downstream areas in Se San District, all families have cattle and pigs. In Veun Sai some 61% of the families have cattle and pigs. In Ta Veaeng riverside areas approx. 30% of families have cattle and 70% pigs, and in Andoung Meas 50 % and 70%, respectively. In the upstream villages of Ou Ya Dav District 37% have cattle and 88% pigs. 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.

Yearly diseases occur among 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 is probably *Pasterela Moltosida*, which can be stopped by vaccination. According to the discussions with villagers, more deaths of cattle have taken place during the previous year along the Se San River. Many people met during the field study had also recognized an increase in animal diseases in the year 2004.

Many people blame deteriorated water quality for the increase in cattle diseases. Yet, epidemics have occurred likewise in the areas far from the Se San River and no general water quality decline in the river has been confirmed. Regualr outbreaks of domestic animal diseases have taken place in the whole Ratanakiri Province during the past ten years. Not least increased animal trade and people's mobility has contributed to contagious diseases spreading. However, villagers notice that some very rapid death cases of cattle and buffaloes have taken place after these have been drinking water from the river. These sudden deaths might have been caused by seasonal toxic algae contamination in the river (see also Chapter 4), however due to lack of data, this can not be confirmed.

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, but selling handicraft products seems to have little importance in the riverside villages. Gold panning has traditionally been the most important cash-generating seasonal activity.

Cashew nut and soybean cultivation has been gaining in importance during the past few years. 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 are run by women. Among Khmer and Lao it is quite customary that women are involved in small trade and small business activities, but also in ethnic minority villages it was women who run the trade business. Salt, kerosene and other items for lighting, fishing equipment, cooking and washing utensils, clothes etc. are traded in the village shops.

5.5.2 Water and Health

Household Water

The most common household water source in the villages by the Se San River is the river itself. The number of wells is still 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 data (2004).

The most well-off families may have dug wells, but in most of the villages along the Se San River visited during the field study, wells are missing. Some of the existing wells are not used due to muddy water or problems with pumping up the water. New wells are being constructed by NGOs like the German Agro Action in many villages, also providing people with filtered water containers. However, according to the provincial officials, in many villages clean water projects fail, because people are used to using river water and find it easier to take their water from the river than from the well. The estimate made by interviewed village and district chiefs was that approx. 50% of the whole population boils their drinking water, but the habit of boiling water varies greatly from village to village. Yet it is clear that awareness raising on water and health issues is urgently needed in the villages along the Se San River.

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 may spoil a large part of the yearly produce. Flooding appeared different in various sections along the river, leading to diverse consequences, but rarely damage of houses. People suffering from the loss of their crops (rice and home gardens) received assistance from the Provincial Government, District Health Center and NGOs like Health Unlimited cooperating with the health authorities. This support consisted of aid with temporary relocation, rice supplies and chlorin tablets to prevent epidemic diarrhea caused by unclean water.

According to province and district authorities and villagers, natural extreme floods during the rainy season occur every 5 –7 years. During the rainy season of 1996, water level in the Se San

River rose extremely high, lasting some 5 days. According to the people this was a natural extreme flood caused by heavy rains and run-off from higher areas. During the fieldwork in different parts of the Study Area, people pointed out the height of the water level in 1996 they had marked on house poles and on the wall of the DHC (in Veun Sai) and District Office (in Ta Veaeng) at the height of 1.8 m for a house at the distance of 150m from the river.

Again, in 1997 and 1998 water levels were unusually high during the rainy season. People all along the river tell about big floods again in the years 1999 and 2000.

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 District Health Centers with severe diarrhea are children. DHCs provide villagers with chlorin tablets to clean drinking water during extreme floods 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. From the village interviews and the information from DHCs it can be estimated that approximately 10% of the riverside population suffers from malaria.

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. 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, especially among children. According to the Provincial Health Department, there is no baseline data on the frequency of skin problems prior to the past few years and it is therefore not possible to assess changes in the disease occurrence. However, a significant increase was recorded in the years 2004 and 2005 by the province and district health authorities. According to the Health Department skin problems were then occurring throughout the year and not only in the riverside areas.

Diet and Health

Fish and rice constitute the cornerstone in the diets of the people residing close to the Se San River, added with both planted and wild growing seasonal vegetables. In the past fish used to be abundant in the river, and in all the villages fishing was a daily activity. Fish is the most important protein source in the human diet in the Study Area. 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 the gardens close to the river. In many villages, banana, mango, milk fruit and other fruit trees are grown 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 today wildlife hunting is restricted. However, hunting habits appear to vary from village to village and the importance of wildlife is therefore 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.

The nutritional basis of the people residing along the Se San River has been changing notably during the last 10 years. Fish catches have been significantly reduced and people have lessened riverbank cultivation both due to erosion and to the occurring high floods, which make the cultivation situation unreliable. Reduced fish cannot be replaced by meat from domestic animals, as people cannot afford eating the income source these constitute. At the same time wildlife hunting has met with restrictions. There is no reliable information on the potentially deteriorated nutritional status of the riverside people. However, in the visited Brau ethnic minority village of Tumpuon Roeung Thum in Ta Veaeng District children were noticeably undernourished. Women interviewed in the village had experienced high floods reaching the village and the rice fields beyond the village, and they were afraid of the river.

Health Care

In every district there is a District Health Center 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 Ratanakiri 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 and 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 to bring water and sanitation competence and facilities into villages. Child vaccination campaigns are brought into villages, and consequently the under five mortality has been reduced considerably during the past ten years.

Fig. 5.17 Veun Sai Health Center

Utilization of health care services depends both on distance and transportation conditions to the District Health Center. 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 District Health Center 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 make regular check-ups of pregnant women in the villages as well. District Health Centers also cooperate with the traditional midwives and have invested in increasing their competence through training projects.

5.5.3 Cultural Significance of Natural Resources Utilization

The livelihoods, culture and lifestyle in the villages along the Se San River are entirely based on utilization of available natural resources and on closeness to the river. Villagers strongly recognize the importance of the Se San 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 access to 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 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 Se San River some areas traditionally were scary for humans due to the spirits believed to dwell there. These areas appear to be the deep water pools that are important for fish reproduction.

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 the 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 Se San 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. Lao 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.

Fig. 5.18 Entrance to a burial forest near Veun Sai

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 under this customary 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 do fishing or collecting forest products, but not to clearing 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 of 2001 communal land 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. (NGO Forum 2005a).

The Forestry Law (2002) and its Sub-decree on Community Forestry Management (2003) 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 Ratanakiri. 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 is increasingly attracting outside actors to the area. At the same time, in parts of the province local communities’ land management is restricted by establishment of protected areas such as Virachey National Park.

The 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.

5.5.4 Organization of People

There appears to be a great awareness about the problems occurring in the Se San River among the provincial and district staff in Ratanakiri and Stung Treng provinces. Persons met during the field visit in different provincial ministries were well prepared to give information and to discuss problems they consider to be caused by the Ialy Hydropower Project in the river. At district and commune level people have mainly been organized by Se San Protection Network, an NGO closely connected to and supported by e.g. International Rivers Network, Probe International and Oxfam America. Their work in the area is aimed at “stopping hydropower” (personal communication) through documentation and information dissemination both to the local people and internationally, referring to international environmental and human rights laws and policies. Most of the available information of the past and current developments along the Se San River in Cambodia is initiated or supported by NGOs like Se San Protection Network, NTFP Project and Oxfam America. People’s resistance is coordinated and lead by international NGOs, which together with the villagers have compiled a list of demands and recommendations to the Vietnamese and Cambodian authorities responsible for the negative impacts they consider to be caused by hydropower development in the Se San River (see 3 S Newsletter, August 2005.

6. IMPACT ASSESSMENT

This section highlights potential significant adverse impacts of the construction and operation of hydropower projects in Vietnam, which will result in changes to the baseline situation in the Se San River in Cambodia. Prior to describing these impacts the section elaborates on impacts from the Ialy Hydropower Project as found in the study. The operation scenarios described in Chapter 2 and in the Hydrodynamic Modeling Study (DHI 2005) are taken into consideration when potential impacts are assessed.

6.1 Impacts from the Ialy Hydropower Project as found under this study

6.1.1 Impacts on Water Quality

Water temperature
The water for Ialy Power Station is withdrawn from the deep water of the Ialy Reservoir. The temperature can be approximately 2-3 degrees centigrade lower than normal just downstream of the reservoir, but this will not be notable in Cambodia and is not expected to create any problems. There may be some small delay on the hatching time of fish eggs in the Vietnamese part of Se San River. If the fish larvae then are released at an inconvenient season, it will have a negative impact of fish biomass in the downstream part of the river. This type of impacts is found in more temperate- and northern climates when the temperature reductions downstream the dam can be up to 10 degrees centigrade. The knowledge about these possible impacts is insufficient in tropical/semi tropical climate.

Erosion
Based on observations during the field survey, the Consultant assesses that the Ialy regulation has created increased erosion, which has increased the turbidity of the river water. The turbidity is coming both from erosion in the reservoir, but also from increased erosion in the downstream river. The daily water level fluctuations are an important source for this increased erosion. Some accidental flooding due to high water releases might also have created great erosion with high turbidity in the water. Increased erosion gives more turbid water, increased siltation and sedimentation. This has reduced the living conditions for several groups of aquatic life, including fish, as well as reduced the suitability of the water for several human water use categories.

The downstream impact of erosion in the reservoir sides will last 2-3 years after commissioning of the power plant, as most of this material will settle in the reservoir itself. In the long run a reservoir will trap sediments making the water downstream clearer. Erosion from the Ialy Reservoir will therefore be minimal at this stage, however, erosion from new reservoir(s) under construction will have future impact.

Erosion due to daily water fluctuations will continue as long as the daily water level fluctuations continue. For the Se San River this will remain until the Se San 4A Re-Regulation Reservoir is commissioned.

Fig. 6.1 Bare base of trees and soil slowly eroding at Pa Kalan Village, Veun Sai District

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.

The report from the Fishery Office (2000) describes water quality problems related to humans and animals health. That may indicate eutrophication problems with blooms of toxic blue green algae. People got itchiness from swimming in the water. The itching lasted only about 1-3 hours after the swim. They got also eye and respiratory irritations. The water had often a strange red color, and a bad smell. The same report says that domestic animals died from drinking the water and also claims that many people died from complications related to drinking the water.

People interviewed in the villages said that the itching problems mainly occurred in the period April-June. The itching problem was well described all along the river, and it was said that it was more or less gone now. It was during the summer 2000 that the itching was a great problem. Some places they also told that household animals died or got sick from drinking the water. Some places the deaths and disease of household animals were tightly linked to the water quality, but other places they were not so sure.

The death of people was not clearly linked to drinking the water from the Se San River according to interviews. In fact people (Village chiefs, elder people, fishermen) did not mention this problem when they were telling what happened in the years after the Ialy regulation. When they were informed about what was written in some of the NGO reports on people deaths, they could not confirm this. The death of household animals was however confirmed in many of the interviews.

The symptoms described in the earlier reports (the Fishery Office Report 2000, and other NGO reports) fit very well with impacts from blue green algal toxins.

The itchiness from swimming and bathing can arise from several algaes. Most common is blue-green algae *(Cyanophycea)*, but some *Chrysophycea* (*Gonyostomum sp*) can cause itchiness. They have some kind of surface sacks containing irritable liquid which burst when you come in contact with them, like the nettle. This itchiness lasts only a few hours.

