NAM THEUN 2 HYDROELECTRIC PROJECT
ENVIRONMENTAL ASSESSMENT AND MANAGEMENT PLAN (EAMP)

DRAFT FINAL REPORT
(MAIN REPORT)

by

SEATEC INTERNATIONAL LTD.

in association with

SINCLAIR KNIGHT MERZ
ECI INC.
EDAW AUSTRALIA

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PREFACE

The Nam Theun 2 Hydroelectric Project has been under active development by NTEC for more than three years. It was originally scheduled to be in operation in the year 2000, with construction starting at the end of 1996. The decision, confirmed in 1995, to implement the Project according to World Bank standards, has resulted in a longer development period. Construction will not now start prior to end 1998 and, depending on agreements reached with EGAT, may be later.

Confirmation of the decision to comply with World Bank standards so as to enable the World Bank to support the Project was based principally on two considerations. First, the cost of servicing the Project debt was assessed as being significantly lower, and financing more easily achieved, with World Bank support. In financial terms this was estimated to add more than $100 million to the Lao benefits in the first eight years of operation because money that would otherwise be spent on servicing debt could be paid to GOL in the form of additional royalties and taxes.

The second consideration was the benefits of demonstrating to investors, multi-lateral agencies, lending institutions and other stakeholders that NT2 would comply with appropriate international standards; environmentally, economically and socially. The benefits emerge in many ways ranging from enhanced corporate reputation to facilitation of financial and insurance arrangements because of a lowered risk profile to market positioning. Compliance with Lao PDR standards and review processes would not be sufficient because they do not yet fully match those commonly used in developed countries for projects such as NT2.

In short, World Bank support, won after a rigorous review of the Project, will benefit both the GOL and the developers in ways that are important to each of them.

The additional development time has allowed more research and studies to be conducted, the environmental and resettlement plans to be prepared in greater detail, more independent assessments to be done and for a comprehensive public consultation program to be implemented.

The World Bank has indicated that it will consider whether or not it will review NT2 after it has received five reports and seen clear evidence that meaningful public consultation is being conducted.

The five reports are:-

Environmental Assessment and Management Plan
Resettlement Action Plan
Study of Alternatives (to NT2)
Economic Impact of NT2
Nakai-Nam Theun NBCA Management Plan

It is planned that these reports will be available for World Bank consideration, at least in advanced draft form, by the end of June 1997. This schedule is intended to allow the staff of the Bank to appraise NT2 by December 1997 , and for the Board of the Bank to consider the Project in early 1998. If approved on acceptable terms, NET and GOL would then focus on

finalising the many contractual, financial and legal arrangements required to achieve Financial Close, which NET requires before commencing construction.

This draft of the [Environmental Assessment and Management Plan] is being made available to interested parties and the public at large for review and comment. To be incorporated in the revised EAMP, such comments should be received no later than [end May] and preferably earlier. A revised report will be made available in June to those who comment on this draft.

ABBREVIATIONS

ADB	Asian Development Bank
BOT	Build Operate Transfer
BPKP	Bolisat Phattana Khet Phudoi
CPAWM	Center for Protected Areas and Watershed Management
DAFO	District Agriculture and Forestry Office
DFR	Draft Final Report
DIH	Department of Industry-Handicraft
DSM	Demand Side Management
EA	Environmental Assessment
EAMP	Environmental Assessment and Management Plan
EASP	Environmental and Social Project
ECI	Engineering Consultants Inc.
EGAT	Electricity Generating Authority of Thailand
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
ENR	Environment and natural resources
ESA	Environmental Study Area
EdF	Electricite de France
EdL	Electricite de Lao
FAO	Food and Agriculture Organisation
FNSRC	French Scientific Research Centre
GHG	Greenhouse gases
GIS	Geographic information system
GOL	Government of Lao PDR
HPPD	Hydropower Policy and Planning Department
IED	Industrial Environment Division
IMWG	Interministerial working Group for Environment and Sustainable Development
IUCN	International Union for Conservation of Nature
JICA	Japanese International Corporation Agency
LWU	Lao Women's Union
MCM	Million cubic meter
MDX	MDX Power Company Ltd.
MIH	Ministry of Industry-Handicraft
MLBs	Multilateral banks
MOU	Memorandum of Understanding
NBCA	National Biodiversity Conservation Area
NGO	Non-governmental organization
NNT	Nakai-Nam Theun (NBCA)
NT2	Nam Theun 2 Project
NTEC	Nam Theun 2 Electricity Consortium
NTFP	Non-timber forest products
NTSEP	Nam Theun Social and Environmental Project
PDG	Project Development Group (NTEC)
PDR	People's Democratic Republic (Lao PDR)
PDV	Provincial, district and village
PLA	Policy, legal and administrative
RAP	Resettlement Action Plan
SEP	Social and Environmental Project (components, as in SEP-type activities)
SI	Seatec International
SKM	Sinclair Knight Merz

SMEC	Snowy Mountains Engineering Corporation Limited
STDs	Sexually transmitted diseases
STENO	Science, Technology and Environment Office
TH	Theun-Hinboun Project
TKC	Turn key contractor
TOR	Terms of reference
UNDP	United Nations Development Program
WB	World Bank
WHO	World Health Organisation
WQ	Water quality
WRC	World Resources Center
XBF	Xe Bang Fai

1. INTRODUCTION

CHAPTER 1

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1. INTRODUCTION

1. INTRODUCTION

The Environmental Assessment and Management Plan (EAMP) for the Nam Theun 2 Hydroelectric Project (NT2) provides a synthesis of all environmental investigations and studies undertaken to address physical and biological impacts relevant to the Project. The EAMP proposes a set of mitigation measures to minimize impacts, provide offsetting benefits, and perform any necessary further surveys and research into specific outstanding issues. The EAMP overviews the relationship between physical and biological factors and the social and economic considerations that are important for both the long term development of the People's Democratic Republic of Lao (Lao PDR) and the region in which the project is proposed.

Mitigation measures that are needed to compensate for impacts on quality of life and human values are addressed through the Resettlement Action Plan (RAP).

The main offsetting measure, conservation of the 3,700 sq km N-NT NBCA, is detailed in the separate International Union for Conservation of Nature/Wildlife Conservation Society report.

1.1 THE PROJECT

NT2 is located in Khammouane Province in Central Laos. It is proposed as a build-own-operate-transfer (BOOT) project, and is being undertaken through a joint venture partnership comprised of the Government of Lao PDR (GOL) and the Nam Theun Electricity Consortium (NTEC). NT2 is being developed as a build-own-operate-transfer (BOOT) project by NTEC which allows the GOL to be protected from construction cost and operating risks, while at the same time benefit from its shareholding in the project, which is expected to be of the order of 25percent.

The NT2 Project will consist of a reservoir on the Nakai Plateau some 450 sq km in extent at full supply level (FSL) of 538 masl. The reservoir is formed by a roller-compacted concrete dam 44m in height along the middle reach of the Nam Theun River. Approximately 210 m^3/sec of flow will be diverted out of the Nam Theun watershed and through the Powerhouse located more than 350 m below Full Supply Level (FSL) at the base of the Nakai Plateau near the town of Gnommalat. The tailwater from the Powerhouse will be regulated and then carried in a purpose-built channel along the Nam Phit River for a distance of 38 km. to enter the natural course of the Xe Bang Fai River down to the Mekong.

The location and main features of the project are shown in Figure 1-1.

1.2 JUSTIFICATION FOR THE PROJECT

Lao PDR is classified by the United Nations as a 'least developed country' with gross domestic product per capita estimated at $355 per year and a mean monthly consumption expenditure per capita of slightly less than 15,000 Kip (about $15 using the current exchange rate). GOL has the intention to move the country into 'developing country status' by the year 2010, and in so doing faces a number of development concerns. These concerns include opportunities and risks associated with the position of Lao PDR within the regional setting, means for facilitating the country's transition to a market economy, the need for rapid economic growth, and critical gaps in human and institutional resources and capabilities. The target is to increase national income, since experience throughout Asia tends to show that maximizing economic growth has been most effective for reducing poverty both in absolute and relative terms. The means for increasing national income are limited to a few opportunities, most of which involve use of natural resources.

Lao PDR is endowed with an extensive natural resource base in forests, hydropower potential, mineral resources and spectacular natural beauty. These resources are located within the heart of a dynamic growth region, and Lao PDR will benefit from its proximity to markets and the availability of foreign investment capital. Opportunities for harvest of timber, exploitation of mineral wealth, development of hydroelectric power and regional tourism are all important contributions to national income, but none can provide the sole measure, and all in fact are essential for the progress of development in Lao PDR. However in parallel with this essential development there must be conservation and protection of these precious natural resources.

The NT2 Project has long been identified as one opportunity with the highest potential for contributing to national economic development. The project also offers the opportunity to conserve one of the largest and most important forest and wildlife areas in the region. NTEC and the GOL are committed to meeting economic, social and environmental standards to meet World Bank's requirements. This will help achieve lower cost financing and compliance with international standards for environmental protection, and therefore greater benefits to the people of Laos.

The installed generating capacity of the project is projected to be 681 MW which will be largely exported to Thailand for distribution through the power grid of the Electricity Generating Authority of Thailand (EGAT). The sale of electricity to Thailand is in keeping with the 1993 Memorandum of Understanding (MOU) between GOL and EGAT for sale of 1,500 MW of installed power capacity. In 1996, GOL and EGAT signed an additional MOU that increased the export target by 1,500 MW to a total of 3,000 MW installed capacity by the year 2000.

NT2 will generate more than $250 million (1996 dollars) per year of electricity for export to Thailand. The GOL will receive substantial revenue from NT2 in resource levies, royalties and dividends - money which is badly needed to implement poverty alleviation and infrastructure development programs within the country. NT2 will also contribute money to the management of a 3,500 square kilometer protected forest area of recognized international significance, as well as improving local infrastructure and agriculture.

Currently there are two hydroelectric facilities that contribute to Lao's export target. Nam Ngum dam was put into operation in 1961 to provide power for domestic use and for export. Nam Ngum currently provides 150 MW of installed capacity for export, and is being expanded. The Nam Leuk hydroelectric project, now under construction, will become part of the Nam Ngum system by diversion of water through its own power generation facility into the Nam Ngum watershed. The second facility is the Xeset Dam on the Bolivans Plateau in Southern Laos which provides 45 MW installed generating capacity for export to Thailand.

Another 921 MW of installed capacity is under implementation and scheduled for completion between 1998 and 2002, including Theun Hinboun (Hydro), Houay Ho (Hydro), and Hong Sa (Lignite).

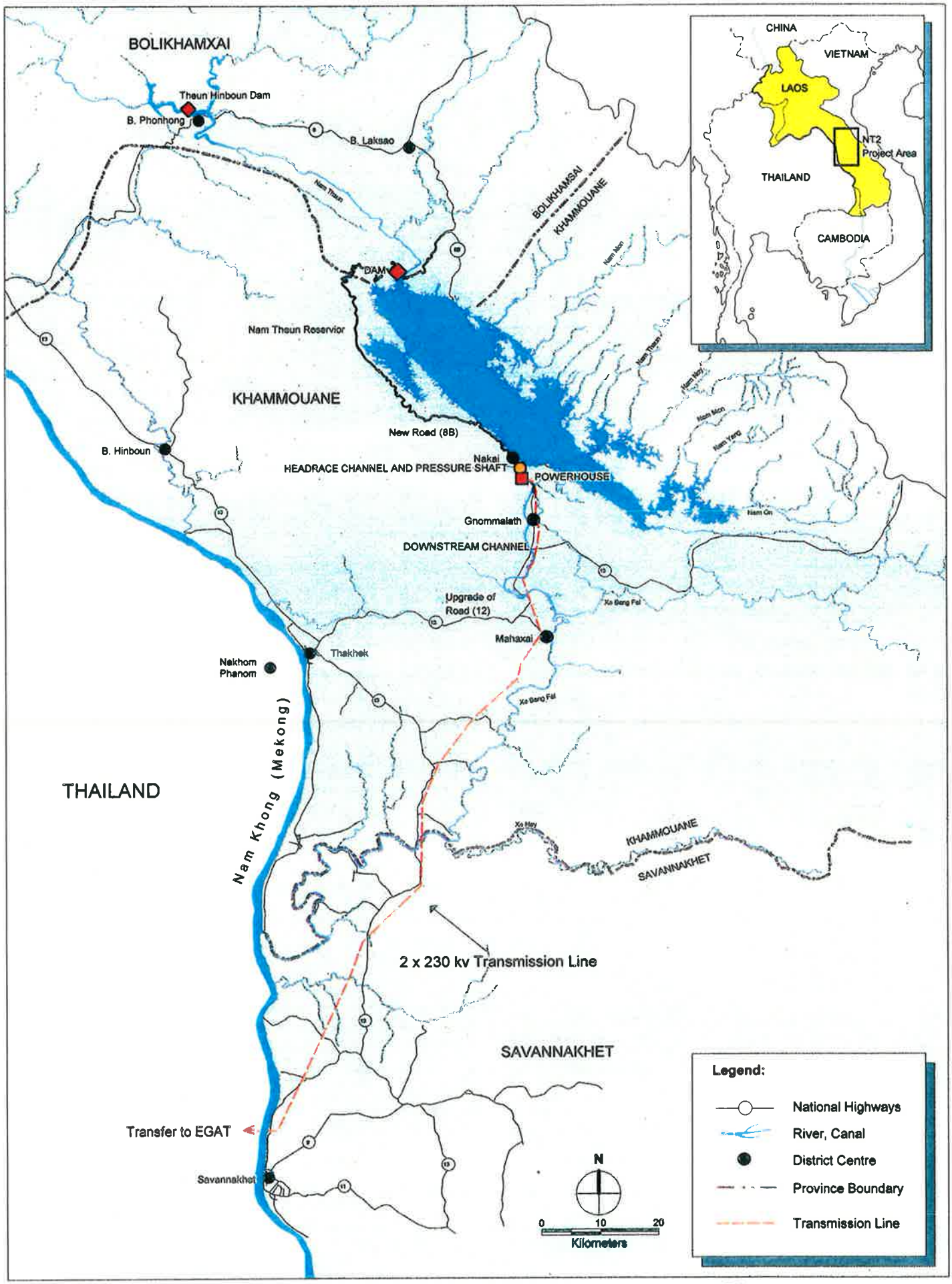

FIGURE 1-1 PROJECT LOCATION AND PROJECT FEATURES MAP

NT2 is a major undertaking within a biologically sensitive and culturally diverse region of Lao PDR, which will undoubtedly bring about profound alteration of the regional setting. As a result, there are fundamental questions that are rightfully addressed within the context of environmental and social assessment. Many specific issues are addressed in the present EAMP having to do with protection of components of the environment and their associated values. Environmental issues are characterized by their relationships within an interdependent context of cause and effect, in which beneficial use and national patrimony are at stake. The EAMP evaluates specific environmental issues, seeks to understand relationships within increasingly comprehensive frames of reference, and formulates an environmental management plan.