The other common source is the so-called “swimmers itch” which arise from a “wrong attack” from a type of water-bird parasite, a flatworm called shistosomes. They have free swimming larvae that are looking for a duck or a goose, but also attach to bathing humans. They penetrate the skin and the itchiness starts. After some days (up to 3 weeks) they recognize that you are not a duck and they leave your skin. This itchiness lasts for several days to weeks.

The described symptom with regard to respiratory problems and vomiting and death after drinking the water, can be caused by two organism groups which under certain conditions occur in fresh water. These are 1) blue-green algae (several species) and 2) the bacteria species *Clostridium botulinium*. The blue-green algae can produce 2 types of toxins, hepatotoxins and neurotoxins. Neurotoxins can cause death just after some minutes after the water has been ingested, while hepato-toxins often takes hours to days before death. In both cases repiratory problems is the most common direct cause of death. The bacteria cited produce the toxin botulin that also is extremely toxic and can kill large animals in short time. It is not likely that botulin is the problem here, algal toxins are much more likely.

The water quality study (chapter 5.1) found low concentrations of algal toxins in the Ialy Reservoir, and it was found algal species (Microcystis sp) that are known to have the ability to produce toxins. The toxin concentration was however low, only 0.04-0.07 µg microcystin per liter. In Se San at both Phum Phi and Veun Sai, the concentrations were below detection limits. World Health Organization (WHO) has set 1 µg microcystin per liter as a limit for drinking water. To be acute toxic for humans the concentrations has to be close to one milligram per liter.

In lakes there are several incidents of livestock animals dying from drinking water with toxic blue green algae. This happens when the algae for some reason floats to the surface, and the wind is transporting them in large densities to the lo-ward end/side of the lake. If a cow, or other animals, comes down to the lake and drink from this strongly green water (may also be of reddish color (some *Planktothrix* species), they can die short time afterwards.

In rivers like the Se San we have not found any incidents of acute killing of animals drinking the water as described in the Fishery Office report (2000). But outlet rivers from eutrophic lakes can contain sub-lethal amounts of algal toxins. The long term impact of microcystin is slowly reducing the liver function, and may become lethal in combination with other liver diseases, e.g hepatitis.

In the monitoring data from May 2001 (the year after the problem was described) nothing indicated high algal biomasses or eutrophic conditions. Neither did the data from 2004/2005. In fact the data from the Srepok River indicated higher algal concentrations than in the Se San River (SWECO 2005). In monitoring from the Vietnamese side in Nov 2004 (provided by PECC1), however, it was observed very high concentrations of total phosphorus in Sesan River just downstream the entrance of the tailrace water from Ialy Power Plant. As the water is withdrawn from the deep water of the reservoir, this can indicate that it takes place accumulation of phosphorus in the deep water which in periods can stimulate algal growth in the downstream river. However, as there are only two water samples from the tailwater, it cannot be drawn a secure conclusion on this. The data sampled during the Nov/Dec 2005 during our field mission showed very low algal biomasses, and nutrient concentrations. This is however, in a season when the potential for algal growth is low in Se San River. Highest algal growth is anticipated in the months April, May and June.

It is not likely that chemicals used during the construction can have caused the deaths. Samples taken during the field survey in December 2005 showed only very low values of heavy metals, which are far below all standards for human use or environmental impact. Analysis for 55 commonly used pesticides did not reveal any positive hit above detection limits. These limits are well below all standards for human water use categories. Nitrogen and phosphorus concentrations were low, and within the oligotrophic levels. Total nitrogen was in the range of 250 µg N/l and total phosphorus 7-15 µg P/l. Taking into account the P connected to erosion material, these is low values.

Toxic algae

It seems very likely that, during the first 2-3 years (1998-2000) after filling the reservoir, there have been incidents with toxic blue green algae, which have given water quality problems in Se San River in Ratanakiri. There is no doubt that people got itchiness from bathing in the Se San River in that period. Local people told that in all interviews. Interview with Ian Baird also confirmed this. He had experienced it himself when taking water samples. Likewise, there are numerous observations about people who got stomach ache, head ache as well as respiratory problems from drinking the water. The water also smelled badly.

The reported problems occurred mainly in the period April-June, with May as the worst month. It is reported that a large number of household animals died in that period. The report from the Fisheries Office (2000) describe that several people died from drinking the water. Interview during the field study confirmed most of the above-mentioned problems, but not the death of people due to drinking the water from Se San River.

Based on the analyses of water and algal samples both from Vietnam and Cambodia, as well as from interviews, algae may have developed in the river downstream of Ialy due to release of nutrient rich bottom water from the Ialy Reservoir. There are some tropical/semi-tropical filamentous blue-green algae of the genus *Lyngbya (cf woolei)* that can give exactly the same symptoms as described. The water can be toxic and produce itchiness. The alga is often called “fireweed” because of the burning feeling to the skin after bathing. This species also gives the water a bad smell, which also was described in several incidents of toxic water (cf the Fishery Office report from 2000). Drinking the water containing this species gives respiratory problems, headache and stomach ache. This species can grow both in reservoirs and rivers, and develop during periods of bright sun and warm weather. Blooms of this alga can also kill fish. These algae were not found during the field survey in Nov/Dec 2005, but the algal problem is most likely to appear in the period April-June. In the survey in Nov/Dec 2005 algal toxins (hepatotoxins), were found in the Ialy reservoir but not in the downstream river.

In general high concentrations of algal toxins have been shown to kill livestock animals, but in such incidents they have been drinking water looking like an algal soup. From water quality data (from 2000 and 2004/2005) and the data collected during the field study late 2005, the concentrations of algae could not have been high enough to create such conditions in Se San River. The Vietnamese monitoring data from 2004 showed very high concentration of phosphorus in the river just downstream of the tailrace outlet from the Yali hydropower plant which is drawing water from the deep water of the reservoir. The possibility that it has happened short incidents of blue green algae blooms cannot be excluded.

Most analyses of the water quality material, both from the Nov/Dec-2005 survey and the earlier data indicate that the Ialy reservoir will not create conditions for such incidents of algal toxins any more. However, to be sure about this conclusion, water samples and algal samples (both planktonic and benthic) should be taken towards the end of the dry season (April-June), and analyzed for nutrients, algal toxins, and algal species composition. In addition the concentration of oxygen and nutrients in the deepwater of Ialy should be monitored with sampling every month over an annual cycle. The new reservoirs under construction can give a new period of nutrient rich water that can create problem algae. The water should be monitored with respect to algae species composition and the algal toxins.

Contamination from other toxic chemicals
The reported water quality problems experienced in Cambodia are most probably not caused by other chemicals from human activity, like heavy metals, organic micro pollutants, pesticides. This is confirmed by the water quality studies. Algal toxins are the only explanation that can be seen

6.1.2 Impacts on Aquatic Life

Impacts on the primary producers
The input of edible organic material (energy input to the aquatic food web) in a river like the Se San is coming via photosynthesis from benthic algae (periphyton) and mosses, as well as from some phytoplankton, and some submerged macrophytes. In addition, litter-fall from riparian forest is an important energy input. Increased turbidity of the water will reduce the light transparency of the water, reducing the primary production of benthic algae, mosses and phytoplankton, and the submerged macrophytes. The algae and mosses will also be intermingled by settling of erosion material, which also reduces the light that reaches the plant cells. As there has been considerable shoreline erosion, the “overhanging” trees are reduced in numbers and less leaves etc, are falling in the river. It is assessed that the daily water level fluctuations have created problems for aquatic macrophytes.
Impacts on bottom animals
Bottom animals like insect larvae, crustaceans, shellfish, worms, etc. is the most important fish food in rivers. Some of these lives from eating periphyton, other lives from eating the bottom sludge, digesting the organic material it contains, and some are eating terrestrial leaves that have fallen into the river. The erosion and later settling has made the sediments of the river bottom inorganic, and thereby less nutrient-rich. It is assessed that the periphyton production has declined, and it has also been intermingled by inorganic erosion material making it less digestible than before. Daily water level variations in the low flow season imply that the water covered (wetted) areas varies a lot. The withdrawal of water is often too quick for the worms, mussels, snails, and other slow bottoms animals. They die from the periodically drying up, and it is therefore likely that the effective bottom animal producing areas (habitat) have been reduced in Se San River by the Ialy regulation.

It is also assessed that many of the bottom animals eaten by man (crabs, clams, and some shrimps) have also faced problems due to the regulation.

Impacts on fish
It is assessed that fish have been impacted in several ways:

- Increased turbidity has made it difficult for the hunters to find their prey
- Reduced food for the fish due to negative impact on lower tropic levels (see above)
- Filling in the deep areas of the river giving problems for the fish to survive in the dry season
- Changed flow pattern has confused the fish in the start of their migrations, particularly the reduction of the triggering flows in the beginning of the wet season (due to filling the reservoir)
- Inadquate flooding of wetlands, forest and tributaries which implicate that many fish species have problems with reaching their spawning grounds
- Siltation of rapids has given problems for the oxygen supply to fish eggs and larvae (apply to fish species that spawn in rapids)
- Many fish habitats are destroyed due to sedimentation, other by erosion

There are reasons to believe the Ialy regulation has impacted the fish stock and species diversity seriously. According to the interviews with village chiefs and local residents in villages along the river, fish yield has been reduced to 10-30 % of what it was before. A major part of this decline is likely caused by the regulation, even though increased fishing pressure also has contributed. The decline is also indicated by fewer fish from Se San River at the fish market in Ban Lung, which used to be the dominating source 10 years ago. The size of the fish has declined. Before the regulation the fishermen often caught big fishes of 20 kg and more, now the fish weighs from 0.5 -2 kg. See section 5.2.2.

6.1.3 Impacts on Water Use

Drinking water

In the first years after the Yali regulation, it is assessed (by interviews and NGO-reports) that the water had increased content of suspended sediments (erosion material), and most likely algae produced from nutrient released by decomposing terrestrial litter in the reservoir. This has most likely caused problems for the Cambodians with respect to the use of the water as untreated drinking water. The algae made the water smell badly, and they had some toxic effects of skin irritation, eye irritations, as well as respiratory problems, headache and stomach ache after drinking the water. These are all typical symptoms from some blue green algae, most likely of the genus *Lyngbya* (cf *L. woolei*). This impact is no longer a problem arising from the Ialy regulation, but some of the same impacts may appear again due to the new regulations that are under implementation.

There seems to have been many periodic water-related health problems in the area, but the magnitude of these is not possible to assess due to the lack of proper data.

Swimming and bathing

Villagers stated that swimming and bathing has been a problem in the first years after the construction of Ialy Reservoir. Toxic algae could have caused itchiness and skin irritation. If this was caused by algae growth from the Ialy Reservoir the first years after commission, it may happen again when the new regulations are set in operation. In the long term these problems will disappear.

However, district and provincial health authorities confirm that the problems with itching skin are prevalent in all areas, not only along the Se San River, and related to rainy season water parasites.

Washing

Local people stated that in the first years after the Ialy regulation the increased turbidity of the water gave some reductions in the suitability of the water for washing. This is no longer a problem arising from Ialy, but it is now starting to be turbid water again in Cambodia due to construction works related to the new projects in Vietnam.

Navigation

For the people living along the Cambodian part of Se San River, the river is the main road. Most families have a boat that is used for transport across the river and along the river. The transport along the river is risky in some places due to rapids with submersed rocks. If the water becomes turbid, it is difficult to see the submerged rocks, and accordingly the boat transport will be more risky. The Yali regulation does not cause this impact any more, but the new regulations may have the same effect.

Local people reported that unexpected flooding that took place at irregular intervals from 1996-2000 and destroyed many boats and harbors along the river. After the Ialy Reservoir was filled in 1998, unexpected rise in water level might be caused by spillway releases from the reservoir. Flooding before the reservoir was filled, is asseses to be natural floods.

Water level is also important for the use of boats, particularly in the dry season. Normally, regulations like in Vietnam, result in higher water flow in the dry season, and thus the boating should be facilitated in this period (if the turbidity is kept low).

Fishing

It is assessed that the Ialy regulation has reduced the fish stock, fish size, and species composition in Se San River to levels where the fisheries no longer can supply the population along the river with the necessary amount of proteins. This has been reported by all the people interviewed during this study, and confirmed by fewer fish from Se San River in the fish market in Ban Lung compared to before. Some ten years ago Se San River was the main source of fish at the fish market in Ban Lung, but now fish came from Kratie in Mekong. The mechanisms behind the reductions in the fish populations are described earlier in this chapter.

The assessed impacts on the fishery can be summarized as follows;

- Reduced fish catches (down to 10-30 % of previous size) due to reduced stocks. The Ialy hydropower regulation is a major cause for this decline.
- Reduced fish sizes due to shift in species composition, but also due to reduction in growth rate
- Some species have more or less disappeared, e.g. *Cirrhinus microlepis, Wallago leeri, and Pangasianodon*
- The fish has taken another spatial distribution and it will be necessary to fish in other places than today.
- Fishery has been particularly poor in the dry season, most likely because the fish migrate out of the river in their search for dry season refuge
- More dangerous boating due to turbid water (difficult to see the submerged rocks)
- There has been a great loss of fishing equipment due to sudden releases of water
- Reduced catches have sent the fish buyers to the Mekong mainstream (e.g. Kratie) because of un-secure delivery from the Se San River
- The local residents cannot longer subsist only on fish as protein source, and they have to use more livestock animals as food or develop aquaculture

6.1.4 Impacts on Land, Agriculture and Biodiversity

Based on the present conditions as presented in Chapter 4 (land and biodiversity) impacts can be grouped into the following:

- River Bank agriculture is highly reduced at present due to the high water level fluctuations and flood episodes, and weak bank slopes. Backyard gardening is also hindered due to the unpredictable water level situation. A general abandoning of river side agricultural areas may be increasing. River related vegetation used by local communities for food is reduced.
- River Banks more vulnerable to slippage and erosion are due to the water level fluctuations. There are more steep bare river bank slopes at present than before, this is due to bank slippage and not necessarily due to the removal of trees/shrubs.
- Rice cultivation is impacted by the lack of ample water levels at the onset of the wet season, as well as too much water during floods. Vegetable lots are impacted similarly.
- Animal populations (e.g., birds, reptiles, crustaceans, insects) have been impacted by high water level fluctuations in that several species have their nesting, breeding and foraging areas associated with the Se San River water, sand banks and river banks (see also specific study by Claassen 2004 on sand bank birds and other observations). Predation and removal of eggs by villagers and domestic animals also has a significant impact on eggs of sand and river bank birds. Increased erosion leads to increased sediments which have adverse impacts on aquatic animals and some plants.
- The riparian environment, in general, is impacted by the erosion levels and water fluctuations – thus ecosystem impacts may be substantial but the lack of biodiversity knowledge, among other data, limits this assessment.

Fig. 6.2 Erosion at Pa Kalan Village, Veun SaiDistrict – see red clay band below trees along the river slopes

6.1.5 Impacts on Socio-Economic Issues

The experienced negative impacts from Ialy Hydropower Plant on the environment in and along the Se San River have affected lives of the people residing in the downstream villages in Cambodia. A summary and analysis of the found impacts on human lives, health, economy and culture is elaborated below. Some reported developments told by people and reported by NGO sources are also taken up and commented in Chapter 4 and below. Not all of these impacts can with certainty be related to or confirmed to be caused by the construction and operation of the Ialy Hydropower Plant. However, all the developments taken place during the past ten years together have affected and changed the living conditions of the riverside people, and mitigation of the impacts from Ialy as recommended in Chapter 7 should be considered in the present overall context with partly changed living situation of the affected people.

6.1.5.1 Changes in the River Affecting Human Populations

Changes in Water Levels and Water Flows

People living along the Se San River in Ratanakiri and Stung Treng provinces in Cambodia have experienced changes in water flow patterns in the river during the past ten years. According to the field study, the water level changes have been felt hardest in the lowland areas of Ta Veaeng and Veun Sai districts. Here the riverbank is rather low in many parts, which makes the villages along the river vulnerable for floods and raising water levels. People have experienced both heavy floods, sudden water level changes and daily water level fluctuations. All these deviations from the natural water flow patterns have greatly impacted the daily lives of people living along the Se San River.

Reduced Fish Catches

All along the river fish populations and catches have been reported to decrease. A decline in fish stock has also been noticed in the neighboring Srepok River, also running from Vietnam through North-Eastern Cambodia to Mekong. Reduced fish is probably partly due to illegal fishing and more effective modern fishing equipment, but the decline in the Se San River is far more serious than in the Srepok River. Fish catches in the Se San River have been reported to have declined significantly since the year 2000, see section 5.2.2.

Deteriorating Water Quality

People along the Se San River in Ratanakiri experience that water quality in the river has deteriorated. During floods the water has a red color and is turbid. Many interviewed villagers also reported that the water often smells bad and is muddy. People moreover connect human and animal diseases with the experienced water quality in the Se San River, according to various interviews in the riverside villages. However, the field study has not been able to confirm neither poor water quality nor animal diseases caused by the river water.

6.1.5.2 Impacts on Human Lives

Impacts on Food Production and Collection

Changes in water levels and water fluctuations have made deep impacts on the daily lives of the people living along the Se San River in Ratanakiri and Stung Treng provinces. People experience conditions in the river now as unpredictable, which confuses and frightens them. Many people, especially ethnic minority women, are afraid of the river and try to avoid going down to the riverbank.

The unpredictable water levels have caused changes in the cultivation patterns and utilization of the river and the riverbank areas. Riverbank erosion has increased, which combined with insecurity of the water level has reduced or ceased riverbank cultivation. Vegetable cultivation that used to take place on the riverbank has in many places been moved higher up from the river.

Moreover, erosion has reduced the availability of wild growing riverbank species, which previously were collected for food and medicine. People now collect more of wild growing forest products for their food, which potentially increases exploitation of NTFPs.

Impacts on Health

Most inhabitants along the Se San River in Ratanakiri lack access to wells and therefore take their drinking water directly from the river. Domestic animals depend on the river water as well as on forest water found in lakes and ponds. Many people report an increase in problems with itching skin after bathing in the river. According to the District Health Centers and Provincial Health Authorities there was an increase in skin diseases in 2004–2005. Some health care workers also noticed an increase in 2000–2001. Health care workers and authorities confirm that an increase has taken place not only among the Se San riverside population but also in the highland population and cannot herefore be connected to water in the Se San River only. Itching skin is a common rainy season problem in Ratanakiri, caused by a skin parasite living in muddy water, prevalent both in low- and highland waters. According to the Ratanakiri Provincial Health Department, there is no previous baseline data on the frequency of skin and the experienced increase is therefore not possible to assess.

People claim the experienced changes in water quality in the Se San River on “the Dam in Vietnam”. They also consider that an increase in cattle diseases leading to deaths of cows and buffaloes is caused by bad water in the river. However, according to the health authorities epidemics have occurred both in areas close to the Se San River and in uplands far from the river and consequently cannot be related to the river water. Experienced water quality problems in the Se San River started occurring at the same time with increased outbreaks of epidemic domestic animal diseases in the whole Ratanakiri Province (Fisheries Office 2000). Increased animal trade and people’s mobility have contributed to spreading of contagious diseases like foot and mouth disease in Ratanakiri during the past years. Reported sudden cattle deaths might have been caused by seasonal toxic blue green algae in the Ialy Reservoir contaminating the water in the Se San River and potentially leading to both itching skin, digestive problems and poisoning (See section 5.1). However, as there is no available water quality data during the seasons for potential toxic algae development in the first years following the reservoir filling, the cause of the reported sudden cattle deaths has neither been possible to confirm nor to be related to the river water quality.

In Fisheries Office 2000 report also human deaths due to contaminated water are reported. Up to almost 1,000 human death cases are counted in this report, and consequently referred to in several later reports, newsletters and press releases. These death cases are reported to have taken place during 1996 - 1999. However, during the field survey no human deaths were mentioned in any of the visited villages. Neither District Health Center staff nor the provincial authorities had any notice or records of an increase in human deaths since the construction of Ialy Hydropower Project. If such a dramatic number of deaths have taken place due to water quality problems and sudden floods, it should have been noticed by the health care staff in District Health Centers who keep record on the inhabitants in all the villages. On the other hand, the time that has passed might have reduced both the water quality problems and the memory of death cases. It is also stated in the Fisheries Office report, that the reported death cases cannot with certainty be connected to water quality problems.

Impacts on Nutrition

Declined fish catches in the Se San River have lead to less fish in the diet of the riverside people. Their main daily food consists of fish, rice and vegetables. Fish is the major and most important protein source in the diet. Less fish in the basic diet imply decline in the protein intake, unless fish can be replaced by another equivalent source of protein. At present there are no alternative daily protein sources to fish, as villagers cannot afford eating meat: Livestock is kept for selling in order to generate cash, and cannot be consumed by households.

At the same time riverbank and sandbank cultivation as well as collection of wild growing vegetables on the riverbank have decreased due to erosion and irregular water level fluctuations and flood occurrences. The variety in the traditional nourishment has consequently decreased.

In the long run, malnourishment, especially for the growing children, and consequently, deterioration of health status is expected, unless viable alternative protein sources to fish can be introduced and the lacking riverbank vegetables can be replaced by other species with equivalent nourishment content.

Impacts on Communications
In parts of the Se San River catchment, the road network is poor or non-existing. Boat transportation has traditionally been the most common way of traveling and transportation for the riverside population. Along most of the river motorbike transportation is replacing boat transportation when road access to villages is improving. However, some villages still lack proper road access and boat transportation is the main communication channel for the villagers.

It is reported (field data and Fisheries Office 2000) that many boats have been lost in high floods In Ba Kham hamlet an elder man told the field team that he previously owned 5 boats but had lost them all together with his fishing equipment in the flood year 2000. The whole village had lost 17 of the totally 20 boats. There is no baseline data on the number of boats in the villages prior to this time, but the low number of boats today in the most flood-affected areas indicates a loss of property during the flooding that year. An estimate made on the costs of lost assets due to floods that in the report are blamed to be caused by Ialy HPP in the Se San River in Ratanakiri Province in 1996-1999 state the number of boats to almost 1200 (Mckenney 2001). During this period several incidents of extreme high natural floods occurred in the area.

Reduced number of boats has had a great impact in reducing boating, fishing and traveling on the river. Moreover, turbid waters and the occurred changes in water levels caused by the operation of Ialy have made people more cautious with boating. This development implies not only a change in the traditional culture, but may also affect contacts of the most remote villagers with other villages and areas.

Impacts on Economy
Gold panning has traditionally been an important dry season income generating activity. After several incidents of rapid water surges and serious, even deathly accidents, gold panning is reported to have ceased almost totally. This means an income loss leading to increasing impoverishment of the households residing along the Se San River.