1.3 ALTERNATIVES TO THE NT2 PROJECT

The Alternatives Analysis for the NT2 project, being undertaken by Lahmeyer and Worley Consultants for the GOL, in response to a request by the World Bank. is one of the more important studies currently in progress. It is intended to address the viability of NT2 as a source of national income for Lao PDR, and to assure the development is justified from a regional perspective, both in terms of regional power demand and in comparison to alternative sources of supply. The study also evaluates design options so as to maximize benefits and minimize environmental and social costs. The scope of the study is extensive, inclusive of demand side management in the recipient market in Thailand, alternatives for satisfying that demand, consideration of the full range of hydroelectric and thermal power options within Lao PDR, and siting and design options for the NT2 project itself. While the study is not yet complete as of this writing, certain preliminary findings are presented in the Second Progress Report dated February 1997. Among these findings are the following:

- Growth in electricity demand in Thailand has been steady at more than 12 percent annually during the period of 1986 to 1996. It is expected to slow to 9.9 percent p.a. from the present to the year 2001.

- In absolute terms, peak power demand is expected to reach more than 41,000 MW by the year 2011 from a 1996 value of 13,300 MW.

- While Thailand has a variety of available options for satisfying the forecast demand, including an aggressive demand side management program expected to achieve a saving of about 2,000 MW by the year 2011, additional power generating capacity of some 34,000 MW will be needed for the period from 1997 to 2011.

- Importation of electric power from Laos is an important component in Thailand's overall supply scenario for which there are various options including more than 24 hydroelectric power proposals and a proposal for a lignite-fired thermal power plant.

The market exists to readily absorb power generated from the NT2 project.

The Alternatives Analysis is expected to be completed in June -July 1997.However initial findings indicate that NT2 ranks very well compared to other near term power development options in Lao PDR. It also shows that NT2 conforms to a rational development sequence for the Lao PDR for meeting power export targets and that there are no other alternatives currently under development that will provide the necessary capacity within the time frame proposed for NT2.

The Alternatives Analysis is carrying out a detailed evaluation of design options available for the NT2 project. In order to reduce the size of the reservoir the analysis considers; moving the dam location upstream; reducing the spillway height; development of NT2 as a pumped storage

or run-of-river project; and provision of upstream regulation of the Nam Theun tributaries. Reduction of the full supply level to an elevation of 528 reduces the project cost by six percent; however it increases the unit cost of power generation by 55 percent. Moreover, the numbers of people requiring resettlement as a result of the project will not be reduced by lowering the full supply level of the reservoir as the bulk of the resettlers live at 525. Other options related to reducing the size of the reservoir involve both increases in project construction cost and power generation cost. Though the Alternatives Analysis includes further analysis of options involved with reducing the reservoir size, the preliminary conclusion is that the present configuration is optimal in terms of minimizing power generation costs. There is a slight preference from the social and environmental perspective for locating the dam at Ban Signo and an even greater preference for the run-of-river option.

The Alternatives Analysis also considers the means for conveyance of water away from the Powerhouse to the Mekong. Diversion of water to the Nam Hinboun is shown to be more expensive and to provide no advantage to the present configuration. Another concern has to do with flooding along the Xe Bang Fai, and the study considers means for reducing or otherwise compensating for potentially worsened flood conditions. While there are still some outstanding considerations, most possibilities have been exhausted without providing any significant improvement, and one option, relocation and compensation, is already incorporated into the overall project plan.

A number of options are considered for mitigation of project impacts on environmental values. The Study considers, for instance, the principal trade-off associated with inundation of the reservoir area, which is the creation of a management plan – with appropriate funding – for the Nakai-Nam Theun National Biodiversity Conservation Area. Specific requirements are addressed which will secure the viability of the strategy in the face of actual constraints. Other considerations are brought out in the Alternatives Analysis, all of which are also addressed in the present EAMP.

The Alternatives Analysis is an important contribution to the ongoing evaluation of NT2. While the final report is expected in June 1997 , it is clear from work already finished that Thailand can readily absorb the power generated by NT2, and that the project as presently conceived is one of the best power generation options available to Lao PDR.

1.4 Other Studies in Progress

It is important to GOL, WB and NTEC to be thoroughly confident that NT2 can deliver its promised economic benefits without undue negative effects on the environment or on the economy of Lao PDR. The EAMP addresses the first of these issues – the environment. Other studies include;

- the Alternatives Study by Lehmeyer and Worley as previously described
- the Economic Impact Analysis being prepared by Louis Berger, which considers macroeconomic effects on the Lao economy and microeconomic effects on the specific region of Central Laos in which the project will be developed
- the Environmental and Social Project (EASP), which concerns the management of the N-NT NBCA
- the Resettlement Action Plan (RAP), which examines human issues that stem from the NT2 project

- the World Bank's Nam Theun Social and Environmental Project (NTSEP) which examines social and environmental impacts as a result of the Project. The study considers the results of the EAMP and RAP and undertakes its own research to determine which individual projects related either directed or indirectly to NT2 , the World Bank will provide implementation funds to GOL if so requested

All of these studies are being undertaken to fully understand the ramifications of developing the NT2 project from the viewpoint of a fully responsible agency constituted by the joint coalition of GOL and NTEC. Taken in total, they represent the most thorough consideration of economic, environmental and social issues related to hydroelectric power generation ever undertaken in Lao PDR, and most likely in mainland Southeast Asia.

At the time the final EAMP report is produced, most other studies also will have reached their final stages. A reconciliation of results will take place that will present a unified picture of the overall viability of the NT2 project. The studies together will provide a comprehensive set of recommendations on preferred development options and necessary mitigation measures to minimize social and environmental impacts and fully benefit from conservation opportunities within the project area.

It can be stated confidently however that – on balance – the studies conclude that NT2 can be successfully implemented and can fulfill its stated purpose of bolstering national income for Lao PDR without undue effects on environment, social or economic systems.

1.5 SCOPING OF THE EAMP

The EAMP is directed at resolving environmental issues in order to enhance further the project benefits for Lao PDR. These issues have been developed over an extensive history of scoping, beginning at the outset of project concept and identification in the 1970s.

Dam sites were identified on the Nam Theun-Nam Kading System in the mid-1970s by the Mekong Secretariat, following implementation of the Nam Ngum project. The Swiss engineering firm of Motor Columbus was engaged by the Mekong Secretariat in the early-1980s to investigate three projects on the Nam Theun River. Motor Columbus' initial work recommended further study on all three projects.

The Australian firm Snowy Mountains Engineering Corporation Ltd. (SMEC) performed the initial geotechnical investigation for the Nam Theun 2 Dam sites for the Mekong Secretariat in 1984 and 1986. SMEC was later commissioned by the World Bank to undertake the Nam Theun 2 hydroelectric project feasibility study. The final reports produced by the study included an 'Environmental Status Report', which represents the first comprehensive evaluation of environmental issues for the NT2 project.

A parallel development involved the formulation of a national protected area management strategy within Lao PDR. IUCN-The World Conservation Union has been working in partnership with the Government of Lao PDR since 1988, and the Government has been a State member of the Union since 1969. IUCN proposed formation of protected areas, or reserve forests, in many parts of the Country, including the Nakai Plateau and in the upstream watershed of the Nam Theun. In June 1991, GOL rationalized the proposed Nakai Plateau and Nam Theun NBCAs by combining both into a single Nakai-Nam Theun NBCA that excluded the NT2 reservoir area. The NBCA was gazetted in October 1993 along with twenty other NBCAs throughout the country.

In 1993 GOL negotiated with the combined SMEC/Transfield group resulting in a Memorandum of Understanding concerning the NT2 project, executed later that year. A new

consortium consisting of Transfield, EdF, Italian-Thai Development, Phatra Thanakit and Jasmine International, then began negotiating with EGAT concerning the power purchase agreement. In the initial MOU, GOL identified a number of issues of importance related to environmental and social impact. The issues that required the attention of the consortium were identified as follows: (i) resettlement of about 1,000 families living in the inundation area, (ii) flooding along the Xe Bang Fai River and compensatory irrigation schemes there and in the area of the re-regulating weir, (iii) re-routing of Highway 8B around the proposed inundation area, and (iv) development of mitigation measures aimed at reducing loss of flora and fauna in the inundation area and below the dam.

By early 1994 the BOOT project concept with GOL equity was firmly in place.

NTEC awaited the ultimate form of the project's financial structure before commitments were made for additional environmental assessment work. When GOL invited the WB to be involved as both provider of funds to GOL and loan guarantor for the project, environmental assessment requirements were determined to be, at a minimum, those required by the Bank. Further environmental assessment work was then targeted to comply with World Bank policies and directives as well as those of the GOL.

NTEC engaged TEAM Consultants of Thailand to prepare an initial environmental assessment, which was released in November 1994. This work outlined tasks and assigned responsibilities between the developer and GOL, and highlighted the limited capacity of GOL to handle environmental and resettlement aspects. Dry season investigations were undertaken in 1994 and 1995 by TEAM, supported by EdF and SMEC on hydrology, and an environmental assessment report was completed in April 1995.

This period saw the first vocal criticism of the project by local and international NGOs. The World Bank issued a list of the outstanding concerns in November 1995, including the need for an alternatives study that ranked power generation projects, and other work required to be undertaken by GOL, including an Economic Impact Analysis and the EASP.

By November 1995, it became apparent the World Bank could not fund the NBCA planning work under the Global Environment Fund, and NTEC stepped forward to facilitate this aspect of the overall project development. Preliminary negotiations were held concerning a joint WCS/IUCN study. The November 1996 WB mission developed the assistance program for GOL known as the Nam Theun Social and Environmental Project (NTSEP), which provides opportunities for parallel funding of activities related to the project by GOL. At about the same time NTEC received proposals from competing environmental firms for preparation of the present EAMP.

The list of environmental and social issues for the NT2 project is extensive, and receives comprehensive coverage in the EAMP and the RAP. NTEC has conducted or funded a number of studies, some of which are listed in Annex A, that provide an in-depth evaluation of critical environmental issues. One such study involves the analysis of water reservoir water quality, which provides a numerical simulation of the expected conditions in the reservoir over a 10-year time frame following filling of the reservoir. The issue is critical for beneficial use of the water to maintain ecological benefits below the dam and for human and ecological uses in the area below the Powerhouse. Further studies have been undertaken on fisheries and terrestrial biodiversity to better understand the potential impacts on these environmental values. Construction and public health impacts are also critical issues and both are addressed extensively in the EAMP. Health issues also receive extensive attention within the context of the RAP.

1.6 PREPARATION OF THE EAMP

The main mitigatory measure, technically an offset or compensation, is NT2 financing the conservation of the 4,013 sq.m. watershed. This vital measure is detailed in a parallel report by IUCN/WCS expected by June 1997. The EAMP provides the perspective, background, identification and mitigation of specific impacts. The approach of the EAMP Team involves determining the likely impact of the Project on environmental resources. Physical systems are dealt with from the standpoint of engineering design adequacy and serviceability for their intended uses. The EA also looks closely at biological issues, both forest and agricultural-land plants and animals, and aquatic ecology and fishery resources. The environmental assessment focuses on losses in the inundation area, and downstream of the dam. It assesses the extent of these losses in comparison with other similar values in the NBCA or elsewhere in the project area.

The baseline conditions for evaluating biodiversity are derived from a distribution of primary habitat elements (which include primary forest types, agricultural land use classifications, riverine habitats and other primary types) and habitat sub-elements, such as sand shoals, karst outcrops, and roadway. Habitat losses are identified in directly affected areas, primarily Zones 1 and 4[1], and key bird and mammal species found in these habitats are identified from reference materials and earlier wildlife surveys. The general types of forest and wildlife resources that are preserved in the NBCA serve as potential offset measures for direct impacts. Indirectly affected areas are also identified, primarily the Dividing Hills in the NBCA, with the intention of mitigating potential damages.

The EAMP considers how aquatic ecology and fisheries will be affected by the presence of the reservoir. Recent work on fish & fisheries by Kottelat (1996 & 1997) and the previously described water quality model provide basic information for the present work which focuses on the types of fish that are found in specific zones. Aquatic biodiversity will almost certainly be impacted as a result of the Theun-Hinboun and NT2 dams.

Human use issues are mostly dealt with in the Resettlement Action Plan (RAP).

1.7 SCHEDULE AND RESPONSIBILITIES

1.7.1 Schedule

The Environmental Assessment and Management Plan (EAMP) is scheduled for agreement in advance of finalising financial arrangements for the Project as a whole, nearly a year in advance of the proposed commencement of construction.

This May 1997 draft will be reviewed and submitted to the World Bank in June 1997, together with a revised draft of the NT2 RAP and other studies as outlined in the Section 1.4. If the Bank decides to proceed with evaluation of NT2, it is likely a further draft will be submitted towards the end of 1997, to assist in that evaluation and update the plan with the results of any further work planned in the interim period.

Provided that the World Bank decides to support NT2, detailed negotiations with Financiers should culminate in Financial Close in the third quarter of 1998. Prior to this a final EAMP will be prepared so that the contents can be incorporated in the Project Documents.

[1] See Figure 4-1 for definition of these zones. Zone 3 and the zones below the powerhouse are also affected: Zone 3 holds potentially valuable biodiversity resources.

1.7.2 Responsibilities - NTECo and GOL

The responsibility to implement all the commitments in the finally agreed EAMP will be distributed between two bodies; the GOL and to the Nam Theun 2 Electricity Company (NTECo).

NTECo is a different body to the consortium developing the project with GOL, known as NTEC. At or before Financial Close, the GOL and the private sector members of the of NT2 Consortium, NTEC, will form the company designated as NTECo.

It is intended that NTECo will have approximately $400 million of equity and loan agreements or about twice that much. Agreement to the EAMP, including its budget and implementation schedule by the Provincial Authorities, the GOL as well as the World Bank and its expert advisors will be necessary before the Project developers and financiers finally commit to funding the construction of NT2.

1.8 THE EAMP TEAM

The Environmental Assessment team is comprised of professional and support staff from Seatec International Ltd. (SI), Sinclair Knight Merz (SKM) and Engineering Consultants Inc. (ECI). Independent consultants provide inputs in specialist fields including forestry and biodiversity, wildlife and public health. EDAW Ltd. Provides the GIS database and maps for the project. Annex B gives a brief description on the background and capabilities of the main EA team members and their respective contribution to the development of this document.

1.9 REFERENCE MATERIALS

The period of time that the NT2 project has been under consideration, and the intensive concerns for environmental and social issues, have led to a large body of information concerning the project. This information was used as essential source references for the present work. The background materials include previous comprehensive EA reports as well as individual studies on specific types of environmental and natural resource issues. There is also a wealth of information related to the physical aspects of the project, including extensive process design information contained in some 24 volumes, and geological reports that in a compiled state fill about 10 volumes. Documents that are cited in the present EAMP are included in a list of references in Annex A.

The references were crucial for the present work, and without these background materials, the EAMP team would not have been able to perform the present work. The task for EAMP Team was essentially to review, verify and interpret previous work. The thrust of the present effort involved use of previous work to highlight the actual environmental impacts that can occur under the with-project scenario. Sincere thanks and appreciation from all of the EAMP team is extended to those previous researchers whose efforts have been invaluable for the present work.

1.10 ORGANIZATION OF THE REPORT

The EAMP conforms to the preferred outline and organization of the World Bank for environmental assessment. There are a few exceptions resulting from the analysis of alternatives and the economic impact analysis being prepared as separate documents, hence neither is included in the current version of the EAMP. The RAP also contains in-depth appraisal of social issues related to the NT2 project.

The Executive Summary, which is both bound as a separate document and included with the main text of the EAMP, provides a general overview of issues taken from each of the chapters of the main text. It constitutes a reliable synopsis of the contents of the EAMP, without adding new content or perspectives to the body of issues.

Chapter 1, the present introductory chapter, has presented the perspective on why NT2 is proposed as an economically viable, as well as environmentally and socially acceptable, project for Lao PDR at the present time. It contains the main exposition of alternatives to NT2 as a key feature of the justification for proceeding with the project. It describes other parallel studies that are being conducted in parallel with the EAMP, including the Economic Impact Analysis, the Environmental and Social Project (EASP) for the Nakai-Nam Theun National Biodiversity Conservation Area (N-NT NBCA), and the Resettlement Action Plan (RAP). It describes the manner in which these diverse yet integrated studies merge to form a comprehensive assessment of the many variegated issues related to NT2. Finally, the introductory chapter provides a brief description of general methodology, and the consulting team undertaking the work, as well as the present description of the contents of the overall report.

Chapter 2 provides the policy, legal and administrative framework for the project. This framework is unique, stemming from the nature of the project as a BOOT undertaking in conjunction with GOL, which serves as both a proponent for the project and the chief regulatory agent for monitoring project mitigation measures. The chapter contains a description of the implementation framework proposed by NTEC for undertaking mitigation actions through the Turn Key Contractor (TKC). It also contains descriptions of existing and proposed policies and laws related to the environment, management of forests and watersheds, and river systems in general. It describes the institutions that are responsible for administering national instruments of policy, including the Science, Technology and Environment Office (STENO) and the Center for Protected Area and Watershed Management (CPAWM), as well as provincial and district level institutions. Chapter 2 also provides a description of relevant policies and laws related to resettlement and human impacts. The requirements of the World Bank in relation to both environmental and social issues are also reviewed.

Chapter 3 presents the project features in detail. From this chapter the reader can obtain a clear understanding of the actual proposals put forth by NTEC, both in terms of the physical components of the project and the proposed environmental components. NTEC proposals for mitigating construction impacts are also described in this chapter, as well as the proposed means for maintaining water quality during the operations phase.

Chapter 4 provides background information related to the environmental setting and baseline values that are at stake in the project. It provides a detailed description of the Environmental Study Area (ESA) and project component ESAs, of which there are 15 in total. It describes physical, biological and social, or human, baseline conditions in terms of baseline trends where possible, since the ongoing trend of the baseline is the most accurate condition with which to compare the effects of the project. The chapter provides a detailed look at the environmental values found in the project area, making use of annexes where possible for inclusion of supplementary information.

Chapter 5 is the environmental assessment. It considers the superposition of the project on the baseline trend, and describes environmental impact, making comparisons with alternatives and offset measures where they exist. Both Chapters 4 and 5 are arranged to present physical, biological and human development factors in that order, and to synthesize information among two or more environmental components wherever possible, in order to show the relationships and linkages among components. Chapter 5 also contains a series of special topics, as follows:

- Component EIA studies focusing on the roadways, resettlement sites, quarry sites, worker camps and transmission line.

- The Cumulative Impact Assessment, which considers NT2 in conjunction with other development activity, at scales relevant to specific types of impact.

- The Intact Rivers Assessment, which considers use of the Nam Theun for extensive hydroelectric power development and the eventuality of other rivers remaining free-flowing within Lao PDR.

- The Multiple Use Assessment, which considers the possible multiple benefits to be obtained from the NT2 project, outside of power generation.

Chapter 6 is the Environmental Management Plan (EMP) for the NT2 project. The EMP comprises of a series of parts, beginning with the institutional recommendations for the project. These encompass means for undertaking mitigation activities as well as monitoring mitigation work in progress, both during construction and operations phases. The EMP describes roles for NTEC, the TKC, STENO and other national agencies as well, including both provincial and district organizations. An institutional strengthening technical assistance is also proposed for the construction phase of the work.

The EMP then provides a detailed list of measures, accompanied by costs where applicable, and assigns responsibility for the measures to one of five different agents. It is important to note that all items of cost identified in the EMP originate with NTEC, either via the TKC, as payee for the NBCA management strategy, or via the RAP, or the NT2 operations group. The thrust of this approach is to divide the costs clearly among different cost centers to be borne by NTEC. Some activities are initiated by GOL; however the costs associated with the activity are borne by NTEC. The EMP does not include a comprehensive set of measures for alleviating and compensating for human impacts, as this topic is primarily the domain of the RAP

1.11 ACKNOWLEDGMENTS

Seatec International and the project team is grateful for the opportunity to study the Nam Theun Basin, the Nakai Plateau and the proposed NT2 project, and extends its sincere appreciation to the Government of Lao PDR for the opportunity, as well as to the Nam Theun Electricity Consortium (NTEC). Seatec International Ltd. is cognizant of the extensive prior work that has been undertaken to understand the great variety of complex issues related to environment within the project area, without which the present work could not have been conducted, or have been nearly as comprehensive. Seatec International Ltd. also understands the complex interaction of environmental factors with social and economic considerations, both in terms of assessment and as part of a normative process that will take Lao PDR and the project area forward. These normative guides include the RAP and the EASP, both of which hold great promise for paving the way for sustainable development and resource use in the project area. The present EAMP is presented as a partner to these plans, and strives for mutual compatibility of purpose and means toward a common goal.

2. POLICY, LEGAL AND ADMINISTRATIVE ISSUES

CHAPTER 2

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2. POLICY, LEGAL AND ADMINISTRATIVE ISSUES

Policy, legal and administrative capacity is essential for environmental management since 'the ultimate success of the EA depends upon the capability and understanding of environmental matters of the government agencies concerned.' (WB, 1991) The NT2 project is being developed within the context of environmental and social policies of the Government of Lao. While the framework for these policies is mostly intact, their articulation will come about as the policies themselves are put into practice. It is the stated aim of NTECo to conform to these policies, and in their absence to comply with all relevant intentions of the World Bank operational policies and directives. The current EAMP is prepared in conformance with both the policies of the Lao Government and the policies and directives of the World Bank.

The main thrust of the institutional issues on the NT2 project has to do with NTECo's role alongside GOL in instituting mitigation measures and monitoring their effectiveness. GOL's position as a shareholder in the project and the terms of the concession agreement (CA) will define actions for NTECo and GOL. GOL's duties will be primarily in human issues and public participation and involvement, whereas NTECo monitors the construction aspects. These roles for GOL occur through the Science Technology and Environment Organisation (STENO), which has oversight for monitoring and studies. The legal framework for implementing environmental protection measures, and the ability of the agency to mobilise institutional capacity are concerns of this section. The recommended arrangement and scope of duties for implementing environmental protection measures (EPMs) is presented in Chapter 6 of the EAMP. This chapter focuses on the role of NTECo in the implementation of mitigation measures, along with a description of the institutional setting within GOL for working alongside NTECo to undertake those measures.

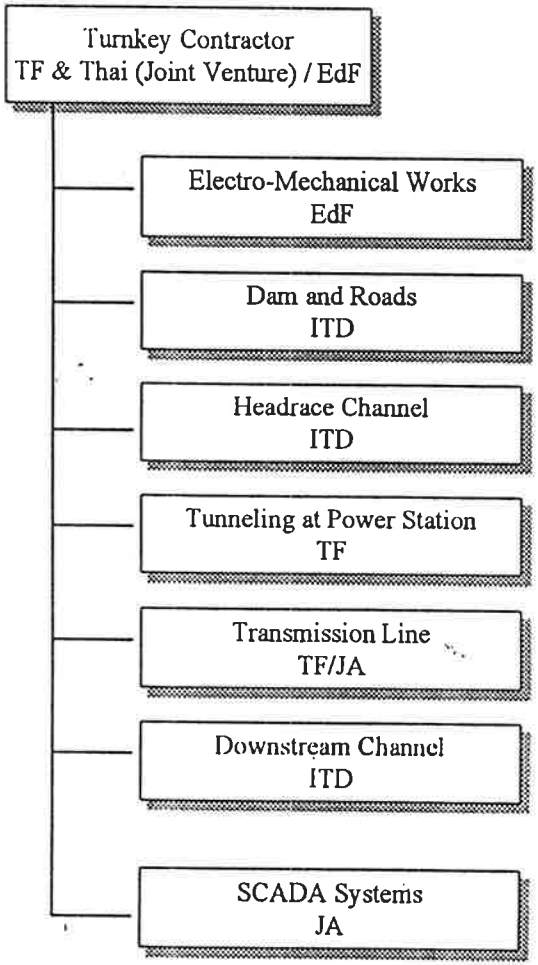
2.1 PROJECT MITIGATION, MONITORING AND ENFORCEMENT

2.1.1 NTEC Proposal for Construction Environmental Management

The NTEC Consortium is made up of five corporate members, including three registered Thai companies (Phatra Thanakit (PT), Jasmine (JA) and Italian-Thai Development (ITD)), one Australian company, Transfield Holdings Ltd. (TH), and the French electricity authority, *Electricité de France* (EdF). NTECo company will become a formal entity with GOL's participation as an equity partner following final negotiations and after contractual arrangements for the partial risk guarantee is approved by the Bank, and the Concession Agreement (CA) is finalised with GOL. NTECo is a different body to the consortium developing the project with GOL, known as NTEC. At or before Financial Close, the GOL and the private sector members of the of NT2 Consortium, NTEC, will form the company designated NTECo.

NTECo will undertake the construction of the project through a turnkey contractor (TKC) which is intended to be a consortium between a joint venture of TF, ITD and Jasmine, and EdF.(WB, 1996d). Figure 2-1 shows the Turnkey Contractor Organisation. The TKC is responsible for undertaking agreed mitigation measures during construction, and for assuring that subcontractors working under the TKC are also conforming to good practice. Construction divisions among the TKC consortium may perform elements of work to construct the project.

Figure 2-1 : Turnkey Contractor Organisation



The TKC plan for implementing construction phase mitigation measures is described in the 'Nam Theun 2 Hydroelectric Project Environmental Management Plan -- Construction'. (NTEC, 1996) The underlying policy addresses the obligation of the Turn Key Contractor 'to meet all specified environmental rules and regulations as defined in the Turnkey Contract and Concession Agreement (CA). The Construction Environmental Management Plan (CEMP) has been established to incorporate safeguards and standards which meet recognised good practice principles and regulatory requirements imposed by Lao PDR authorities and others as defined in the Concession Agreement. This policy has the total commitment of Senior Management and staff of the Turnkey Contractor. It is the basic policy of all consultants and subcontractors to conform with the policy and they will be encouraged to contribute to continuing improvement of the environmental management system and protection practices.(NTEC, 1996: p. 3)

The responsibility for environmental management for the TKC is held by the project managers, who are also responsible for conducting reviews and approving corrective actions. The Quality Assurance Manager is responsible for performing process quality audits. The Environmental Manager is responsible for ensuring compliance with all aspects of the EMP, and approval of the technical approach. Other responsibilities for the Environmental Manager include identifying corrective actions, and preparation of a monthly environmental report. Additional information on the proposed TKC environmental management approach is given in Chapter 3.

The Construction EMP primarily covers mitigation activities that will be undertaken by the TKC. A monitoring function has been assumed by NTEC in order to assure compliance with the contractual standards in agreements between NTEC and GOL and in the agreement with the TKC. The involvement of GOL agencies provides the opportunity for many Lao agency staff to undergo training, and to have more direct involvement with provincial and district agencies involved with NT2. The CA will define responsibilities for mitigation and monitoring to be assumed by NTECo and the TKC, through incorporation of the agreed-upon measures proposed by the EAMP. Chapter 6 of the EAMP presents a description of mitigation measures that appear reasonable and acceptable to the various parties. These or amended versions will be incorporated into the Concession Agreement (CA).

The TKC assumes contractual responsibility related to construction issues for the Main Works and Resettlement infrastructure. The TKC's responsibilities extend only over the construction phase, to include self-monitoring and enforcement via standard international quality assurance procedures. The responsibilities of the TKC are coordinated with those of NTECo, so that the latter can assume an overall surveillance role during and in relation to construction, can undertake implementation of specific measures falling outside the domain of the TKC, and can continue its activities as necessary into the operations phase.

The Panel of Experts Report (MIH, 1997; p. 6) identifies the need for independent review of project mitigation and compensatory measures. The November 1996 World Bank Mission reports that it is STENO 'who are responsible for environmental protection.'(WB, 1996c) The EMP (Chapter 6) recommends that STENO be involved in monitoring of mitigation along with the Hydropower Office of Ministry of Industry and Handicraft (HPO/MIH) and EdL in conjunction with Provincial and district governments in the project area. The details of this proposed arrangement are provided in the EMP.

2.1.2 Functional Aspects of Environmental Protection

2.1.2.1 Policy Aspect

Policy Formulation

Policies of the Government of Lao PDR related to environmental protection have received support from international sectoral lending programs and through direct bilateral assistance aimed at improved resource management and biodiversity conservation. Many policies have undergone rapid development over the last seven years, since 1990, with major policy advances by means of the National Environmental Action Plan (STENO 1993). All environmental and sustainable natural resource policy development efforts have received significant support from sources internal to the Government.

The National Environmental Action Plan (NEAP) states that the Government of Lao PDR recognises the need for a process-oriented planning and management framework that provides the umbrella for specific sector interventions. The management framework has focused on (i) development of environmental policy, legal and regulatory mechanisms; (ii) continued implementation by STENO of its mandate; (iii) integration of environmental concerns into the national planning system; and (iv) establishment of a national environmental assessment procedure. Sectoral actions fall within the specific domains of the line ministries, and focus on forest management and conservation policy, improved agricultural production systems and watershed management, development of management plans for the protected areas system, and implementation of a national level environmental awareness and education program. Key actions over the last five years include definition of environmental guidelines and standards for the industrial and mining sectors, expansion of water supply and sanitation, and improvement of environmental data collection. In addition, it is the government's policy to take fully into account the question of community participation, and to reorient the Government to a community based resource management system of social and economic planning which links central, provincial and district level organisations.(STENO 1993)

A major environmental policy advance over the last seven years has been the revision of the mandate and structure of STENO, plus organisational reforms that re-focus the role and functions of STENO into a national environmental management agency operating in parallel with the State Planning Committee (SPC) at Executive Government level, reporting to the Prime Minister's Office (PMO). In conjunction with this re-formulation of STENO's mandate has been the formation of interministerial working groups (IMWGs) for co-ordinating environmental planning and management across all sectors.