When fish was abundant in the Se San River, many households could catch more fish than they needed. Traditionally in most of the villages some households were specialized in fishing and could sell fish to other households during the most busy times in the cultivation season when most of the people were occupied in planting or harvesting and had no time for fishing. Fish could also be sold to mobile traders transporting the fish further to be sold at the provincial market. Fish therefore was an important income source for many households along the Se San River. At present fish catches are so small that they hardly satisfy daily household needs. No fish from the Se San River is any more sold at the provincial market. Fishermen have lost their income, or moved to try fishing in the Srepok River, where over-fishing threatens the current fish population. The reduced income from fishing leads to impoverishment of many households. It is also reported that young men move to Ban Lung town in search of working opportunities when fishing no longer is a viable option for income earning.

At the same time epidemic cattle diseases are reported to have increased, killing many cows and buffaloes. Animals are raised for selling and they provide an important source of household income. Cattle deaths together with the reduced income from fishing and gold panning leave no alternatives for cash generation apart from wildlife hunting which in its turn is met with regulations and therefore takes place illegally. The overall situation of deteriorating income sources, due not only to changes in the Se San River but also caused by other factors, threatens to lead to a considerable impoverishment of many riverside villagers.

Cultural and Mental Impacts

Mostly men traditionally practice fishery. Daily fishing and fishing trips over several days are part of their lifestyle. This traditional occupation has been reduced both due to decreased fish population and due to the reduced number of The traditional sphere of men in fishing and hunting and the way of life connected to the river is forced into a major change.

At the same time many women have stopped doing riverbank cultivation and collecting of wild growing riverbank food and medicinal plants. Natural patterns in the river have been changing, which has caused fear and insecurity among riverside residents. Most of the villagers living along the Se San River are ethnic minority people living in a world inhabited with spirits in the nature. According to their thinking any unpredicted natural phenomena are caused by angry spirits.

The traditional lifestyle of the riverside population is based on natural resources utilization, where the Se San River is the very basic asset providing both water, food, income, communications and a cultural framework. At present riverside people feel insecure about the river due to past accidents related to water level changes and floods in the Se San River. They have also experienced other negative developments like reducing fish stocks and increasing cattle and skin diseases during the past ten years. Learning about the existence of the Ialy dam people now seem to connect all occurring negative phenomena in their environment to the dam.

6.2 Impacts during Construction of New Hydroelectric Projects

Construction work can lead to impacts on the aquatic, terrestrial and social environment. Following international regulations all construction work should be guided by proper plans for environmental management, monitoring and auditing. If such regulations are followed, most of the impacts described below will be significantly reduced.

6.2.1 Possible 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 can affect water quality, aquatic life, land use practices and biodiversity down stream.

- 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 of the water column from increased turbidity.
- Run off from crushed and ground rock material from the drilling, blasting and stone crushing plant (quarry)
- Sanitary effluents from the construction worker's camp
- Oil and chemical spills
- Leaching of ammonia and nitrogen from the tunnel blasting and spoil rock deposits
- Temperature effects is not expected
- Possible dry-ups during filling the reservoirs

Erosion from Natural Soils

Impacts on aquatic life

The flora and fauna of the Se San River are adapted to considerable variations in the concentration of particles. While pure clear water type rivers are very susceptible towards large inputs of erosion material from construction work, the Se San type of river can tolerate considerable amounts. During the construction phase, the excavation, filling, deposit and clearance activities could 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 rainshowers. 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. Human water use such as drinking water, clothes washing, bathing, fishing, eco-tourism, etc. will also face problems from this intensive erosion.

The erosion material will settle on the bottom in slow flowing 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 sized fish species. According to fishermen in the villages, there are many of these pools in the Se San River, several of them very deep. According to the fishermen, these pools have become shallower due to sedimentation after the Ialy Falls Regulation. 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 are not filled with sediments. On the contrary, the strong currents during this period will clear the pools for sediments. These special currents are made by the curvature of the river or the rapids just upstream. If such a pool has been made considerably shallow due to sedimentation of erosion material during the construction phase, the excavating currents may not be formed and the pool will disappear.

In rivers the bottom dwelling animals are normally the most important fish food. Most of the bottom dwelling animals in slow flowing stretches of a river live like the earth worm (i.a., oligochaeta, chironomidae, some trichoptera), eat the surface sediment and digest nutrient containing organic material. Under normal conditions the sediment consist of a mixture of organic and inorganic material. When a river has been exposed to heavy load by erosion material, the sediment is 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. After heavy erosion, it may take many years to restore the river to its natural condition.

Impacts on land use and biodiversity

Domestic animals that drink water from the river can be impacted due to change of water quality in a negative way.

Impacts on riverbank agriculture are expected to be minimum, although riparian vegetation (riverbank) and aquatic plants may be impacted. It should be noted that any sudden release of water could be devastating to agriculture. The impacts here will be different based on the season.

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 since no exhaustive studies of fauna (other than some large mammals and fishes) and flora (other than tree communities types) diversity has been conducted and little is known of the ecology of most species, precise impacts are unknown. The deep pools in the Se San River can accumulate sediments which will impact pool dependent aquatic life – both flora and fauna.

Therefore, appropriate actions should be taken to reduce erosion during the construction phase. The most erosion prone areas are recently denuded soil-areas, like roads, roadsides and parking places, camp sites, and soil deposits, etc.

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 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. In Ialy power station the water is diverted out of the old river few km by a tunnel, but in the coming regulations there should be no tunnels involved. The free ammonia fish kills should therefore not be a problem.

Sanitary Runoff from Construction Workers Camp

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

Oil and Chemical Spills

Construction of hydropower plants include the 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. If these chemicals reach the river, the water quality will be seriously affected.

Necessary measures should be used to prevent oil and other chemicals to reach the river.

Reservoir Filling
Filling the reservoir for the first time takes long time. Large reservoirs 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 downstream areas

Filling of the reservoir during the dry season can be devastating as the water flow and level can be rather low. If the flow is entirely stopped then riverbank agriculture, which only exists due to the river, and home gardens will be heavily impacted. In fact riverbank agriculture would not be possible under no flow regimes and periods. Similarly aquatic animals, amphibians, reptiles, and wild and domestic animals dependent on the river for drinking, spawning and nesting sites will be impacted if the flow is reduced or stopped during the reservoir filling.

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.

6.2.2 Impacts on Socio-Economy and Culture

The anticipated impacts from construction of new hydropower projects on aquatic and terrestrial environment along the river will affect the people living in the downstream villages. Lessons from the past negative experiences should be considered in construction of new hydropower plants in order to minimize the impacts in the downstream areas.

Water and Health
During the hydropower plant construction, the downstream area is prone to be affected by various activities in the construction site as listed in Section 6.3.1 above.

Poorer water quality potentially leads to negative human and animal health effects. The Se San River is the main household water source in all villages on the Cambodian side along 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 toxics causing poisoning risk for people and animals. 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 strange material in the river water enter the human and animal bodies both through drinking, bathing and washing. It is therefore an increased risk of drinking water causing: 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.

Reservoir Filling
During the filling of the reservoir the water flow and level may become very low, especially if it is taking place during the dry season. This may affect both riverbank cultivation and the access of people and domestic animals to the water for drinking, washing and irrigation.

Fishery
The potential effects of new hydropower plants construction on fish populations have been described above in Section 6.3.1. Changes in fish affect the fishery and lead to negative impacts

on people's diet and nutrition, with potential effects on health status. If toxics affect fish, they will later enter humans eating fish and consequently endanger their health.

Fish is daily food and the main protein source for people living along the Se San River. Decline in fish availability has already taken place, which will with time have a serious effect on human nutrition along the riverside. Because fishing is an important income-bringing activity as well, reduced fish also affects the economy of many households in the riverside villages.

Economic and Mental Effects
Accidental floods and dry-ups can occur during the construction of hydropower projects as the experiences from Ialy HPP have shown. 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 as reported above. It is therefore imperative to follow international regulations for mitigation measures for hydropower development.

6.3 Impacts during Operation Phase

Given that the Se Sen 4A Hydropower Project is being built as a re-regulation plant (construction started November 2004) is now and will be in operation in August 2007 (Information from EVN), potential impacts during the operation phase will be reduced for several of the parameters. However it is imperative to understand that if appropriate measures are not undertaken during the construction phase impacts can carry over to the operation phase and be perceived, at least in the early stages, as those of the operation period. Such impacts can be related to sendimentation, erosion, and aquatic life.

6.3.1 Impacts on water quality and aquatic life

6.3.1.1 Impact on erosion activity

Hydropower regulation schemes affect many of the erosion processes taking place in a watercourse. Often the erosion activity increases, and the river water becomes more turbid. But in the long run the reservoir will trap sediments, which means that the water coming out of a reservoir after some years will contain less erosion material than the river water did at the same point before the regulation. The operation mode of power plants can, on the other hand, give more erosion in the downstream stretch of the river, e.g. through daily flow variations.

Erosion in the reservoir area
In the first period after the regulation several erosion processes will take place. The sides of the reservoirs will be eroded. The sediment binding roots will be destroyed by the inundation, and the soils will be prone to erosion from waves and varying water levels. Most of this erosion material will end up in the reservoir bottom, but 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 10 years of the operation.

Erosion due to daily water flow fluctuation
The daily variation of water flow and water level (see section 3.5.4) will cause erosion on a long stretch of the downstream river. The impact will be most significant during the dry season.

The mechanism behind this type of erosion can be described as follows: The dry season up-and-down movement of the water surface, combined with differences in flow speeds, will create erosion in the lower part of the river bank, making this steeper, and causing slides, etc. When the water level is high for 18 hours for instance the river bank 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 switched off, 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 bank surface. When the flow is increasing again when the power plants are switched on, the scouring forces of the current will easily dig out some cm of this loose bank zone material. This will in the long run dig out the lower part of the river bank causing slides, tree-fall, bamboo-fall, and important riverbank stabilizing roots will eventually disappear. The river bank will be more vertical, and will be prone to large scale erosion during flood periods. The increased steepness, and inorganic character of the changed river bank, will make it less suitable for river bank gardening than before.

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

Therefore, it will be important to minimize this daily water level fluctuation as much as possible, particularly in the dry season. The building of the re-regulation reservoir Sesan 4 will reduce the downstream water level fluctuations and thereby the erosion problems described above.

Erosion due to increased human activity

A large scale hydropower development, as planned on the Vietnamese side of the Se San River, normally results in permanently increase in human activity in the area. Several of these activities give rice to increased erosion, such as building of roads with erosion prone road sides, residential areas, agricultural activities, etc.

Erosion due to sudden spillway releases

During operation of a hydropower station there will occur situations where it is necessary to release water through the spillway. This may be done during the rainy season, when the reservoir is reaching full supply level. If a heavy rain then is forecasted, it may be necessary to release large amount of water through the spillway. In addition to the rain driven river swelling you will get an addition due to release of reservoir water. In this way the flow can be stronger than before. These sudden and powerful floods will create erosion in the unconsolidated and root-free river banks. In the cascade of reservoirs which will be present when the new regulations are built, the chances of having sudden and powerful spillway releases will be small.

Sediment flushing of the reservoir

In the beginning of the rainy season, when the reservoir is at minimum operation level, it is possible to flush out some of the accumulated sludge in the reservoir by using the first part of the monsoon flow. This activity results in extremely high turbidity in the downstream river, often with large impact on the aquatic life. This sediment flushing can also contribute to fill up the deep pools in the river, which are important dry season refuges for several fish species. EVN informs that none of the reservoirs in Se San River are planned to have sediment flushing.

6.3.1.2 Impacts on water quality

Turbidity

In the first period after the regulation the water will be more turbid. However, this will not be a permanent situation. After the initial erosion in the reservoir (approximately 5-10 years) the reservoirs will accumulate particulate material from the upstream catchment.