A key thrust of Lao PDR environmental policy has been the integration of policies across all sectors, and at all levels of Government. STENO plays a key role in this undertaking by (i) providing management assistance to line agencies; (ii) co-ordinating formulation of research and technology policies that often involve line ministries; (iii) assuming responsibility for international linkages concerning science, technology and environment issues; (iv) and serving as the main co-ordinating agency for environmental planning and management activities. STENO will develop provincial-level representation that provides the means for community-based action. STENO is also charged with development of guidelines for a national EA system and working with line agencies to develop sectoral guidelines for EA.

The SPC works alongside STENO to integrate environmental concerns with the overall economic priorities of the Nation. It promotes policies to increase transparency in public investment planning, including assignment of decision making responsibilities, assuring the proper documentation of public investment projects, refinement of decision making procedures,

and furthering the development of the EA process. STENO's environmental planning capability is linked to SPC's economic planning agenda. Both executive-level agencies support the formulation of specific procedures for line agencies concerning environment and the preparation of a national environmental policy framework, developed from the National Environmental Action Plan, and ratified by the PMO.

Various sectoral policy components are found within the national policy framework for environmental and national resources management. These are described briefly below. Further discussion of specific legal and administrative issues as they relate to the NT2 project are found in other sections of this chapter.

The forestry sector has adopted a forestry management and conservation policy that focuses on sustainable yield management of production forests, community based resource management that incorporates long term use and access for purposes of customary use, and protection of forests in critical areas. Forestry policy is reflected in the recently adopted Forestry Law, described in Section 2.2.1.2 of this chapter. Other important elements of forestry policy involve (i) revision of the timber pricing policy to reflect cross-border parity prices; (ii) preparation of the national forestry inventory; and (iii) institutional strengthening of the Forestry Department.

The water resource sector has developed management policies that include (i) development and implementation of catchment management programs in watersheds with existing hydropower schemes; (ii) designation of a key agency, the Centre for Watershed and Protected Areas Management, in charge of developing and implementing catchment management plans; (iii) development of EIA protocols for hydropower development; and (iv) improved sanitation and solid waste management in urban areas. In keeping with these policy objectives, the Government has promulgated a national water law, the Law on Water and Water Resources (No 02-96 dated 11 October 1996, described in Section 2.2.1.1 of this chapter), which states that 'water and water resources are the property of the national community represented by the State in the management and distribution for widespread and reasonable consumption'(Article 4) in which 'management ... must unfold according to the principles of centralised, full and integrated management according to the management plans provided' under the Law.(Article 6)

Policies concerning the urban and industrial sector include (i) a mandate for institutional review to reallocate responsibilities for urban environmental planning and management; (ii) development of water quality standards; (iii) establishment of a regulatory framework for safety and pollution control in conjunction with industrial guidelines and standards; (iv) application of an enforcement and monitoring system.; and (v) improvements in water supply and sanitation along with an overall revamping of public health priorities.

Policy Implementation

GOL will find an opportunity for sound environmental policy implementation within the framework of the NT 2 project, because of NTECo's commitments to international standards of practice during construction, to mitigating social impacts, and to biodiversity conservation. The expertise and physical resources will remain strained for the foreseeable future; however the opportunities for training presented by NT2 will benefit this basic objective.

One essential aspect of Lao policy involves involvement and exchange between national and provincial and district level organisations. This arrangement will be supported by the NT 2 project through links between NTECo and Government organisations at all levels. STENO works closely with NTEC to scope the project and assist in public consultation, and will play a key role in the monitoring and mitigation strategy. In summary, environmental policies are in place within GOL, however the means for implementation will require additional resources for

full development. There also needs to be a more fully developed understanding of the implications of many environmental policy matters, especially at sub-national levels of government.

2.1.2.2 Legal Aspect

The pending 'Prime Minister's Decree on Environmental Protection' provides a legal framework for environmental management of development projects. The decree establishes the framework for 'unified environmental management with the aim of preserving the environment and making rational and sustainable use of natural resources in contribution to the national socio-economic development and the people's guaranteed health and upgraded quality of life.'(GOL, 1996; p. 1) This decree will establish central and local environmental management authorities (coincident with STENO at the national level), and limit acts by individuals and juridical entities, including restrictions on acts which degrade the natural resource base or contribute to environmental pollution. Specific requirements are described under Chapter II of the Decree (italics added for emphasis):

Article 10 states that 'environmental management agencies at various levels shall have *the duty* to study and issue laws and regulations on the management of environment in relation to their sectors...'

Articles 12, 14 16 and 17 describes compliance requirements for juridical entities to 'preserve forests, land, water, air, fauna, and flora, and religious and historical sites' and, 'during the exploitation of natural resources ..., shall apply to the relevant environmental management of Government for consideration and approval.' Projects 'shall be *based on plans to avoid the degradation of nearby natural resources*.' 'Construction and maintenance in a site ... shall comply to the environmental regulations to avoid and restrict any obstacle to traffic, damage to others, [and] negative impacts on health.'

Article 23 states that 'Development projects with medium scale investment and above (hydropower, roads and bridges, mineral exploitation, factories, tourist sites, tree exploitation, ...) *shall require studies and the submission of environmental impact assessment reports* as provided by the regulations.'

Enforcement is addressed in Article 22 which states that 'Factories, production units, businesses, operations shall outline plans and budgets for the prevention of environmental impacts and *the environmental quality shall be controlled by the relevant environment management agency*.' This statement mandates the involvement of STENO in monitoring of mitigation and the ambient environment in the vicinity of the project. STENO is charged with similar mandates in other spheres which tend to outstrip its capacity for implementation.

The pending Prime Ministerial Decree is followed as well by a draft environmental law. The law will not likely be promulgated in the near future due to pressure of other business in the National Assembly. The decree can be made effective by a signature from the Prime Minister. It has undergone review by the Ministry of Justice without significant further change, and is currently under consideration by the Prime Minister's Office.

2.1.2.3 STENO Organisation

STENO is composed of six departments and one institute reporting to its President, who in turn reports to the Prime Minister's office, as shown on Figure 2-2. Two departments house most environmental functions for STENO: Environmental Quality Development and Promotion, and Environmental Policy and Management. The former has a total of 12 staff, eight of whom are professional staff. The latter has a slightly larger staff, with about 15 total. Attrition is made

up by hiring, but the overall numbers typically remain static. There is some opportunity to obtain addition staff on term contract.

STENO has two mechanisms in place for provincial activity: the Provincial STENO office (not yet established in any of the provinces) and the individual representatives of the national STENO at the provincial level. One STENO staff member is located at Attapeu, to respond to hydropower projects in the south, and there are four staff at Savannakhet. STENO is envisioned as an umbrella agency that co-ordinates activities laterally at the national level and vertically with provincial and lower hierarchy organisations. There have been four technical assistance projects either completed or in various stages of progress for STENO, all of which promote co-ordinating functions.

The first project was funded by Swedish International Development Agency (SIDA) through UNDP with some support from the Asia Foundation. It targeted mechanisms for formation of working groups comparable to the IMWG/ISD to address specific matters including EA review and policy consensus. The first phase was undertaken in 1994 - 95. A second phase is underway which focuses on strengthening the capacity of working groups and providing workable linkages with provincial level agencies.

The second project, funded by NORAD through UNDP and still in its preparation phase, involves establishing a water quality laboratory which can perform analyses for STENO as well as other agencies and which can provide a quality control function for other labs as they are established in Laos.

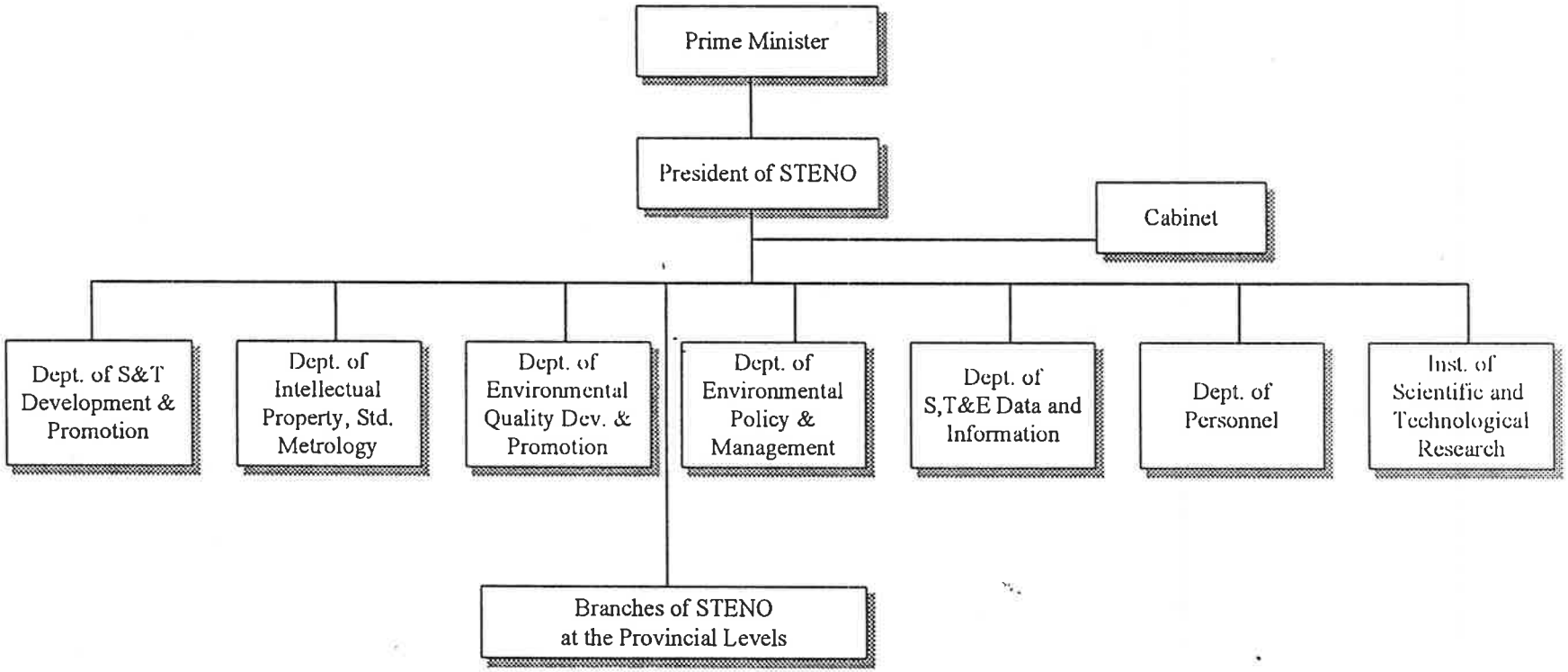
Thirdly, there is a policy development project, funded by NORAD through UNDP grant, which focuses on developing legal instruments for environmental and natural resources protection in conjunction with the Ministry of Justice.

Finally, there is a project to establish an environmental training centre under German funding (GTZ) that is now in its pilot phase. The vision is catalysed by specific training efforts, the first of which is a five week course in general environmental management, followed by a planned course in general environmental assessment methodology. The long term goal is to establish a National Centre for Environmental Protection to provide training for Lao agency staff and youth.

Considering the length of time since STENO was established, in 1992, and the intensity of environmental issues related to development funding in Laos, international financial support for STENO has been meager. STENO's effect on the development process has, however, been significant in the raising of awareness of environmental issues among agencies throughout GOL and at provincial administration levels. The orientation toward diffuse functions at provincial levels holds promise, but a significant effort is necessary to make the orientation operational.

The Inter-Ministerial Working Group for Environment and Sustainable Development (IMWG/ISD) was established to incorporate concerns from various ministries on environmental matters related to development projects. It has functioned in the past as a review committee for environmental assessments performed for hydropower projects, and has representatives from ten ministries and government organisations as ordinary members. The Vice-President of STENO performs the duties of chairman for the IMWG, and the Director of DOE fills the post of secretary general. DOE serves as the secretariat for the IMWG. The IMWG/ISD is extended in many instances through ad hoc groups for specific functions.

Figure 2-2 : STENO Organisational Chart



2.2 WATERSHED MANAGEMENT AND BIODIVERSITY CONSERVATION

2.2.1 Legal Framework

2.2.1.1 Water Law

The Law on Water and Water Resources (No. 02-90 11 October 1996) is intended to assure sustainability of use through a system of policies related to ownership, preservation, use and management. It establishes a basis for classifying water according to use, defining catchments, and setting our requirements for EIA for any 'large scale uses', inclusive of construction of water reservoirs for the purpose of irrigation, consumption and energy production. In this respect 126/PR mandates the requirement for the current EAMP work, and should necessitate a review of the EAMP among the appropriate groups within GOL. 126/PR also promotes 'designated watersheds' in Article 25:

> 'Wherever appropriate, several power dams should be built or power dams generating benefits in several aspects based on plans along a same river.'

This approach is in keeping with a portion of the intact rivers policy of the World Bank.(OD 4.00 Annex B1) Certain environmental and multi-use considerations are stipulated by the Water Law for hydropower projects:

> 'in building a hydropower dam, consideration shall be given to the preservation of the sources of water, forests, the environment, flood protection, water supply, irrigation, water transport, fishing fishery, aquatic life and others.'

Medium and large-scale users of the resource are restricted by permit, and in particular water source developments (inclusive of reservoir developments) 'shall abide by the principles of conformity with the socio-economic and environmental development plans, master plans, periodical development plans of each sector.' There are, however, no specific requirements for the development of master plans for specific basins undergoing development.

2.2.1.2 Conservation Legislation

Protected areas were formally established in Lao PDR under 1994 Prime Ministerial Decree Number 164. Decree 164 established 18 protected areas including the Nakai - Nam Theun. It requires that GOL develop management plans for each of the designated protected areas (NBCA). These are essentially zoning plans specifying areas of the NBCA to be placed under strict protection, conservation, and other uses. Written into the Decree is the accommodation of potential or existing uses deemed feasible and appropriate in portions of the NBCA without compromising the overriding goal of biodiversity conservation. Such developments and uses include, for example, hydropower projects and customary use by populations which have been resident in or near the NBCA prior to the gazettement.

The legal and policy framework for conservation management in Lao PDR is embodied primarily in the National Forest Law of 1996. The Law categorises forests into 5 types, namely, protection, conservation, production, regeneration, and degraded. For each type, the Law stipulates permitted and prohibited uses.

Article 16 of the Lao PDR Forest Law classifies forests and forest land into 5 categories.

Protection forest is forest and forest land classified for purposes of protecting water sources, protecting land from erosion, strategic areas for national defence, natural disaster prevention, environmental protection, and others.

Conservation forest is forest and forest land classified for the purpose of preserving animal and plant species, nature, historical, cultural, tourism, and other environmental values including educational and scientific research purposes

Production forest is forest and forest land classified for the purpose of sustainably meeting national and local community socio-economic development needs for wood and forest products without seriously impacting the environment.

Regeneration forest is young fallow forest classified for regeneration to later stages of succession or return to their prior natural status.

Degraded forests are those which have been severely damaged such as prior forest lands currently lacking forest cover. They can be allocated to individuals and organisations for permanent reforestation, agriculture-forestry production, livestock grazing, or other purposes based on national economic development plans.

Article 41 specifies that **Protection Forests** require restricting shifting cultivation, tree felling, destruction, burning, tree removal, fire wood cutting, grazing, settlement, and other constructions including land, rock or mineral exploitation, and hunting or gathering of restricted forest products.

To preserve forest wealth, protect and develop tree and animal species and biodiversity and ensure conservation of forests and their aesthetic values in national parks, Article 42 divides **Conservation Forests** into 3 sub-categories, namely:

1. **Total Protective Zones** where forest and forest land serve as the main habitat and reproduction sites for various animals and plant species. Forestry operations, plant and animal removal, and access are strictly prohibited without authorisation.

2. **Controlled Use Zones** where forest or forest land adjoining or neighbouring Strictly Restricted Zones can be authorised for the population's use of wood and forest produce within specified limitations enabling preservation of the Strictly Restricted Zone.

3. **Corridor Zones** where forest and forest land corridors used by animals between restricted forests or between restricted forests and other types of forests are preserved to protect wild life and their reproduction. Hunting, tree felling, forestry or other operations impeding or destroying animal migration routes are forbidden.

Article 30 refers to the **Customary Use** of forests and forest lands (in Article 55, synonymously, as Customary Use). Traditional use refers to long-standing use of forests, forest land and forest produces acknowledged by society or law including non-restricted wood collection for fencing and firewood, forest product gathering, hunting and fishing of non-restricted species for family consumption, and other traditional uses. Traditional use must avoid damaging forests or forest resources and shall avoid causing prejudice to the interest of individuals or organisations.

Traditional forest, forest land and forest product use shall abide by the village forest and forest land regulations outlined by the village administrative authorities in accordance with the characteristics of each village and in compliance with Article 63[1].

Article 63 refers to the **Rights and Duties of the Village Administrative Authorities** with respect to forest and forest land management and forestry operations to

1. Implement the district's instructions regarding forests, forest land and forestry operations.

2. Organise the allocation of village forest and forest land to individuals and organisations within the village for their effective management, preservation, regeneration, reforestation, development and use based on contracts, plans and regulations approved by the District Agriculture-Forestry Office (DAFO).

3. Inform and educate the village population on the importance and utility of forests, forest land, aquatic and wild life, water resources and the natural environment.

4. Monitor and gather information on the re-oriented use of forests, the environment, and forestry activities within their villages and report to the DAFO.

5. Organise the population for management of forests and forest land within their village territory.

6. Outline specific regulations on the proper management and preservation of forests, water sources, aquatic and wildlife and the natural environment within the village territory in accordance with village conditions.

7. Settle and provide sedentary occupations to the population with the aim of restricting and progressing toward complete cessation of tree felling and forest destruction, achieving environmental protection, and ensuring regeneration of forests and forestry resources and their wealth.

8. Consider authorising tree felling by the population of their villages in accordance with regulations.

9. Monitor, control, and restrict wild life hunting and sale inconsistent with the regulations.

10. Counter negative activities impacting forestry resources, water sources, and the environment such as illicit felling and forest burning, and restrict all acts destructive to forestry resources, aquatic and wild life and water resources in due time.

In summary, the Forest Law divides forests into 5 main- and 3 sub-classifications linking each with a set of management parameters designed to accomplish national forest protection, production and rehabilitation goals. **Protection** and **Conservation** classifications are primarily for conservation, but Article 30 establishes a variance enabling traditional occupants and forest users with legitimate inhabitancy and use claims to continue to reside in and sustainably utilise specified forest areas. Article 63 sets forth regulations and procedures wherein sustainable village forest management plans and areas are specified by communities in collaboration with DAFO, authorised by DAFO, and collaboratively monitored and enforced. Regarding biodiversity conservation, Decree Number 164 establishes 18 NBCAs including Nakai-Nam Theun. The Decree enables, (with proper authorisation), economic developments to proceed in

[1] Article 63 incorporates the spirit of the March 1994 Order on Customary Rights and the Use of Forest Resources with Explanatory Attachment.

the NBCAs, (including hydropower projects), where such developments are justifiable with regard to their impact on biodiversity, or in terms of overriding national development interests.

Zoning categories for the NT2 Project area and NBCA in the context of Lao Forestry Law are addressed in a later section of the report. The Forest Law provides all of the forest and forest land management categories required to plan for implementation of the NT2 Project's forest and forest management components. This includes areas directly affected by the project, such as construction areas and the inundation zone, the resettlement areas, and the NBCA.

2.2.2 Institutional Framework for Conservation Management

2.2.2.1 Centre for Protected Areas and Watershed Management

The CPAWM mission statement, taken from its Mandate, Article 1, establishes it as

> 'a technical sub-organisation within the Department of Forestry. It is responsible for management and monitoring with respect to the protection and conservation of watershed resources, protected forest areas, wetlands and wildlife. It is responsible for ensuring that these principles of management and monitoring are transferred from the central to local level throughout the country.'

CPAWM is directed by a Board of Management under which there are two major divisions for Protected Areas and Watershed Management, and Administration. The former houses four programs for wildlife, watershed protection, protected areas and wetlands. There are also five units reporting directly to the Board of Management for technical extension, land use survey and monitoring, database and evaluation, biodiversity survey and monitoring, and water quality analysis and monitoring. The organisation contained about 23 staff as of September 1995.(CPAWM, 1995) CPAWM will possibly have an important role in management of the N-NT NBCA.

2.2.2.2 Bolisat Phattana Khet Phudoi (BPKP)

The BPKP is a semi-autonomous governmental agency reporting to the Prime Minister's Office (PMO) with the mandate to initiate and enhance the social and economic development of Central Laos. Similar organisations exist in other parts of the country and were created in the 1980's.

BPKP fulfills this role, and would certainly do so in the region of the project and the adjacent NBCA.

2.2.2.3 Provincial and District Organisations

The forestry Law establishes 'forest and forestry operations management agencies' as the Ministry of Agriculture and Forestry (MAF), the provincial/municipal and district level Agriculture-Forestry Services, and the village administrative authorities. Specific duties are assigned through the law to these agencies at the provincial/municipal and district levels:

Provincial/Municipal

1. Staff support directly to MAF in all aspects of macro-level forest management.
2. Survey and assist in investment decisions and issue licenses based on Government approval, and in accord with regulations.

District

1. Staff support directly to Provincial/Municipal forestry offices.
2. Organise village populations to manage and preserve forests and forest lands, and assign lands for afforestation to families

	at village level.
3. Manage and register tree felling equipment and hunting devices.	3. Monitor and control the implementation of regulations governing tree felling, wood and forestry procedure processing, hunting, fishing and sale of wildlife.

Future rights and duties are assigned to the Village Administrative Authorities to implement district instructions to allocate land to individuals and organisations within the village for management, preservation and control. Other responsibilities include:

- education of the village population on the importance and utility of forests and wildlife,
- gathering information on the reorientation of forest use,
- organise the population for management of forests within their territories,
- outline regulations on proper management and preservation,
- provide sedentary occupations for villagers with the aim of restricting tree felling and forest destruction,
- authorise tree cutting according to use rules,
- monitor and control wildlife hunting outside of regulations, and
- counter negative activities that impact the resource and the environment.

2.2.2.4 NBCA Institutional Framework

The 'issues and options for establishing a watershed management institution' are described in a paper by Spergel (1997). This strategic institutional planning effort is in its beginning phase while the Draft Final EAMP is being prepared. The institution will have the responsibility for 'managing and spending the money from hydroelectric revenues that is earmarked for watershed conservation; and regulating all activities in the watershed area that potentially affect watershed conservation.'(Spergel, 1997; p. 3)

Spergel describes three organisational alternatives defined as (a) separate trust fund and regulatory authority, (b) newly created, single government institution, and (c) multiple and decentralised authority with existing institutions. A number of issues need to be resolved, including the scope of authority, offshore or domestic management of the fund account, board make-up for trust and conservation institutions, and assignment of specific watershed management activities to specific organisations. The report does not indicate which institutional arrangement might be most workable in accomplishing these objectives:

> 'The report does not recommend specific institutional structures, but is limited to a general presentation of issues, options, and legal background. However, it is expected that a subsequent report will make more specific recommendations, after extensive discussions during the next NTSEP mission to Lao PDR in April/May 1997.'(p. 6)
>
> The February update on the status of the conservation fund organisational mechanism does not go much further than the November 1996 report of the Bank (WB, 1996e) except to confirm the formation by GOL of an 'NTSEP working group to consider watershed management issues' (WB 1997a); and to indicate that GOL will need one or

two months for internal discussions, before they would be in a position to express specific preferences or propose alternative models.'(WB 1997c)

2.3 INTERAGENCY CO-ORDINATION

The relationship of GOL to NTECo is as a 25 percent (approximate) equity holder in return for its contribution of natural resources (land and water use rights) and equity investment. GOL receives resource levies, royalties and dividends from its participation in the project. Interagency co-ordination between NTECo and GOL is described as follows:

> 'The Ministry of Industry and Handicrafts is responsible for over-seeing the development of NT2. Other GOL organisations are also involved in the planning for NT2, including the Ministry of Agriculture and its Forestry Department, Irrigation Department, Fisheries Division, the Centre for Protected Areas and Watershed Management; the Ministry of Health; the Institute of Epidemiology; the Science Technology and Environment Organisation (STENO); provincial and local authorities; the Lao Women's Union; Bolisat Phattana Khet Phudoi (BPKP); and the NT2 resettlement Committee ...'(NTEC 1997)

Co-ordination occurs on four fronts,

⇒ project development with MIH,

⇒ conservation management in the Project Area with STENO

⇒ conservation management in the NBCAs with CPAWM, and

⇒ the resettlement action plan, which integrates the bulk of the organisations mentioned in the previous paragraph.

2.4 WORLD BANK OPERATIONAL POLICIES AND DIRECTIVES

The Bank's OD (Operational Directive) 4.01 describes the requirement for environmental assessment of Bank-funded projects within certain categories, depending on their expected impact, in conformance with standard screening procedures. The current assessment work falls within the category of project-specific EAs, and approaches the task according to the *pro forma* approach for existing baseline conditions, which we interpret to include the baseline trend, considered especially relevant in the present context, impact assessment per se, systematic consideration of alternatives, and preventive mitigation measures and other forms of offset. Monitoring, management, and training, also addressed in the present EA, are considered as substantive parts of the mitigation plan. 'Capital and recurrent costs' as referenced in the OD (p. 2) are associated with mitigation and management, or other forms of offset, and are included in the mitigation plan. The EA also includes other issues mentioned in the OD, including global issues, institutional aspects (this chapter), and 'involvement of affected groups and non-governmental organisations.'(p. 5)

Some issues highlighted by the Bank in OD 4.01 Annex A that are of particular importance on the present project include biological diversity, indigenous peoples, induced development, tropical forests, watersheds, wetlands and wildlands. The EA is responsive to specific directives and policies that address these subjects. The outline for the present work conforms to that suggested by the Bank, as does contents of the Mitigation or Environmental Management Plan.

The Bank's directive concerning dam and reservoir projects (OD 4.00 Annex B) explicitly identifies the necessary components of related EA work. These include consideration of cumulative impacts, multiple uses and maintenance of intact rivers. The area of influence for the project, according to Bank guidelines, extends from the upper reaches of the catchment to the downstream extent of the Mekong estuary. NT2 is a project 'involving international waterways and subject to the World Bank Operational Directive (OD) 7.50 "Project on International Waterways".'(WB 1991). In addition to Bank internal procedures for international waterways, there is a requirement to formally notify riparian countries of the project.

2.5 PUBLIC PARTICIPATION

The NT2 Project has undertaken some preliminary public participation in support of environmental assessment, resettlement activities and the proposed forest conservation area. It has also disseminated information on the Project internationally, nationally and locally. Public participation will be the responsibility of the Science, Technology and Environment Organisation (STENO) of the Lao PDR Government, though local and regional consultations will be undertaken also by GOL provincial staff and NTEC. STENO will be assisted by a firm of consultants with expertise in consultative approaches to environmental management and resettlement. Details on NTEC's public participation effort are provided in Appendix A.

2.6 INTERNATIONAL TREATIES AND AGREEMENTS

The record of international treaties and agreements for which Lao PDR is a signatory or party to ratification, beginning in 1972, has developed slowly along a number of fronts. Among the international treaties ratified by Lao PDR is included the International Convention on Important Wetlands (RAMSAR), the International Convention on Climate Change, the UN Convention on Biological Diversity, and the International Convention to combat desertification in those countries experiencing serious drought.

Lao PDR has not ratified the CITES Agreement, arising from the International Convention on Trade of Endangered and Rare Wildlife/Plant Species; however there is a Decree of the Prime Minister's Office similar in content to this Convention.

Lao PDR participated in the Conference leading to the Rio Declaration of Environment and Development. Lao PDR registered acknowledgment of the Convention on Climate Change in April 1994. Lao PDR registered the UN Convention on Biological Diversity on 20 September 1996, and its effective date in Laos was 19 December 1996. Lao PDR signed the International Convention to Combat Desertification in Those Countries Experiencing Serious Drought on 30 August 1995.

2.7 CONCLUSION

STENO's role in environmental management of the hydropower sector is supported by the Prime Ministerial Decree on environment, and the project aims to support STENO along with other national and local agencies in the task of monitoring mitigation during construction and operations. The proposed approach builds on precedents established at the Theun-Hinboun Hydropower Project, at which an 'EMCO' (Environmental Management Committee Office) performs monitoring of mitigation. The EMCO is staffed by two persons from EdL and one each from the provincial governments of Bolikhamsay and Khammouane. STENO's involvement at NT2 will fit the framework already established by the EMCO at Theun-Hinboun; however other local agencies need to be involved. STENO and these agencies will receive assistance in the form of additional staff and budget, and external technical support to accomplish the goals set out in OD 4.00 Annex B (p. 5):

major dam and reservoir projects should be used to help build environmental capacity (analytical, regulatory, and enforcement) in institutions at the national and sectoral levels through training, consultancy, and policy dialogue,...'

The need for strengthening institutional capacity at provincial and local levels is brought about by the NT2 and Theun Hinboun projects, along with the general need for better watershed management and conservation. Planning aimed at the region, whether for water, land or biodiversity, will confront the same need for additional institutional capacity.

CPAWM, BPKP and provincial governments have separate mandates with significant degrees of overlap and/or complementarity, though none of these mandates encompasses water resource issues effectively at the basin level. CPAWM can be effective in influencing the technical issues of watershed management over the mid to long term, whereas BPKP provides the support network at the village level to stave of critical food shortages. Provincial and district roles could be influential and contributory as part of an integrated planning scenario, but will first need significant human and materials inputs. Support for STENO would assist it over the short term to enter the arena of planning within the Central Laos region.

Whatever institutions are deemed necessary for accomplishing area-wide goals will need significant financial and technical support. NTEC will provide the resources over a narrowly defined domain of direct project responsibility. Power generation revenues will provide support for the NBCA, in which BPKP will likely have an essential management role. Another factor not yet addressed is the sectoral water resource domain within the regional geographic scope. Whether this needs to be addressed in the short term is a consideration for the Bank and GOL.