If sediment flushing of the reservoirs is practiced in any of the Vietnamese regulations, the turbidity will be very high in the beginning of the rainy season. This will create problem both for human use of the water as well as for the river biota. none of the reservoirs in Se San River will practice sediment flushing.

Daily water flow and water level variations can create river bank erosion along the Se San River in the lower Vietnamese stretch and the upper Cambodian stretch, and thereby cause turbidity problems, see the chapter on erosion for more details. The Se San 4A Re-Regulation Reservoir will level out most of the diurnal water level fluctuation, which means that this will be a small problem in Cambodia in the future.

Coliform bacteria and hygienic pollution

The Vietnamese part of the Se San River catchment has high density of people. It is therefore likely that the river is considerably contaminated by domestic sewage water, and runoff from livestock animals. The river water 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 the fact that several planktonic organisms eat bacteria. The longer the water 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.

In the area downstream of the Se San 4, there can in periods be very low flow, and the river can be susceptible to local discharges. However, in this area few people reside both on the Vietnamese and the Cambodian side of the border, and it is not expected to be a problem.

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.

The plant nutrient phosphate is the main factor causing eutrophication in fresh waters. Part of the phosphorus that enters a lake is retained in the lake sediment. The retention is a function of the water 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. This means that when all the reservoirs in Vietnam are built, and the initial period with nutrient release from decomposing terrestrial litter is over (5-10 years), the danger of developing eutrophication problems in downstream reaches in Cambodia is less than to day.

Both the Pleiku area and the Kon Tum area lie within the catchment of Se San River. Kon Tum drains directly to the Ialy Reservoir, while Pleiku drains mostly to the Se San River downstream the Ialy Dam (via Ry Ninh River and Ia Grang River). In addition there is a lot of agriculture in the area. It is therefore likely that there might be eutrophication problems in the new reservoirs of Se San 3, Se San 3A and Se San 4 with possibilities of having blue-green algal blooms in the dry season. In the NHP projects, model calculations with the well known and well accepted

Vollenweider eutrophication model (Vollenweider 1976) it was calculated that the average P concentration in the reservoirs (Se San 3, Se San 3A and Se San 4) all will be approximately 16-17 g P/l in the algal growing season. Using the RBJ-model the corresponding algal amount will be 6-7 g Chla/l. This is in the upper part of the mesotrophic level. This means that in the long run there is not expected to occur eutrophication problems in the reservoirs, neither with respect to algal blooms or oxygen deficiency in the deep water. However, in a short transitional phase of 5-10 years, when the nutrients are released from decomposing organic litter from the inundated terrestrial areas, the reservoirs can be more eutrophic and can have blue green algal problems in periods. This is most likely to happen towards the end of the low flow period (April-May). Therefore the water should be monitored for nutrients, algal species composition and algal toxins for some years after the regulation.

In the long run reservoirs always causes oligotrophication of the downstream stretches due to trapping of nutrients in the reservoirs. This is an advantage with respect to using the river for drinking water, but a disadvantage when it comes to fish productivity, which will be lower.

Temperature
The water is withdrawn from the deep water (below MOL) of the reservoirs. The temperature can be approximately 2-3 degrees centigrade lower than normal just downstream of the reservoir of Se San 4, but will not be notable in Cambodia. This is not expected to create any notable problem. It may be some small impacts on the hatching period of fish eggs in the upper reaches between the border and the dam of Se San 4.

Concluding remarks on impacts on water quality from the future regulations Se San 3, Se San 3A and Se San 4 in relation to water quality
The future regulations will inundate new terrestrial areas and will create nutrient rich water in the downstream river for a period of 5-10 years after the regulation. This may produce new algal problems. It should be established an algal monitoring program which could reveal any such problems as well as an information campaign that informs the people about the danger of drinking water with high algal content. A toxic algal bloom can develop within 2-3 days and it should be established a warning system with the necessary short and efficient dissipation time.

In a period of approximately 5-10 years after the regulations, the river will get increased turbidity due to erosion in the reservoir and river banks.

After this initial period, water quality problems are not expected in the Cambodian part of the Se San River. In fact the reservoirs will retain nutrients and bacteria and improve the water quality in that sense. If some of the reservoir will be anaerobic in the hypolimnion for a long time, and the turbine withdraw water from the hypolimnion, then the water quality problems can last up to 10 years after the regulations.

6.3.1.3 Impacts on aquatic life

Impact on the growth of attached algae
Algae growing on stones, sediments, on macrophytes, on branches of trees, on mosses are the most important primary producers in river. A lot of bottom animals (fish food) are subsisting on periphyton. Some fish species also eat 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.

Sight problems for the carnivorous fish and other water animals
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, hence reduced production for the fish population.

The bottom sludge will turn inorganic
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 totally inorganic, settles in the slow flowing stretches, the sediments are converted to inorganic sand and silt like in a dessert. The production of the bottom animals is strongly reduced in such sediments.

Impacts on fish migration
Regardless of the mode of operation of the power plants, the dams will create migration barriers. Several fish species migrate to day far up in Vietnam, for feeding, spawning and nursery purposes (see chapter 5.1). 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). It is possible to build fish bypass systems for some fish species. This has been partly successfully done for Atlantic Salmon (*Salmo salar*) and brown trout (Salmo trutta) in Europe and North America, but for the fishes of the Mekong river system the knowledge on efficient fish ladders, bypass canals, etc. is very limited.

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 flows are often delayed and reduced in regulated rivers with reservoirs. The first part of the rainy season is used for filling the reservoirs. In several regulations in Norway and in other European countries, the Power Companies are obliged as part of the concession to release triggering floods for salmon .

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, resulting that the fish is not able to reach their destination in time, e.g. a spawning ground.

Impact on fish spawning and nursery
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 to allow the eggs to hatch, and to provide suitable living conditions for the first life-stage of the fish larvae. Filling of the reservoirs in the first part of the rainy season are often a major reason why spawning conditions are not reached in regulated rivers. It may be lack of flooding, the flooding comes too late, or the flood does not last long enough to allow for nursery of the young-of-the-year fish.

Erosion can be a problem for some spawners, eg. 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 necessary oxygen supply for the eggs and larvae.

Impacts on the production of fish food and fish feeding
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 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
- 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 (long term effect)
- The erosion of the river banks reduces the overhanging trees and riparian vegetation which reduces the organic litter (leaves, insects, etc) falling into the water.

Impacts on dry season refuges – the deep pools
The Se San 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 (told us by the villagers) used to be as deep as 20 m at dry season water level, but have now become much more shallow due to sedimentation of erosion material after the Ialy regulation. All activities that increase the content of soil in the water (erosion process), particularly those that contribute to suspended sediments in the dry season, will fill up the deep pools. Filling of these pools will cause a great loss in fish abundance and species richness. Daily flow variation in the dry season is most likely the most important aspect. During flood flow 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 system 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 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 system, the ecological niches are very narrow and only small physical encroachments can wipe out several species. Hydropower regulation is known to be a big threat to aquatic biodiversity in Asian rivers to day (Dudgeon 2002). There is no doubt that the existing and planned regulation schemes in Vietnam will lead to eradication of several species of fish and other water living organisms in the Se San River. According to professor Ho Thanh Hai and professor Nguyen Kiem Son at the Institute of Ecology and Bioresources in Hanoi, who have undertaken biological studies in the Vietnamese part of the Se San River in connection with the Plei Krong EIA, more than 30 species of fish migrate all the way into Vietnam from the Mekong River. As the Se San 4 dam will be close to the Cambodian border, those fish species that have their spawning grounds in Vietnam, will face serious problems, and may disappear from the Se San fish fauna and also give biodiversity changes in Mekong unless mitigation measures are taken.

There is little knowledge about the requirements of all these organisms with respect to water flow, water level, water quality, etc., to be able manage the different populations properly in the new regulated river situation. Today 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.

6.3.1.4 Impacts on human water use

Drinking water

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 cause problems with respect to the use of the water as drinking water without treatment. This seems to have been a problem the first years after the Ialy regulation (according to the Fishery Office Report 2000), and it may easily occur again in the first years after the Se San 3, Se San 3A and Se San 4 regulations. The impacts from Plei Krong are believed to be reduced through the Ialy Reservoir. After 5-10 years, the initial erosion will be over, and the reservoirs will trap sediments and nutrients, and the water of Se San will improve.

In the long run, with respect to algae content and bacteria content, the concentrations in the Se San River on the Cambodian side will be less than before, because the reservoirs will trap both nutrients and bacteria.

Swimming and bathing

Swimming and bathing has been a problem in the first years after construction of the Ialy Reservoir. There has most likely been an algal problem that has caused itchiness and skin irritation. This may happen again with the new regulations. After some years these problems will disappear.

Washing

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 some years the river water will be of the same turbidity as now or better. Otherwise the daily water flow variations may cause long lasting turbidity problems. This implies the use of Se San 4A as a re-regulation reservoir.

Navigation

For the people along the Cambodian part of the Se San River, boats are used for transport across the river and along the river. The transport along the river is risky at some places due to rapids with submersed rocks. When the water will be more turbid in the first years after the regulation, the rocks will be more difficult to see for the boat driver, and accordingly the boat transport will be more risky. However, after some years the turbidity is not anticipated to be much impacted.

The water level is important for the use of boats, particularly in the dry season. The regulations undertaken in Vietnam, result normally in higher water flow in the dry season, and thus the boating should be facilitated in this period.

Fishing

The Ialy regulation has already contributed severely to reduced fish stocks, fish size and species composition in the Se San River to levels where fisheries no longer can supply the population along the river with the necessary amount of proteins. The planned new regulation schemes in Vietnam can very easily give additional negative impact on the fish stock in the Cambodian part of the Se San River. The mechanisms behind the impacts on the fish populations are described earlier in this chapter. Impacts on the fishery would be as follows:

- 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 in case of spillway releases
- Reduced catch will send the fish buyers to Mekong mainstream (e.g. Kratie) because of un-secure delivery from the Se San fishermen
- The local residents cannot subsist only on fish as protein source, they have to use more livestock animals as food or develop aquaculture

6.3.2 Impacts on Land Use and Biodiversity

Assumption is that the water flow will be the same as it was before, and during the construction phase, due to the construction of the Se San 4A as a re-regulation plant. 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 the feasibility of these agricultural activities, riparian vegetation (riverbank) and aquatic plants may still be in the impacted state due to previous conditions unless mitigation actions are taken.
- This may still affect aquatic animals, amphibians, reptiles, and wild and domestic animals that are dependent on the river for drinking, spawning and nesting sites. The re-regulation plant (Se San 4A) will certainly reduce impacts eventually particularly if the current erosion causing conditions are mitigated to the best possible degree. Note that since no exhaustive studies of fauna and flora (other than tree communities types) have been conducted and little is known of the ecology of most species.
- The deep pools in the Se San River can accumulate sediments that will impact pool dependent aquatic life and this wil continue until the Se San 4A is in operation and erosion impacts are mitigated along the Se San River.

Daily River Water Level Fluctuation

This will not be a problem due to the operation of Se San 4A as a re-regulation plant from August 2007 onwards. Thus previous impacts related to the usually high daily water level fluctuations that 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, disrupt deep pool water levels, and disorient fish migratory currents will be minimized.

When the Se San 4A re-regulation plant is in operation riverbank agriculture will still be difficult during the dry season, as the present condition for the Se San river banks due to previous water level fluctuations have made their impacts in weakening the slopes and triggered a state of slope slippage in the future.

Before the Se San 4A is in operation as a regulation plant small crustaceans, amphibians and reptiles may have difficulty in adjusting to water fluctuations since 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 a few on large mammals and fishes) and flora (other than tree community types) have been conducted and little is known of the ecology of most species, precise impacts are unknown. If animals do cross the Se San River their migratory routes may be influenced by the unusual water levels, and may be deterred by such uncertainty and new environmental conditions. Once the Se San 4A is in operation most of these impacts would be minimized, although species lost cannot be replaced.

Filling of Reservoir and Delay in Release in Water

Decrease in floodplain (recession) agriculture can be a serious impact of hydropower projects as reported in present conditions as a result of the Ialy Hydropower Project. 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. As mentioned once the Se San 4A is in operation this impact would be minimized, making sure that is enough water that can be used to flood fields is nevertheless salient.

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, birds, 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.

6.3.3 Anticipated Impacts on Socio-economy and Culture

Most of the potential impacts on human settlements during the operation phase are similar to those during the construction phase. The anticipated negative impacts on aquatic and terrestrial environment along the river affect the people living in the downstream villages. Accordingly, the evaluation of the expected impacts on people’s lives is based on the assessment in Sections 6.1 and 6.2 above as well as the reported impacts from Ialy Hydropower Project in Chapter 4 and Chapter 6.1. In the worst-case situation, the negative impacts already taken place in the downstream areas will be cumulative due to operation of further hydropower plants. However, if the water flow will be restored close to the normal due to the construction of the Se San 4A as a re-regulation plant many cumpative negative impacts can be avoided.

Water and Health
During the first years of operation, increased content of suspended sediments (erosion material), and possibly algae produced from nutrient released by decomposing terrestrial litter in the reservoirs, will risk to 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 will clear up. In the long run, the concentrations of algae and bacteria contents in the Cambodian part of the Se San River will be less than before, because the reservoirs will trap both nutrients and bacteria. Increased turbidity of water will give some reductions in the suitability of the water for washing, but after 5–10 years the river water will be less turbid. This implies the use of the Se San 4A as a re-regulation reservoir. Otherwise the daily water flow variations may cause long lasting turbidity problems.

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 materia 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 in humans and domestic animals.

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.

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 fetching water, washing and bathing, boat transportation and animal watering.

Erosion cause riverside vegetation to slip down into the river and can lead to sudden landslides on the riverbankIf 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. This development has already taken place due to the riverbank erosion caused by water releases from Ialy HPP. The construction of the Se San 4A re-regualtion reservoir is expected to establish a constant flow in the river and consequently mitigate the effects.

Navigation
For the people along the Cambodian part of Se San, the river is still a major transportation route. If turbidity in the river increase again due to new HPPs, boat transport will become 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.

Fishery
The potential effects of the hydropower plant operation on fish have been described above in Section 6.3.1 and a significant reduction of fish stocks has already taken place in the Se San River in Cambodia. Reduced fish and the extinction of some types of fish have already lead to

smaller catches and impacted negatively on both people's economy, nutrition and consequently culture.

Fish is staple food and the main protein source for people living along the Se San River. 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 is anticipated if fish will be further 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 also negatively affects the economy of many households in the riverside villages. Less income from fish impoverish many households. As the spatial distribution of fish is changed, fishermen have already moved to do fishing in other areas, which cause changed fishing practices and culture. Stricter rules for fishing rights and fishing are probably necessary in the rivers in North-Eastern Cambodia in order to protect the remaining fish stocks from extinction.

Economic and Cultural Effects

The cumulative negative impacts from new hydropower plants can lead to further changes in the very basic conditions for economic and cultural life in the downstream villages along the Se San River if they are not operated in a way to give a constant water flow at normal levels. Both gradual and rapid changes 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 also lead to fear for future incidents. People 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 lead into increasing poverty and force changes in the culture.

7. MITIGATION AND ENHANCEMENT MEASURES

Introductory Remarks

This environmental assessment is only assessing downstream impacts in the Se San River in Cambodia and only include measures that reduce the negative impacts along this part of the river. Impacts in the reservoir area, aimed to improve the aquatic ecology, and water use in the reservoir area, are therefore not considered.

The 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 which is relatively predictable from year to year. The monsoon rain is causing flood flow, which again triggers the spawning migration of hundreds of fish species. The floodplains are flooded and the farmers are planting rice in the paddy fields. In November-December the water levels are reduced and the dry season starts. Fish migrate back to the larger rivers, the farmers harvest the rice, etc. Every year, approximately the same cycle is repeated, with deviating years in between. These deviating years are also important to prevent certain organisms to develop too strong and become dominating populations.

Hydropower development interrupt 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 of reaching their spawning grounds, feeding grounds, nursery areas, etc. The changes in hydrology often bring increased erosion activity, which gives water quality problems, siltation problems, and sedimentation problems.

Changes in the natural hydrological regime also affects peoples use of the river and hence their living conditions.

7.1 Mitigation of impacts due to the Operation of Ialy Hydropower Project and Future Hydropower Stations

7.1.1 Main Conclusions

Based on the impacts presented in Chapter 5 the mitigation needs to focus on (i) reducing the water fluctuation levels and synchronizing river water levels with agricultural seasonality, (ii) reducing erosion and stabilizing river banks, (iii) increasing awareness of vulnerable animals among villagers, and (iv) community based involvement in conservation and monitoring.

As EVN informs that Se San 4A will be commissioned as a re-regulation reservoir from August 2007, this reservoir will mitigate some of the main impact by Ialy Power Plant as well as impact fropm future power plants. The re-regulation plant will in particular mitigate impacts due to daily water level fluctuations which also causes erosion on the river banks.

Mitigation measures related to impacts from Yali Hydropower Project should be implemented as soon as possible to counteract existing impacts.

The main measures to mitigate impacts from hydropower development in Se San River are

1) The flow out of Se San 4A re-regulation reservoir should be stable and as equal to natural flow as possible.

2) Until the Se San 4A regulation reservoir is in operation August 2007, Ialy HPP should be operated in a way to minimize daily flow fluctuations.
3) Establish an efficient warning system that can inform people living along the river in time about floods and impacts on water quality.
4) Implement environmental monitoring programs among others for early detection of water quality changes.

These and other mitigation measures are described in more detail below.

7.1.2 Se San 4A Re-regulation Reservoir

Including Ialy, 6 hydropower plants are planned in the Se San River. Two of these hydropower projects are located upstream the Ialy Reservoir and are anticipated to have very little additional impacts downstream the Ialy Reservoir. The new projects Se San 3, Se San 3A and Se San 4 are located downstream the Ialy Reservoir and may give new impacts in Cambodia. Se San 3 and Se San 3A have very small reservoirs and the daily flow from these power stations will follow the release from the Ialy HPP. Se San 4 has a larger reservoir.

Se San 4A will be commissioned as a re-regulation reservoir from August 2007, this reservoir will mitigate some of the main impact by Ialy Power Plant as well as impact fropm future power plants. The re-regulation plant will in particular mitigate impacts due to daily water level fluctuations which also causes erosion on the river banks. The flow out from Se San 4A should be kept as close to the Natural Flow as possible. This will almost eliminate sudden daily flow fluctuations and be the best measure to bring the river in Cambodia back as close as possible to the condition before Ialy HPP was developed.

Until Se San 4 is developed, operational measures should be taken at Ialy to reduce the daily flow variations.

7.1.3 Early Warning System

It is recommended to set up a system for early warning of floods, spillway releases from Ialy (and other reservoirs when Se San 3, Se 3A, and Se San 4 are in operation) as well as rapid changes in water quality which can affect people and animals. The warning system should be based on direct warning from the operation staff at the Ialy Hydropower station to the people living along the Se San River. This system could be based on battery/solar cell-operated sirens with wireless transmission.

7.1.4 Mitigation Measures for Water Quality and Aquatic Life

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.

Reduce the Nutrient Inputs to the Reservoirs
Densely populated areas with corresponding high sanitary effluents drain towards the Se San 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.

Building Fish Bypass Systems

It is likely that fish from Se San River migrate far up in Vietnam, as the river does not seem to have any physical barriers. According to professor Ho Thanh Hai and professor Nguyen Kiem Son at the Institute of Ecology and Bioresources in Hanoi, who have undertaken biological studies in the Vietnamese part of the Se San River in connection with the Plei Krong EIA, more than 30 species of fish migrate all the way into Vietnam from the Mekong River. 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. This should be further studied, 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 Se San River, needs to be considered very carefully by expertise on the fish species present.

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.

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 Se San 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 if it is true as the villagers now claimed that Tilapia already is spread to the Se San River, this could also be considered.

7.1.5 Mitigation Measures for Land, Agriculture and Biodiversity

Water Fluctuations

The main reason for the environmental impacts caused by the Ialy Hydropower Project is related to changes in the hydrological cycle. Reducing water level fluctuations to ecologically sound levels especially in the dry season is of utmost importance as these have impacted the present conditions related to land use, agriculture and biodiversity.

As stated in previous chapters changes in hydrology has resulted in increased erosion activity, inducing, among others, sedimentation problems. Large fluctuations in water levels in the river induce river bank land slides and weaken banks in general, making river bank agriculture difficult to practice. Paddy production can also be seriously impacted if early wet season water levels are low, and when water cannot be channeled to areas away from the river. Reducing water level fluctuations will reduce erosion and enhance possibilities for river bank agriculture.

One of the significant impacts of reducing water fluctuation levels will be on bird populations which nest, breed and forage on sand banks and river edges. Similarly impacts can be reduced on lizards, turtles, reptiles and particularly crustaceans, which are prone to desiccation.

These impacts will mainly be mitigated when the Se San 4A re-regulation plant is in operation. Until then, operational measures should be taken at Ialy to reduce the above impacts related to the hydrological cycle.

Wet Season River Water Levels

The requirement of ample water for the flooding of the paddy fields at the onset of the wet season is also vital thus either release of appropriate levels of water should be determined or preferably prolonging wet season filling (gradual) of reservoirs. The latter is a more plausible way to mitigate this impact. In addition pumps may also be made available so that water can be pumped into waterways (channels or dikes) into the paddy fields and associated agricultural areas more predictably.

Reducing Erosion and Bank Stabilization

Erosion is seen as one of the most significant problems resulting from the impacts of the Ialy Hydropower Project. Se San 4A re-regulation plant will not change the need for mitigation of erosion damages already present. Mitigation through revegetation or rehabilitation of river banks would be a major need by the Se San River. Most importantly river banks, and abandoned areas by and near the river (some back yard gardens, grassy areas, and newly deforested areas) can be revegetated and rehabilitated. Plant enrichment techniques may be employed to reduce erosion. Steep slopes are particularly erosion prone and such areas near the river also add to the erosion. Note that erosion does not only result in loss of valuable top soil but also leaching of soil nutrients and loss of organic matter.

Rehabilitation and revegetation measures for river banks must include:

1) using fast growing species (starting with grasses) for rapid bank stabilization;
2) using nurse plants (grasses) which help stability in wide and gentle open patches and
3) plant in and encourage perennial herbaceous species and slower growing tree species to establish in parallel to fast growing species.
4) designating areas that are not too steep for terracing and river bank agriculture and revegetate others.
5) terracing of river banks can be improved by bio-engineering techniques
6) increasing local awareness of measuring slope vulnerability to erosion and slippage, and the use of simple slope revegetation tools.

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 (like river bank gardening) has to be considered. 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 be prepared. Table 7.1 provides benefits and limitations of choosing grass, trees, shrubs and bamboos for revegetation of river banks.