On the following immediate issues, the corresponding status is noted : (WB, 1991; p. 182)

- status of national requirements for environmental review

  The statutory requirement for review of hydropower and other water resource-related projects exists through the Water Law. The pending Environmental Decree will also mandate environmental review of development projects. Administrative procedures for review are effective within the limits of local capability.

- status of national environmental legislation and regulations, and record of compliance

  Promulgation of national legislation for environment will be coincident with EA review requirements as part of the upcoming Prime Ministerial decree. A law to this effect passed by the assembly will be some years away, according to best estimates. Other laws, specifically the Forest Law and Water Law, put forth environmental priorities.

- working relationship at provincial and district level

  Mandates are in place through both the pending Environment Decree and the Forest Law for involvement on provincial, district and village level organisations. Functional liaison exists more with the PAFO and DAFO offices than for STENO.

- record of enforcement at previous dam and hydropower projects

  STENO undertook reviews of Nam Leuk and Theun Hinboun hydropower EAs. EdL is also involved in monitoring of mitigation at Theun-Hinboun. Enforcement of conditions presents difficulty due to resource and knowledge constraints.

- capability within STENO for EA review

  Review of complex EA reports geared to an international audience present difficulty for STENO due to language and technical skills levels. Technical staff from other ministries are often relied upon to assist in conducting reviews.

- consistency in administration of environmental functions

Most environmental functions are not fully developed. STENO is consistent in implementing the functions that are within its level of capacity.

3. PROJECT DESCRIPTION

CHAPTER 3

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3. PROJECT DESCRIPTION

3.1 PROJECT DEVELOPMENT CONTEXT

The proposed Nam Theun 2 Hydroelectric Project (NT2) is a part of the long term collaboration effort between Lao PDR and Thailand which provides an opportunity for Laos, to export 3000 MW of hydropower energy to Thailand, from new capacity by the Year 2006.

As a part of that effort NTECo will undertake the NT2 Project on a build, own, operate and transfer basis (BOOT), and has discussed with EGAT the purchase of this electricity for a period of 25 years.

NT2 is proposed to produce on the average 5,400 GWh per year through the installation of (3 x 227 MW) 681 MW with a fourth spare unit or 5,700 GWh per year with an alternate configuration of 908 MW, through a trans-basin diversion of the Nam Theun River waters to the southern base of the Nakai escarpment. Thereafter, the diverted water flows to the Xe Bang Fai River system and then to the Mekong River. The electricity generated will be transmitted to the Thailand border where it will enter the EGAT electric power grid. The various components of the NT2 Hydroelectric Project are illustrated in Figure 3-1 Project Features, and a summary provided in Table 3-1.

Construction management will be provided by the Turnkey Contractor who will be responsible for carrying out all construction activities with least possible impacts to the environment.

3.2 PROJECT COMPONENTS

The Project reservoir is proposed to be located on the Nakai Plateau in Central Laos, approximately 250 kilometres east of Vientiane. The headwaters are in the Annamite Mountains along the border with Vietnam. The catchment area is 4,013 km^2 and the reservoir will be created by a gravity dam with a maximum height of 44 m and a crest length of 315 m. The full reservoir will hold 3,180 million m^3 of water and cover 450 square km, approximately 40 percent of the Plateau area.

The hydroelectric power plant will be located in an excavated cavern approximately 500 m into the base of the escarpment forming the Plateau, and about 40 km upstream from the dam. The water will be conducted to the plant by a Headrace Channel from the reservoir to the Intake, thereafter into the headrace tunnel and onto the Power House. It will be transported away from the Power House in a Tailrace Tunnel and 2.8 km long Tailrace Channel to a Regulating Pond. A 35km long Downstream Channel will be constructed to carry the turbined water from the Regulating Pond to the Xe Bang Fai River. After passing through the Gnommalat plain for abut 10 km the channel follows the course of the natural tree-lined drainage channels for approximately 25 km. Plant output will require a maximum flow of 210 ^{3}/s.for the 3+1 unit configuration.

The electricity produced will be delivered by a 144-km long twin double circuit 230 kV transmission line to the Thailand border near Savannakhet where it will be connected to the EGAT transmission system at Mukdahan.

The detailed design of the NT2 Project will commence following negotiation of terms with financial institutions and GOL. The following descriptions are based on current process design and value engineering details.

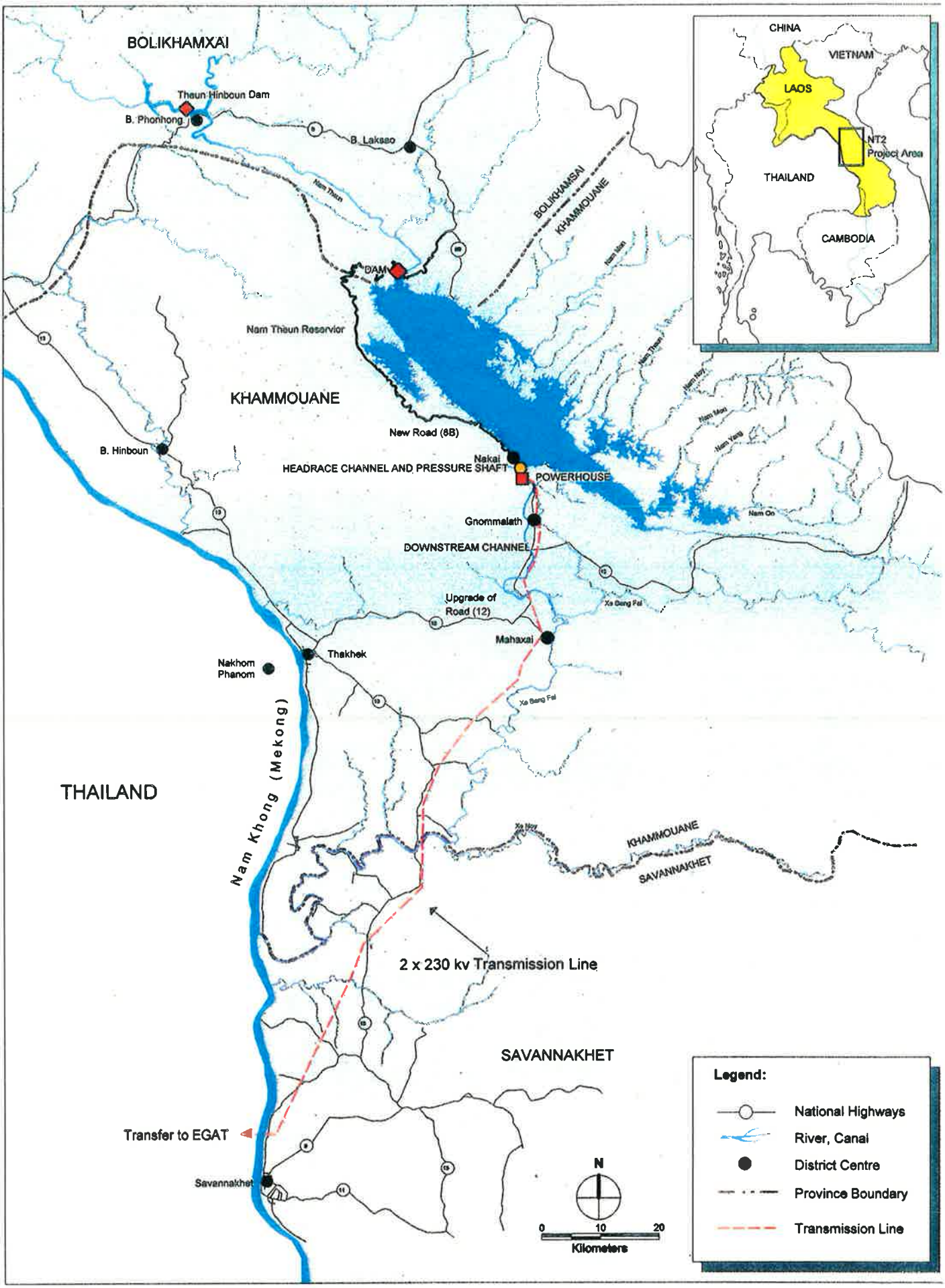


FIGURE 3-1 PROJECT FEATURES

Table 3-1 : Summary of Project Components

Main Dam	Type	Gravity, roller compacted concrete
	Crest Level	El 540.0
	Foundation Level	El 496
	Maximum Height	44 m
	Crest Length	315 m
Saddle Dams	Type	Earthfill
	Number	6
	Crest Level	El 541.0 and 542.0
Spillway	Type	5 radial gates in dam
	Sill Level	El 523.5
	Size of each	15.5 m high by 16 m wide
	Spillway Discharge Capacity at FSL	9,200 m^3/s
	Inflow PMF Peak Discharge	13,500 m^3/s
Catchment	Area to Damsite	4,013 km^2
	Average Annual Runoff	7,380 million m^3
		1,840 mm
	Annual Sediment Yield	107 tons/km^2
Reservoir	Full Supply Level (FSL)	El 538
	Minimum Operating Level (MOL)	El 528
	Maximum Water Level (MWL)	El 539.5
	Surface Area at FSL	450 km^2
	Surface Area at MOL	164 km^2
	Active Storage	2,690 million m^3
	Dead Storage at MOL	490 million m^3
Headrace Channel	Capacity	210 m^3/s
	Invert Level	El 522
	Base Width	45 m
	Maximum Cut	14 m
	Length	11.5 km
Intake	Number of Openings	3
	Size of Each	15 m high by 6 m wide
Headrace Tunnel	Diameter	7.8 m
	Length	1,818 m
Pressure Shaft	Diameter	7.8 m
	Length	520 m
Pressure Tunnel	Diameter	6.45 m
	Length	600 m
Manifold	Diameter	Variable
	Length	75 m
	Lining	Steel
Power Plant	Power House	Underground Cavern
	Number of Units	Four

Table 3-1 : Summary of Project Components

	Turbines	Underhung Francis, each 227 MW
	Generators	Vertical axis, each 252MVA/227MW
	Station Rate Power Output	681 MW
	Average Annual Generation	5,400 GWh
	Rated Net Head	355 m
	Synchronous Speed	333 rpm
	Machine Hall Maximum Dimensions	124 m long by 22 m wide by 42 m high
Transformers	Transformer Hall Maximum Dimensions	108 m long by 11.5 m wide by 17.6 m high
Tailrace Tunnel	Number	2
	Diameter	7.3 m
	Length	570 m
Tailrace Channel	Bottom Width	50 m
	Length	2.8 km
Regulating Weirs	Crest Level	Varies, El 167.5 to 169.8
	Length of Structures	360 m
	Pondage	1 million m^3
	Pond Length	1.65 km
Downstream Channel	Bottom Width	45 to 95 m
	Length	35 km
	Maximum Discharge Capacity	210 m^3/s plus 2-year flood
	Maximum Average Velocity	1.0 m/s
	Outfall	Xe Bangfai River
Transmission Line	Voltage	230 KV
	Circuits	Twin double
	Tower Height	45 to 55 m
	Normal Tower Spacing	300-400 m
	Length	144 km
	Terminal	Thailand Border
Road Works	Grade Rehabilitation	99 km
	Bridges Rehabilitated	6
	New Road	127 km

Further modifications to the design of the Project are not expected to have any substantial affect on the environmental attributes of the Project. Design, construction, and commissioning are anticipated to last 51 months, but efforts are underway to reduce the overall duration.

3.2.1 Dam and Spillway

The Long Journey
From the moment a parcel of water enters the mouth of the Headrace Channel to when it is discharged into the Xe Bang Fai, all under the control of the Nam Theun Hydroelectric Project, it will have travelled 60 km in 21 hours. This path will have taken the parcel along excavated channels, through tunnels, hydraulic turbines, gates and valves, a pond, and over aeration sills.

The reservoir will be formed by a gravity dam with a maximum height of 44 m (deepest foundation to crest) and a crest length of 315 m. The dam crest is set at El 540 masl. The dam axis is located at a sandstone outcrop in a horseshoe-shaped bend in the Nam Theun. The dam is proposed to be constructed with roller compacted concrete between hills on the right and left abutments. Roller compacted concrete is a leaner and drier concrete mix with coarser aggregate than conventional structural concrete. Roller compacted concrete is prepared in a large batch plant or pugmill then placed on the dam, spread into a thin layer about 30 cm deep, and compacted by heavy rollers in the same manner as done for earth-fill dams. Roller compacted concrete in place costs much less than conventional concrete and the construction technique allows for rapid placement, resulting in short construction time.

Both faces of the dam are proposed to be formed of structural concrete. The vertical upstream side will be formed with precast panels and impervious membrane between these panels and roller compacted concrete, and the downstream side will be formed with 90-cm high steps. The downstream slope of the dam will average 0.75 horizontal to 1 vertical for the lower portion, and 0.4 horizontal to 1 vertical for the top section. The foundation will be grouted down to El 472 for seepage control and a drainage curtain provided.

The gated spillway will be constructed integrally with the dam section, and centred on the alignment of the downstream river channel. The design incorporates five radial gates, each 16 m wide by 15.5 m high. A flap will be added to the top of the centre gate to allow for discharge of small floods in preference to cracking a large radial gate. The crest of the curved overflow shape (the Creager shape) of the spillway sill is set for El 523.5. The spillway chute is 100 m wide and terminates in a hydraulic jump stilling basin with a sloping floor and walls to El 514. The spillway and reservoir will accommodate passage of the Probable Maximum Flood with an inflow peak of 13,500 m^3/s with the reservoir at its maximum flood level, El 539.5 (0.5 m below the dam crest), but is designed for a spillway discharge peak of 9200 m^3/s, one-third less than that of the Probable Maximum Flood inflow peak.

The Probable Maximum Flood is the estimate of the largest flood that can be produced in the Nam Theun catchment. It is determined from the regional rainfall records and includes the studies of typhoons that have crossed Laos from the South China Sea. Meteorological parameters for the typhoon are maximised to the degree thought reasonable as an upper limit.. The rain resulting from this maximised typhoon is then routed from the saturated drainage area through the channel network to the reservoir. In transiting through the reservoir, the flood peak is attenuated so the peak passing over the spillway is less than the inflow peak. The spillway is sized to work efficiently, in a hydraulic sense, for any lesser flood and will not experience damage with the passage of the Probable Maximum Flood. Figure 3-2 illustrates the plan of dam and spillway.

Large amounts of floating debris during floods could cause operational problems on the reservoir. At the Dam, any large floating debris from the uncleared reservoir area will be kept

away from the dam and spillway with a floating log boom which will stop their movement downstream to the spillway. Any floating logs in the vicinity of the spillway which get past the log boom will be removed by equipment provided for that purpose.

Part of the existing Route 8B road will be submerged in the reservoir. A new section of Route 8B will be constructed and will pass over the Nam Theun River on the dam crest and on a concrete bridge over the spillway. A 6 m wide road has been incorpororated. Consideration is also being given to a bridge over the Nam Theun a short distance downstream of the dam for this road crossing.

An outlet conduit will be provided next to the spillway for the downstream release of a minimum quantity of water for riparian maintenance. The riparian water will be taken from a multi-level intake, transported along side the spillway wall in a steel pipe and released through a control valve into the spillway stilling basin. The water will be well aerated with the cone valve spreading the water in an ever increasing hollow-cone shape, providing a large area of turbulent contact with the surrounding air, before falling into the pool below.