Table 7.1 Benefits and limitations of different vegetation types for river banks in particular (Dhillion unpublished)

Vegetation type	Benefits	Limitations
TREES	Deep rooting zone, root soil binder. Species with surface roots may help to be used in the early stages of revetation.	Slow to develop additional weight to slope. Legume species are usually suitable and root farly rapidly. Hard wood species are unsuitable.
	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.
	Leaf litter of broadleafs plants produces good quality humus and improves understory growth.	Some tannin rich leaf litter can increase soil acidity, degrading understory and increasing potential for erosion.
	When planting trees with NTFP value can encourage local people to actively nurture trees	Can be over harvested and lead to death. Using plants of non-timber value but those which have NTFP yeild are most secure.
SHRUBS	Form a dense lower cover; have moderately deep roots.	Do not effectively control surface erosion. Have to planted among grasses to function to control surface erosion.
	Moderate increase in infiltration.	On naturally unstable slopes, the slightest change in slope hydrology can produce failure. Thus not a wise choice for the many very weak river banks of Se San, unless preceeded by grass cover.
	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.
	Plant in low slopes or open areas near the river – this increasing binding of soil rapidly.	Clumps high on unstable slopes can fall depending on the slope.

		Once rooted they are difficult to get rid off, so areas with bamboo revetation should be well planned.

Biodiversity Management and Protected Areas
The presence of a protected area (VNP) 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 VNP 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. There is also a good knowledge base and experience to draw from the protected areas in Mondulkiri Province.

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.

Community Based Management. The already begun initiatives by the Management of VNP and NGOs for involving local communities in managing natural resources in the buffer zone of VNP (by the Se San River in general) should be supported and championed. This can have significant impacts on increasing conservation awareness (indirectly reducing illegal activities), involving local communities in monitoring activities near the river, increasing confidence among local people by allowing them to govern (through management) their own natural resources, and increase synergies between different stakeholders.

Ecosystem integrity and watershed.
Of utmost importance would be to establish an environmental monitoring system targeted on both physical and biological components to address both localized and ecosystem integrity and watershed level component. As mentioned in the baseline section the whole region is of high conservation value and a comprehensive river related monitoring will be needed.

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. Rehabilitation of river banks to increase bank stability is receommended.

Increasing Awareness of vulnerable animals
Many of the bird nests are robbed of eggs by both villagers (ranked second after water fluctuation as impacting factors, Claassen 2004) and domestic animals. Furthermore other animals like lizards, turtles and reptiles have also been reported to be reduced in number. A campaign to increase awareness of the detrimental impact of the removal of eggs during the breeding season and hunting of other water related animals can help securing the increase of populations of species impacted.

7.1.6 Mitigation Measures for Socio-Economic Impacts

The daily lives of the people living along the Se San River in Cambodia are affected by negative developments in the river and the surrounding land areas. Part of the impacts have been caused by the construction and operation of Ialy Hydropower Plant in Vietnam. Local people have experienced dry up of the river, daily water fluctuations, riverbank erosion, turbid waters and reduced fish stocks, all of which the HPP has contributed to. Food production and income earning of the riverside populations have been disturbed to a significant extent.

Re-establishment of sustainable living conditions and livelihoods for the downstream people depends on the technical solutions taken both in the dam site and along the river in order to alleviate the negative effects from hydropower plant operation. The social impacts alleviation also depends on implementation of the measures suggested above in Section 7.1.1 – 7.1.5: Measures to restore the natural water flow and fish stock in the river, to reduce riverbank erosion, to develop a warning system and a program for aquaculture as well as a community based management system of natural resources are important measures for social mitigation and are not revisited here.

Mitigation Measures

Further studies of the impact of reduced fish (protein) in the diet and livelihood is recommended to provide information for deciding appropriate mitigation measures. An option to introduce fishponds in order to replace the lost river fish with pond fish should be seriously considered, connected to extension training in order to provide people with appropriate skills in fish breeding. Extension training to improve the capacity of people in cultivation and livestock breeding is another option in order to mitigate the potentially deteriorating nutritional status caused by reduced fish. The option of introducing new, fast growing small species like rabbits to increase meat protein in the diet, and the needed training in breeding these animals is one more option. Preferably several strategies should be combined, according to the preferences of the affected people. Consultations with local people are imperative for finding sustainable mitigation measures.

Given that it is impossible to estimate the actual losses of the affected people, it is recommended that EVN should consider negotiating with the Cambodian counterpart the electrification of the affected communities along the Se San River as a benefit sharing from the upstream hydropower development.

Stakeholder Consultations Plan for a Mitigation Program

It should be emphasized that the recommended mitigation measures in this report are based on a rapid study in the affected downstream area. In order to guarantee a sustainable future for the riverside population, it is recommended that a comprehensive *social impact assessment* study should be conducted and a detailed mitigation plan made in cooperation with different stakeholders. Following the recommendations of the WCD (2000) of involvement of various stakeholder categories, in the Se San 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 1.5.3.
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.
5) District health care staff and traditional health providers.
6) Village and commune chiefs of the directly affected areas.

7) District administration representatives from Ou Ya Dav, Andoung Meas, Ta Veaeng, Veun Sai and Se San districts.
8) Provincial ministries representatives from Ratanakiri and Stung provinces.
9) NGOs working in the affected areas (e.g. Se San Protection Network, Health International, Health Unlimited, Cambodian Red Cross, NTFP Project, etc.)

The stakeholder consultation process should be based on the risk and rights assessment and lead to agreed measures for mitigating the negative impacts along the Se San River in Cambodia due to hydropower development in Vietnam. The institutional capacity in the riverside districts and the affected communes and villages along the Se San River for implementing the mitigation measures should be carefully evaluated. Both planning and implementation of mitigation measures should take place in cooperation with and support from 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.

7.2 Mitigation of Impacts from Construction of New Hydroelectric Projects

During construction of new special mitigation measures must be taken that will come in addition to the mitigation measures for impacts of hydropower projects in operation.

7.2.1 Measures Against Erosion

Erosion from Construction Roads and Permanent Roads
Excavation of roads in steep valley sides with soft soil leaves large areas of denuded soil 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 of roads) will require similar procedures adjusted to the specific sites. The team responsible for this should 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

should be taken. Weeds may be harvested for compost, fodder or biogas and regulating water discharge and manipulation of water levels to discourage weed growth should be considered. In similar lines sedimentation in the reservoir and subsequent loss of storage capacity may be minimized by control of land use in the watershed (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).

7.2.2 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 discharged into the river. In the wet season, the ammonia discharge will not harm the river biota.

7.2.3 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 is important and the final rehabilitation is important.

Location and Water Handling
These deposits should not be placed in steep terrain. The best location would be 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 spoil rock deposit in a flat area with little runoff (i.e. upstream catchment) and with 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 spoil 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 need to be separately deposited. Upon spoil deposition top soil needs to spread onto the spoil material, and 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. Planting of tree species needs to be done immediately at edges and grass lines on contours. Open flat areas of the spoil deposits where top soil is deposited, should be immediately made available to the local people for agricultural practices of agro-forestry. It is vital that the rehabilitated areas is not open for grazing until all vegetation is established, 6 years minimum, as this will result in spoil slope weakening.

7.2.4 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, 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 (gray water) should be separated. Toilet water should be collected in watertight tanks and infiltrated at a safe place. The gray water can be infiltrated in the terrain.

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

7.2.5 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 Se San 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.

7.2.6 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.

7.2.7 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.

8. MONITORING PROGRAM

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

It is emphasized that in line with international recommendations, monitoring is necessary even if Se San 4A is operated as are-regulation reservoir.

8.1 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 Phase 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.

8.1.1 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. 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;

8.1.2 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 in the table below. It is also anticipated that an environmental audit will be prepared on an annual basis by an independent monitoring specialist.

8.1.3 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. The main parameters for measurement will include:

- Flow and sediment yield monitoring
- River water quality monitoring
- Monitoring of effects of the proposed hydro power maneuvering regimes on water ecosystems with the objective of minimizing downstream effects;

- Monitoring of effects on the ecosystems of sudden start and stops in operation of the turbines;
- Monitoring of effects of the proposed minimum release from the dam on water ecosystems, wildlife and riparian vegetation. The objective should be to determine the optimal minimum release strategy which maintain a sufficient water level in the river to maintain aquatic life, wildlife interests and riparian vegetation;
- Quality of potable water supply to affected villages;
- Public safety and security monitoring

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.

8.1.4 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.

8.1.5 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.

8.1.6 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 Phase 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.

8.2 Monitoring Program for Water Quality, Aquatic Life And Erosion

8.2.1 Monitoring Stations

Figure 8.1 shows the proposed stations in the Se San River for monitoring the water quality, aquatic life and erosion.

1) Downstream the Ialy Reservoir
2) Se San 4 reservoir
3) Downstream Se San 4 Reservoir (Border between Vietnam and Cambodia)
4) Andoung Meas
5) Veun Sai

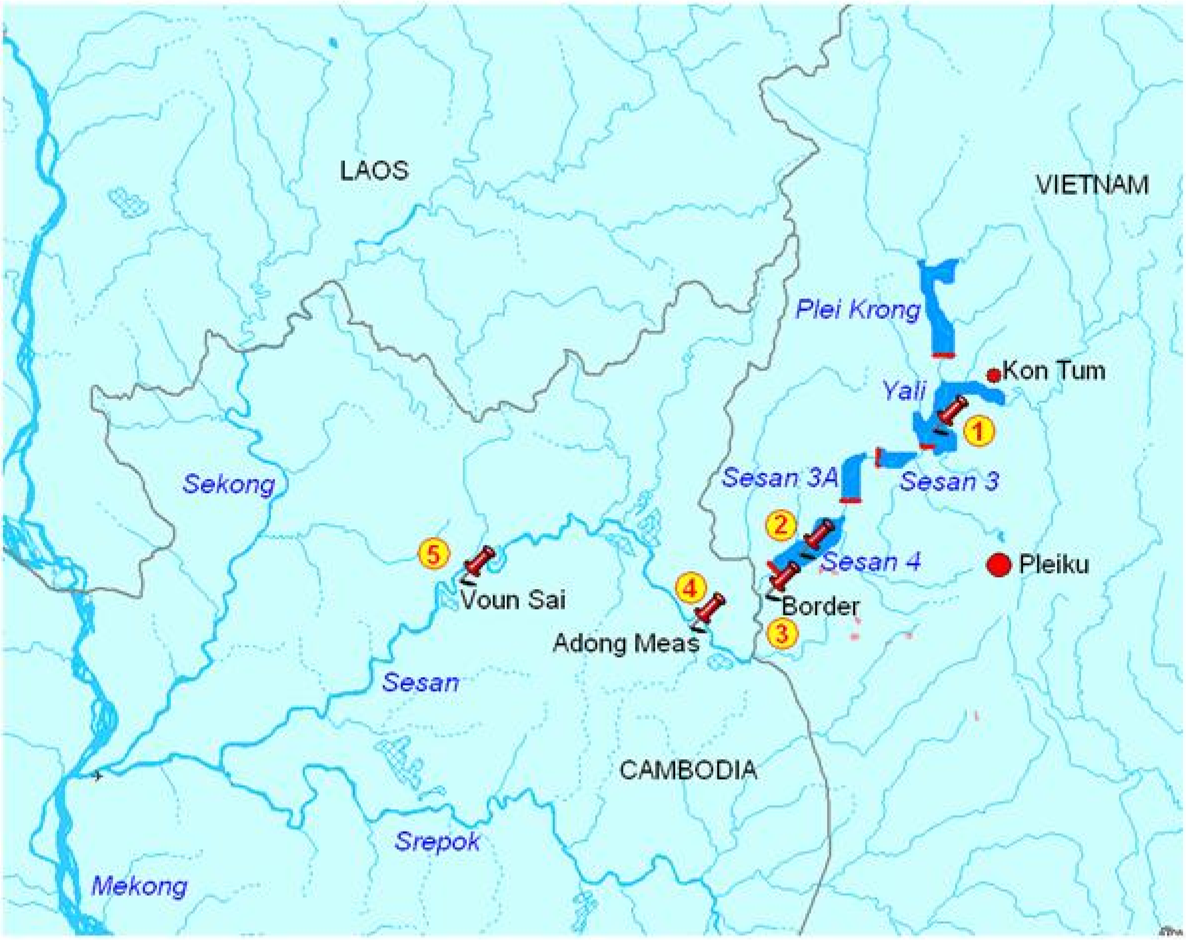


Figure 8.1 Proposed stations for monitoring water quality in the Se San River. Three river stations (3, 4, and 5), and 2 reservoir stations (1 and 2)

8.2.2 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), fish stocks (described by fish yields by fishermen (catch per unit effort, CPUE)). The last parameter applies only for the two river stations located in Cambodia.
Monitoring parameters:

- Water level fluctuation
- Temperature
- pH
- Oxygen
- Turbidity
- Suspended sediments
- Total Phosphorus
- Total Nitrogen
- E. Coli (or Termostabile coliform bacteria 44 ^{o}C)
- Total Coliform Bacteria 37 ^{o}C
- Chl-a

- Algae-filter
- Fish yield (CPUE)

8.2.3 Observation Frequency

To get data 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 in Cambodia could be performed by the MOWRAM staff in Ban Lung and sent by plane to Phnom Penh for analysis. The sampling in Vietnam could be done by personnel at Ialy Hydropower Plant, and the samples could be sent to Ho Chi Minh City, Da Nang or Hanoi 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.