River flow will be diverted during construction through one 6 m high horseshoe-shaped, 210 m long concrete-lined tunnel in the right abutment. The tunnel invert at the upstream end is set for El 501. Two coffer dams, 15 m high earth and rockfill embankments, will isolate the dam and spillway construction area from the river water. The upstream cofferdam will divert the river flow into the diversion tunnel. The downstream cofferdam will prevent the river flow from backing into the dam construction area.

3.2.2 Reservoir and Saddle Dams

Nine saddle dams will be required along the escarpment side of the reservoir rim to create storage to the Full Supply Level of El 538., all being earth embankments, three with crests at El 542, and the others at El 541. Their total length is estimated at 1,920 m and some will be provided with quarry riprap for slope protection from wave action. The largest earth saddle dam will have a height of 9 m, about a fifth that of the main roller compacted concrete dam. Figure 3-3 illustrates the plan of the reservoir.

At Full Supply Level, the reservoir will hold 3,180 million cubic meters of water Minimum Operating Level at El 528.0, will result in 2,690 million m^3 of active storage (usable for energy production) and 490 million m^3 of dead (inactive) storage. The reservoir survey has been largely conducted by geographical position system (GPS) techniques using satellites and interpretation of aerial photographs. Because of the large area covered some corrections have to be made for the earth's curvature. There is thus a spread of probable results for reservoir volume as a consequence, which will be minimised during the detailed design phase. Currently professional survey opinion is that the reservoir has a volume of :

Minimum Guaranteed	3,180 million m^3
Most Probable	3,680 million m^3
Maximum	4,180 million m^3

The reservoir will rest on deep, thick deposits of siltstone and mudstone thoroughly isolating it from the more pervious underlying limestone formations.

Figure 3-2 : Dam and Spillway Plan (on - HOLD)

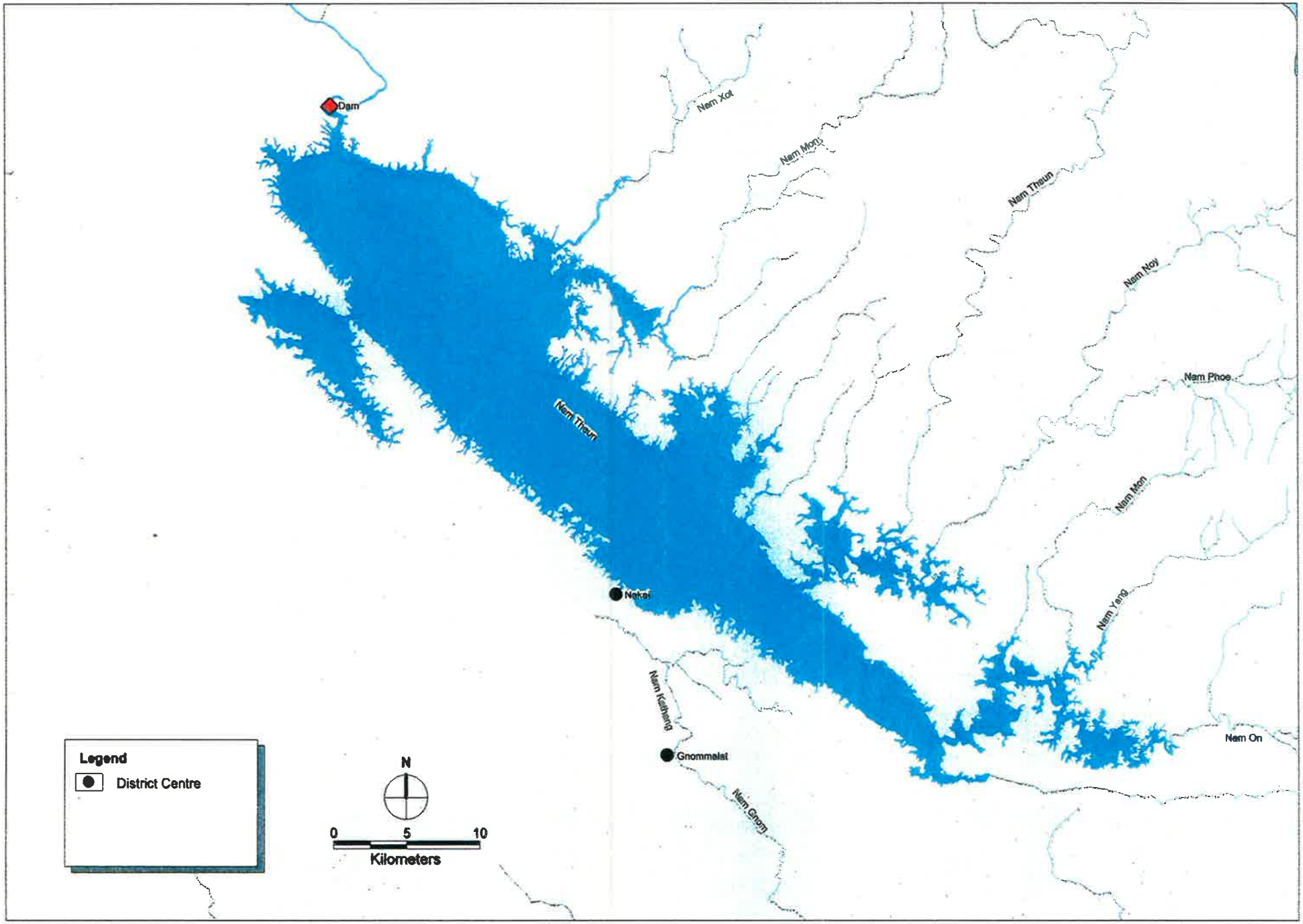


FIGURE 3-3 RESERVOIR PLAN

The main tributaries to the reservoir rise in the Annamite Mountains to the north, bringing water and sediment . The inorganic portion of the sediment , the sand, gravel and cobbles, will be deposited in the reservoir and in the backwaters up the tributaries. The annual drawdown of the reservoir level will result in the movement of some of the sediment down to lower levels by the first large floods of the wet season. Later floods may again place the new sediment in the backwaters along the tributaries.

A Comparison of Two Lao Reservoirs		
Element	*Nam Theun 2*	*Nam Ngum*
Total Volume, million m^3	*3,180*	*9,300*
Surface area at FSL, km^2	*450*	*450*
Average depth at FSL, m	*7.1*	*20.7*

3.2.3 Headrace Channel and Intake Structures

The water in the Nam Theun reservoir will begin its journey to the powerhouse as it enters the Headrace Channel excavated in the reservoir bottom.. At its starting point, the invert of the channel will be at El 524, with the bed sloping uniformly to El 522 to Intake structure rock trap. The channel has an overall length of 11.5 km. The bed width will be 45m and the side slopes 4:1 in soft ground and 1.5 :1 in the sedimentary rocks. Five-meter wide berms will be provided where appropriate for slope stability. Excavated materials will be placed in the reservoir area adjacent to the channel to create sediment retention dyke, roads and saddle dams and resettlement area fills. The Headrace Channel is isolated from the valley of the Nam Theun river channel which is on the north, to the opposite side of the reservoir. Any direct connection to hypolimnion water of the reservoir will thus be avoided. The channel will be widened and deepened immediately before the intake to provide a rock trap for any loose material.

The Intake will be a concrete structure with three openings, each 15 m high and 6 m wide, and provided with mechanised trash racks. The invert of the water passage is El 502. The Intake will be set deep so as to provide adequate submergence of the opening to prevent any occurrence of vortices. These form at the water surface with the fluid rotation about the vertical axis drawing air into the tunnel. Air in sufficient quantities would cause hydraulic transients in the tunnel and a cyclic variation in the generator output.

From the intake portal, the water passage will slope down at 0.8 percent transforming to a rectangular section for the two gates, (i) the downstream gate, a fixed-wheel service gate and (ii) the upstream guard gate for emergencies and maintenance work. Each gate will be 7 m high and 5.7 m wide. The service gate is used to isolate the Headrace Tunnel from the Reservoir, allowing for dewatering and inspection of the Tunnel and Surge Shaft. A vent from the surface will supply air to the downstream side of the service gate for mitigation of any adverse hydraulic conditions during opening and closing. Normally, the service gate will be parked well above the water passageway and the emergency gate at the top of the gate shaft. The working platform for the gates will be at El 543.5 and will be connected by bridge to the crest of the saddle dam behind. Downstream from the gates, there will be a transition in the water passage from rectangular to the 7.8 m diameter Headrace Tunnel.

3.2.4 Headrace Tunnel, Surge Shaft, and Pressure Shaft

The 7.8 m diameter concrete lined Headrace Tunnel will slope 8 percent from the Intake to the base of the Surge Shaft (El 450), a distance of 1,820 m. At the Surge Shaft junction during start up and load rejection operation pressure surges will force water to and from the tunnel into the vertical 100 m deep concrete-lined Surge Shaft. The lower section will be 7.8 m in

diameter, the middle section 12 m. and the upper section 36 m, daylighting at the ground surface, El 550. The Surge Shaft will accommodate load rejection pressure transients.

Twenty meters beyond the Surge Shaft, the 7.8 m concrete lined tunnel will drop vertically to the powerhouse level . After a length of 520 m, including bends, the tunnel diameter will be reduced to 6.45 m, and the lining changed to steel for a further 525 m. Near the power house, the water will be distributed to the four hydraulic turbines with a steel fourway manifold distributor system.

3.2.5 Power Station and Transformer Hall

The Power Station and Transformer Hall will be located in an excavated cavern approximately 500 m inside the base of the escarpment. The machine hall cavern for the Power House will have maximum dimensions of 124 m long, 22 m wide, and 42m deep; and the Transformer Hall, 108 m long, 11.5 m wide, and 17.6 m deep. The centerlines of these caverns will be separated by a 47-m tunnel and connected by cable galleries Figure 3-4 provides the power station and transmission hall locations. Some consideration may be given in further detailed design to an above ground power station.

The centerline of the turbine runners will be at El 143, which is 395 m below Full Supply Level. A steel penstock will connect the manifold to the scroll case of each turbine. A spherical valve will be placed in each penstock within the powerhouse chamber so that the turbine can be isolated from the pressurised water supply tunnel. The valves will be completely open during turbine operations so that there is no loss of head due to their presence. The hydraulic turbines will be underhung vertical-shaft Francis type, connected to synchronous generators, both rotating at 333 rpm.

The three generating units and the reserve unit, will each have a maximum capacity of 227 MW, with maximum power of each unit corresponding to 252 MVA with a power factor of 0.90 lagging to 0.95 leading. Line frequency will be 50 Hz. Three phase unit transformers will step up the generator output to 230 kV. A SCADA system will be installed to monitor, supervise, and control the elements of the Power House. This system senses reservoir, power house, generator, transformer, and tailrace conditions, checks them against predefined limits and causes changes to be made in the operations. For example, if the turbine thrust bearing temperature becomes too high, SCADA will shut down that unit. The Plant can be started entirely automatically, including synchronising the generator output with the line frequency. The SCADA system will also provide a direct on line link to EGAT's main control centre for dispatch control.

Entry to the Power Station will be through a 7.5 m high horseshoe-shaped Access Tunnel, 460 m long. Ventilation and drainage will be through the exploratory tunnel excavated during the investigation phase of the work.

Figure 3-4 : Power Station and Transformer Hall (on - HOLD)

3.2.6 Tailrace Tunnel, Tailrace Channel, and Regulating Weir

The water discharged from the hydraulic turbines will be collected into two concrete-lined 7.3 m diameter tunnels 570 m long, connecting the Power House to the Tailrace Channel. The tunnels will slope upward with design outlet invert level of 163 masl at the portal The Tailrace Tunnels will spill through a concrete transition stilling structure with highest invert level of 169.5 masl into the Tailrace Channel, an excavation in the bed of the Nam Kathang Noi. The cross section will have a bed width of 50 m and side slopes of 3:1. The design velocity is kept high because the majority of the channel is to be excavated in rock. The section is larger than that of the river, and is designed to carry the 2-year flood from the Nam Kathang Noi as well as the Project's 210 m^3/s.

The Tailrace Channel will transform into the Regulating Pond in the Nam Kathang starting just downstream of the confluence of the Nam Kathang Noi and Nam Kathang Gnai. The pond will be created with the Regulating Weir, two concrete structures, one spilling into the continuation of the Nam Kathang and the other into the Downstream Channel. Neither will be gated. There is an outlet works planned to pass water from the pond to the Nam Kathang. Figure 3-5 provides an illustration of the Regulating pond and weirs.

The purpose of the Regulating Weir is to dampen the flow variations during the startup and shutdown of the turbines. Regulation mitigates the rate of change of the flow and water level in the Downstream Channel to ensure people and animals have time to vacate the area if they are in the channel in low flow conditions. The weir will also have the capacity to spill flows in excess of the maximum turbined discharge into the Nam Kathang. This excess is the floods from the natural drainage upstream in excess of the 2 years frequency. The precise design and storage volume of the regulating weir is under review. The surface area of the options being considered range from 15 to 40 ha. This EA has assumed 40 ha. During the dry season, the Nam Kathang will be supplied with some turbined water to the degree that this water will enhance the environmental, social, and economic features of the Nam Kathang. A channel will be excavated on the left side of the Regulating Pond to serve as the Nam Kathang River channel.

3.2.7 Downstream Channel

Originally NTEC considered transferring water from the power station to the Xe Bang Fai via the Nam Kathang as had been proposed in the initial SMEC report. However because of the number of people living along this river, about 15% of whom would require short distance resettlement, NTEC took the decision to use the largely unpopulated Nam Phit for this purpose. Also, adding water to the Nam Phit provided the potential for irrigation of this area. This increased quantities of excavation and total project costs. However, NTEC considered it best to take this step because of the social benefit which accrued.

As the Power House discharge will be substantially greater than the average flow in the Nam Kathang, the Project will provide a separate excavated channel from the Regulating Weir to the Xe Bang Fai near Mahaxai. In the first 10 km, the alignment of this Downstream Channel will pass through paddy fields. Through the paddy fields the cross section will be kept narrow as possible (approximately bed width of 45m) so as to limit land infringement from the Project. Figure 3-6 illustrates the planned routing of the downstream channel.