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

8.3 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 is recommended consist of:

- Riverbank stability (riverbank soil slips, tree drops, slope changes, vegetation cover/agriculture). Certain areas can be selected for regular monitoring by local communities.
- Animal diversity and occurrence, nesting/breeding site presence (indicator species can be targeted. For example sand bank birds can be the focus)
- Plant community type and habitat structure (micro-environmental conditions) – (indicator species can be targeted for each group/community of relevance). This if done can be part of a biodiversity monitorying plan and should be done with the Forestry Department

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

8.4 Monitoring Program of Social Consequences

There is a considerable experience from different countries on the consequences of hydropower projects on the lives of the affected people. Some of the understanding is compiled in the WCD Report (2000) and form a basis for the recommendations concerning hydropower planning and construction process. Assessment of the social impacts and their mitigation have been made mainly in the dam construction and surrounding areas. Often the entire focus has been put on the people that have to be resettled and consequently on the resettlement areas. Considering the social effects of dams in the downstream areas have late, if at all, come into the agenda, mainly due to reports on warning situations with unexpected consequences. Likewise the monitoring of social consequences in a longer time perspective, even if rarely done, has been focused on the resettlement areas and the resettled people only.

Below a monitoring program is proposed for following the socio-economic and cultural consequences from hydropower development in the Se San River in Vietnam on the downstream areas in Cambodia. The indicator approach developed in Song Hinh multipurpose project (2003) and in the National Hydropower Plan Study, NHP (2006) in Vietnam is applied in the proposed monitoring program for the Se San River in Cambodia downstream the Ialy HPP in Vietnam.

8.4.1 Purpose of the Monitoring Program

The proposed monitoring program is intended to follow the most vulnerable issues in the Se San riverside villages in Cambodia that have been and might be affected by hydropower development in the upstream area in Vietnam. The monitoring of socio-economic consequences should be coordinated with the issues for environmental monitoring. Experience from previous hydropower projects points out a few socio-economic topics that are the most essential for people’s lives (see below). Which of the issues become the most important ones can vary between different affected areas, as the Song Hinh Multipurpose Project shows, comparing the socio-economic and health consequences in resettlement areas of three different hydropower projects (Song Hinh, Ialy and Thac Mo). Regular monitoring makes it possible to detect and follow the vulnerability issues in each village. The purpose of the monitoring is to follow up problem areas and point out required inputs.

8.4.2 Timing and Implementation

A monitoring program for following the socio-economic consequences should ideally be designed already before the start of the construction of any hydropower plant. Monitoring should be based on the baseline situation where the central socio-economic and cultural issues and activities are apparent. Monitoring should then be done on a regular basis, e.g. at 2 or 5-year intervals. In the Ratanakiri and Stung Treng provinces it should be beneficial to integrate the monitoring with the yearly village level data collection for the Ministry of Planning within the SEILA program. The socio-economic indicators suggested in this study could be easily added to the socio-economic issues in the SEILA village surveys. Reporting the monitoring indicators could then follow the same design as the SEILA data. Coordination of the data collection activities should in that way be efficient and require only minor extra work input.

8.4.3 Indicators

The proposed indicators listed below are based on the present situation in the villages along the Se San River in Cambodia. The amount of indicators is reduced to the minimum and they focus on the obvious issues which are problematic and where vulnerability is likely to increase after continued upstream hydropower development. The most crucial indicators for monitoring the immediate negative developments are:

1) Water use and availability
2) Fishery and food security
3) Health and water-related diseases
4) Land access

<u>Water use and availability</u>
The present study has pointed out the dependence of the Se San 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.

<u>Fishery and food security</u>

Fish is staple food and eaten practically every day in the villages along the Se San River where the basic diet consists of fish and rice. The frequency of fishery and the volume of fish catches per household should be monitored carefully. As fish catches have decreased, food security situation is already at risk. Monitoring of the fish availability should be done on a regular basis and compared to the intake of meat and vegetables in the diet of the local people, connected to their overall nutritiona status.

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. Potential increase of water-related diseases like diarrhoea

Land access

According to the present study most villagers along the Se San River have traditionally enough cultivation land for food production. However, riverbank cultivation land has been lost due to flooding and erosion, and pressure for more cultivation land higher up from the river has increased. Households' land use (how much cultivation land) and access to different types of land as well as distance to fields should therefore be followed in the long term. Land access is also connected to productivity monitoring.

The indicators suggested above for monitoring the downstream development situation along the Se San River in Cambodia, should be developed in detail to give measurable values that can be followed on a regular basis. Determining measurable indicator values should be based on the current 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 taken to further mitigate negative consequences in the Se san River from hydropower development could then be decided upon these measurable scales.

APPENDIX 1 - REFERENCES

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Information material from Se San Protection network

APPENDIX 2 - RECORD OF CONSULTATIONS

Phnom Penh

Government officials

Representative for SEILA Program, Data Base Office, Ministry of Planning
H.E. Mr. Bun Hean, General Director of Technical Affairs, Ministry of Water Resources and Meteorology (MOWRAM), Oct. 2205, Nov. 2005
H.E. Mr. Kol Vathana, Deputy Director of Ministry of Environment (MoE), Deputy Secretary General, Cambodia National Mekong Committee
Mr. Mao Hak, Director Dept. of Hydrology and River Works, Ministry of Water Resources and Meteorology
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, Min. Agr. Fish., Oct. 2005
Mr. Lieng Sopha, Director Inland Fisheries Research and Development Institute, Min. Agr. Fish., Nov. 2005

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 Henrik Garsdal, Senior Hydraulic Engineer, DHI, Danish Hydraulic Institute. 22 Nov.
Mr Warwick Browne, Regional Program Officer, Oxfam America. 23 Nov.
Ms Jessica Rosien, Oxfam Australia. 23 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

Ratanakiri Province

Government officials - Provincial

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. 29 Nov.
Provincial MOWRAM group meeting. 29 Nov.
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. 29 Nov.
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.
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 Im Sovan, Vice Deputy District Governor, Facilitator for SEILA program, Andoung Meas District. 27 Nov.
Mr Peng Buwvath, Chief of District, Veun Sai District. 28 Nov.
Mr Sovan Bun Moum, Vice President of Veun Sai District Health Centre. 30 Nov.
Mr Ap Der, Vice District Governor, Ta Veaeng District. 28 Nov.
Mr Aoum Sokha, Vice President of Ta Veaeng District Health Centre. 28 Nov.

Commune and village level meetings
Village Chief and villagers in Phi Village, Se Sant Commune, Ou Ya Dav District. 27 Nov.
Villagers in Ba Kham Hamlet, Nhang Commune, Andoung Meas District. 27 Nov.
Village chief and villagers in Ta Lav Village, Ta Lav Commune, Andoung Meas District. 27 Nov.
Village chief and villagers in Pa Kap Hamlet, Nhang Commune, Andoung Meas District. 27 Nov.
Commune Chief of Ta Veaeng Kraom Commune, Ta Veaeng District. 28 Nov.
Villagers in Tumpuon Roeung Thum Village, Ta Veaeng Kraom Commune, Ta Veaeng District. 28 Nov.
Village Chief of Ta Ngach Village, Ta Veaeng Kraom Commune, Ta Veaeng District. 28 Nov.
Village Chief of Ke Kuong Village, Ta Veaeng Kraom Commune, Ta Veaeng District. 28 Nov.
Villagers in Kaoh Pong Village, Ta Veaeng Kraom Commune, Ta Veaeng District. 28 Nov.
Villagers in Pha Yang Village, Ta Veaeng Kraom Commune, Ta Veaeng District. 28 Nov.
Villagers in Veun Sai Village, Veun Sai Commune, Veun Sai District. 28 Nov.
Villagers in Ban Hvang Village, Ban Pong Commune, Veun Sai District. 30 Nov.
Villagers in Ban Pong Village, Ban Pong Commune, Veun Sai District. 30 Nov.
Villagers in Thmei Village, Veun Sai Commune, Veun Sai District. 30 Nov.
Village Chief and villagers in Pa Kalan Village, Pa Kalan Commune, Veun Sai District. 30 Nov.

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 (PDWRAM). 26 Nov.

Commune and village level meetings

Village Chief and villagers in Phum Muoy (Srae Kor I) Village, Se San District.
26 Nov.
Villagers in Phum Pir (Srae Kor II) Village, Se San District. 26 Nov.

Vietnam (upper Se San River, Ialy are)

Mr. Ta Van Luan, Deputy Director, Ialy Hydropower Plant, Pleiku, Dec. 2005.
Mr. Nguyen Huy Hoach, Dep. Man. Sci. Tech. Env. Div., PECC 1., Dec 2005

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 Eanghourt, Terrestrial Ecologist
Tem Sareivouth, Socio-Economist
Meas Rithy, Socio-Economist

Vietmamese Team

Nguyen Huy Hoach, Team Leader (PECC1)
Cao Thi Thu Yen, Environmentalist (PECC1)

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 (river bank 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 river bank? 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 river bank? 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? (find out even cultural/sacred meanings)	
Are there graves near the river? Other cultural/religious relics?	
Have there been changes in the river flow during past years? Which kind? When?	
Have there been accidents related to the river? What has happened?	

APPENDIX 5 - LIST OF ABBREVIATIONS

DHC	District Health Centre
DHI	Danish Hydraulic Institute
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 Metereology (Cambodia)
MRC	Mekong River Commission
NGO	Non-Governmental Organization
NIVA	Norwegian Institute for Water Reasearch
NHP	National Hydropower Plan Study, Vietnam
NTFP	Non-timber forest product
PA	Protected Area
PECC1	Power Engineering Consulting Company No. 1 (Hanoi, Vietnam)
PDOWRAM	Provincial Department of Water Resources and Metereology (Ratanakiri)
PIDC1	Power Investigation and Design Company No. 1 (now PECC1)
WWF	World Wide Fund for Nature