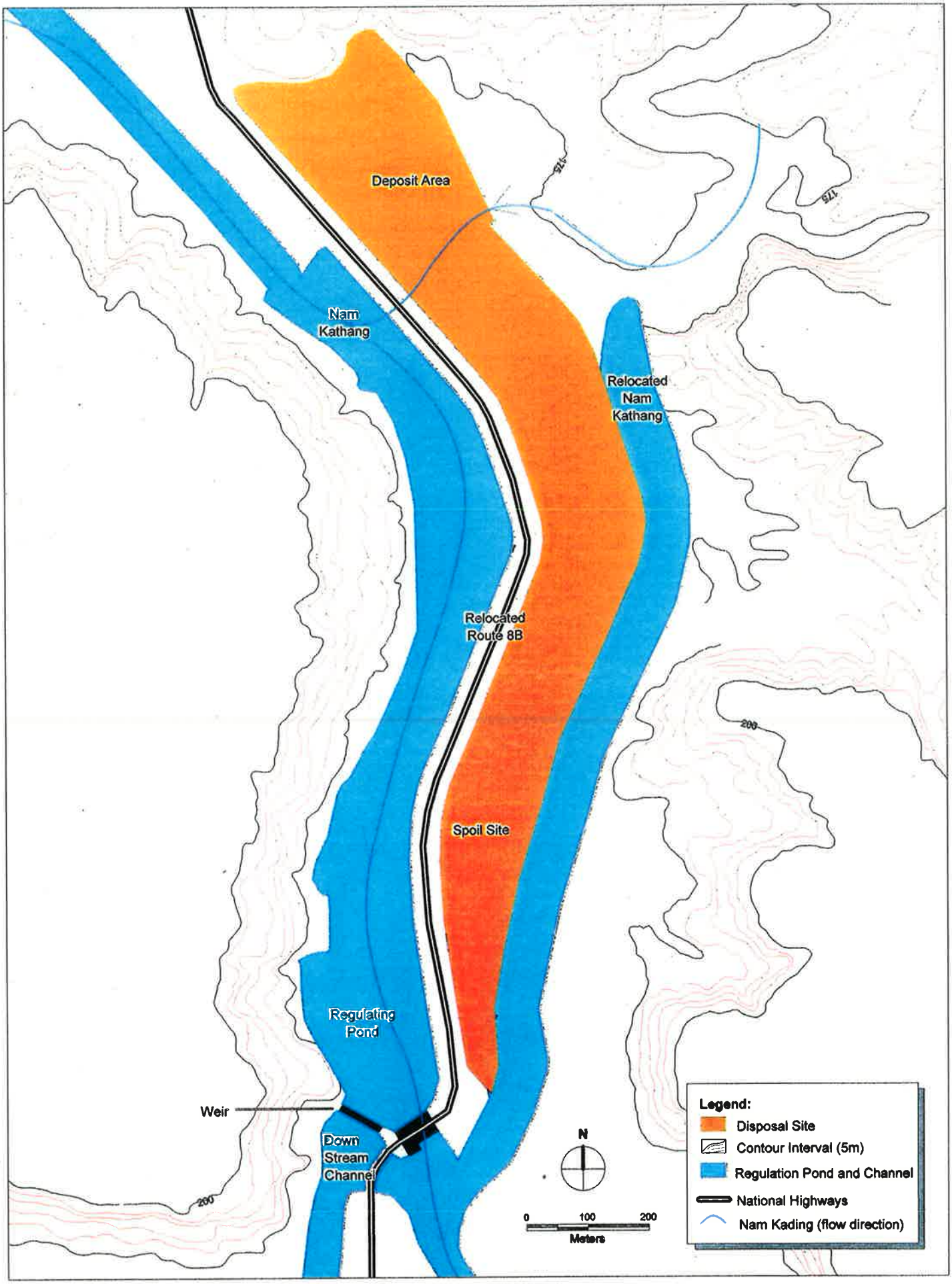


FIGURE 3-5 REGULATION POND AND WEIRS PLAN

Source: EDF, 1995

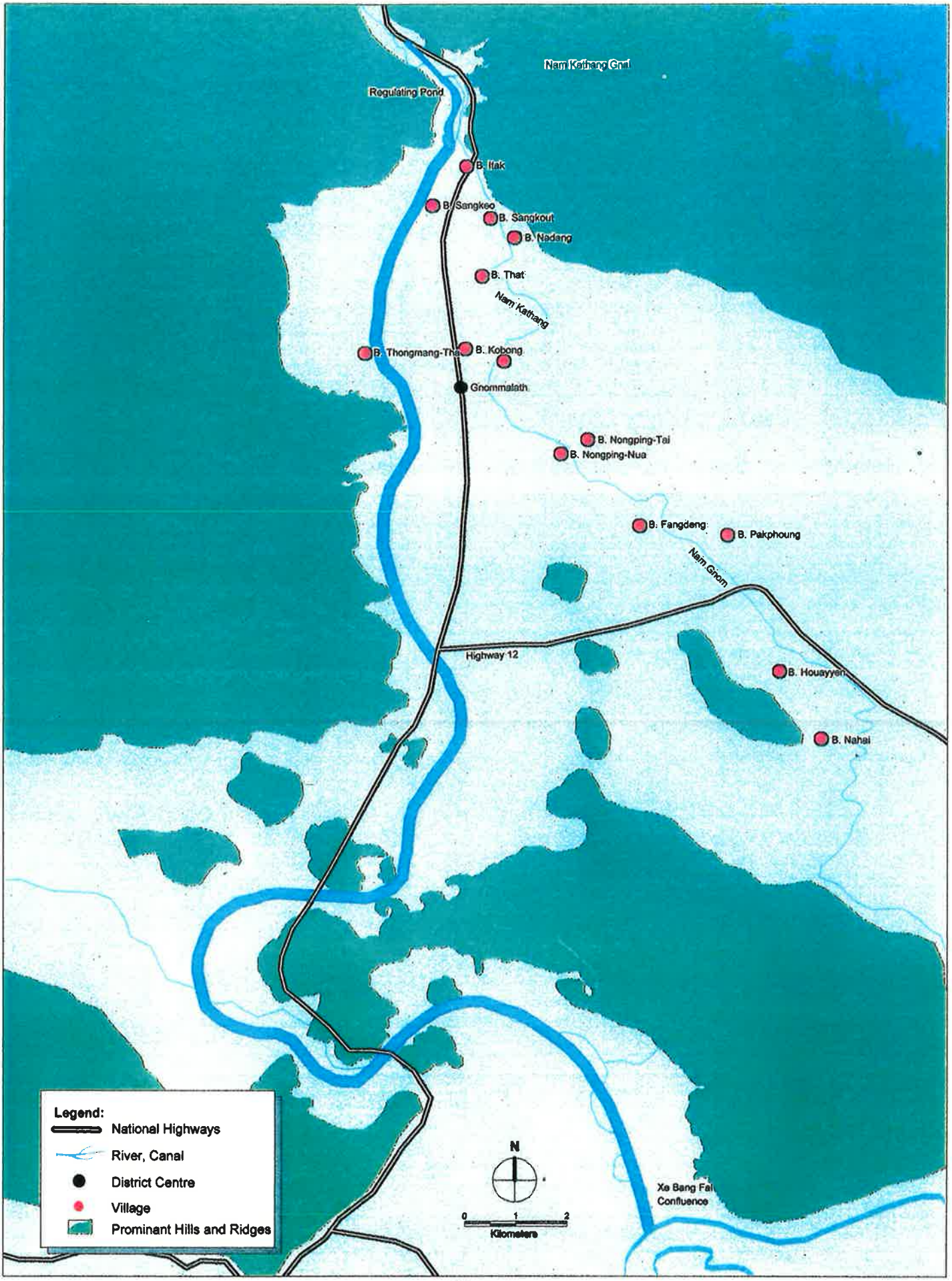


FIGURE 3-6 ROUTE OF DOWNSTREAM CHANNEL

Source: EDF, 1995

An inverted siphon will take the Downstream Channel under the Nam Gnom River at Gnommalat. Thereafter, the bed width will be increased to 95 m so as to minimise the amount of excavation in the harder underlying materials. After crossing Highway 12, the Downstream Channel will follow the alignment of the Nam Phit. This vegetated streambed carries the flood waters of the wet season to the Xe Bang Fai but is dry the rest of the year, with the exception of ponds along the way. The streambed increases in size in the downstream direction.

Bridges will be placed across the Downstream Channel to ensure adequate access across the channel in keeping with the stakeholder's requirements.. The pathway bridges will be wide enough to carry small farm tractors.

The Downstream Channel will be designed for flow of 210 m^3/s plus the 2-year flood for the drainage area contributing to the former watercourse. The cross section will be cut into the landscape so that drainage waters can reach the channel and be transported with the turbined flow.. The approximate quantity of excavation for the Downstream Channel is of the order of 12.5 million m^3

An average velocity of 1 m/s was chosen for the design of the Downstream Channel so that the current does not erode the channel material.. There will be a total of eight drop structures of heights between 1.15m and 5 m.

3.2.8 Transmission Line

The Project will construct 144 km of twin double circuit 230 kV transmission line to deliver electricity from the Power Station to the transfer point on the Lao-Thailand border near Savannakhet. The planned route is shown in Figure 3-1, Project Features. The towers bridging the Mekong will be designed to cater for any eventual upgrading to 500kV. The 230 kV transmission line will continue under the supervision of EGAT from the Lao-Thailand border to the Mukdahan switching station where it will be linked with the foreshadowed EGAT 500 kV system in this area. One outdoor switching station will be required, an outdoor station near the access tunnel exit from the Power Station.

The two transmission lines will be parallel and 60-100 m apart. The towers will be constructed as steel lattice, self-supporting, to a height of 45 to 55m. The normal spacing between consecutive towers will be 300-400 m. The route of the lines will avoid any houses or settlements and, where practical, any agricultural areas.

3.2.9 Roads and Bridges

Approximately 84 km of public road are to be upgraded and another 97 km of new public roads are to be constructed, making a total improvement of 181 km to the road system in the area. In addition, access roads and tracks will be constructed between public roads and Project facilities to enable operation and maintenance. Several temporary roads and tracks will be required for construction access and some of these, specially along the Downstream Channel, will be left in place for possible future use as intermittent maintenance access. In addition 45 km of minor unsealed roads will be constructed to resettlement sites. Of this length 30 km will be new alignment with 15 km being upgrade of existing tracks.

The length of public roads to be upgraded and new roads to be constructed is as follows.

Route	New Roads (km)	Upgrading of Existing Roads (km)	Total (km)
Thakhek to Gnommalat	0	64	64
Gnommalat to Nakai	0	20	20
Nakai to Road 8B via Dam	97	0	97
Resettlement Roads	30	15	45
Total	**127**	**99**	**226**

Thakhek to Gnommalat : Generally, the existing alignment of roads 12 and 8B will be followed with minor local realignment to improve sight distances, gradients and drainage. The carriageway will be upgraded to provide safe two-lane traffic conditions. Bridges will be improved or rebuilt as needed to a safe and serviceable condition. Existing culverts will be cleaned and repaired and additional culverts installed to ensure adequate drainage in all seasons.

Gnommalat to Nakai : Generally, the existing alignment will be followed, but with significant upgrading of the roadway. In the section between Gnommalat and the Nam Kathang, the carriageway will be raised above flood levels and drainage works will be installed. The crossing of the Nam Kathang will occur at the regulating weir where a bridge will be constructed in conjunction with the weir structure. In the section of road on the escarpment between the Nam Kathang and Nakai, extensive earthworks and drainage improvements are required to ensure a stable and safe all season road.

Nakai Road to Road 8B : A new 2-lane road will be constructed to replace the section of Road 8B which will be flooded by the reservoir. The route will generally follow the southern rim of the Plateau, around Nam Malou and crossing the Nam Theun at the Dam, where a bridge will be constructed across the spillway. It is possible this river crossing will be made by a bridge just downstream of the dam. The new road will join existing Road 8B a few kilometers south of Phuo Phako.

Resettlement site roads . These 45 km of roads will be two, 2m wide paved but unsurfaced lanes and will have a maximum impact area of 30 ha.

3.2.10 Operator's Village

The operation of the Nam Theun 2 Project will require a village to be established for 125 employees and their families near the Power House. It will accommodate a total of 550 people A small permanent facility will be constructed near the dam for operation and periodic maintenance purposes. The main village is to be built at the base of the escarpment adjacent to Road 8B. This location will provide good access to all the other components of the Project requiring continuous or daily operation. The area is located on relatively flat terrain. The following facilities are intended to be provided in the village.

- One hundred and twenty five comfortable and well equipped lodgings for permanent staff.
- A hotel to accommodate visitors.
- Services including a canteen, restaurant, supermarket, cleaners, co-operative stores, post office, and telecommunications center.
- Maintenance services including water treatment plant, sewage treatment plant, fire fighting units, emergency power supply, garbage collection facility, helipad, guards, and fencing.
- Recreational and leisure facilities such as playground, swimming pool, auditorium and library.
- Health, social, and educational services with a dispensary, school, and temple.

3.2.11 Materials Sources and Spoil Disposal Areas

There are two planned limestone quarries for concrete aggregate production and riprap; Phou Phako for the Plateau works, and Pha Thung (ITD) quarry for Power House and Downstream Works. There is an area just downstream from the damsite where sandstone can be quarried for materials. Sand is available in many places on the Plateau. Crushing has already started at a limestone quarry near the Thakhek-Gnommalat road at Pha Thung approximately 8km south of Gnommalat, for the power house and downstream works. Spoil disposal sites for the construction waste materials not utilised in road, saddle dam, sediment traps, landscaping and resettlement fill construction, will be in the dead storage of the reservoir near the dam and intake works, on top of the escarpment for some of the tunnel works, at the escarpment base for the rest of the underground works, and in depressions and other places along the alignment of the Downstream Channel. Figure 3-7 illustrates the quarry and spoil disposal sites.

3.3 CONSTRUCTION SCHEDULE AND EQUIPMENT

Figure 3-8 indicates the Nam Theun 2 value engineering review and project development preliminary timetable. It shows the timetable for various agreements such as the Owners agreement, the TKC proposal, the ECA agreement, the Concession agreement, the IFC A & B agreement, the Lao equity commitment and the World Bank sign-off.

Figure 3-9 indicates the proposed construction schedule for the NT2 Hydroelectric Project. This includes a schedule for the dam, saddle dams, headrace channel, inlet works, tunnels and shafts, power house, tailrace channel, re-regulation weir, downstream channel, transmission lines, switching station, E&M plant, roads, and operator's village. Detail design and construction of the Project facilities will commence on the award of the Turnkey Contract. The award of the contract is pending World Bank guarantees for the loans covering GOL's share of the Project, other Project documents and the requirements of the commercial banks. The construction phase for the entire Project, including commissioning is currently estimated to last 51 months, but methods to shorten this are being investigated.

Some of the preliminary works to be commenced following financial approval will include the construction of access roads to the tunnel portals and improvement of access to the construction camps and work sites on the Plateau. Further road work and camp site construction will start almost at the same time. Work on the tunnel and RCC dam will start during the first dry season. Construction activities are expected to be impacted by heavy rains in each wet season. However, the dam and appurtenant features including the tunnel and spillway are anticipated to be completed with in 38 months. The mechanical and electrical installations will proceed in conjunction with civil works. Commissioning of the power plant equipment will take the balance of the estimated 51 months

Cost and time estimates have had to take account of the difficult conditions due to the climate, access, and site location.

The following typical construction equipment is proposed for use on the Project.

1. Scrapers - may be used for topsoil and subsoil removal. It is anticipated that scrapers in the 300kW power range will be needed.
2. Bulldozers - necessary for ripping of rock strata, providing support in the construction of the downstream channel, and spreading of earth materials. The dozer size will range from D8's to D10's (190 kW to 500 kW)

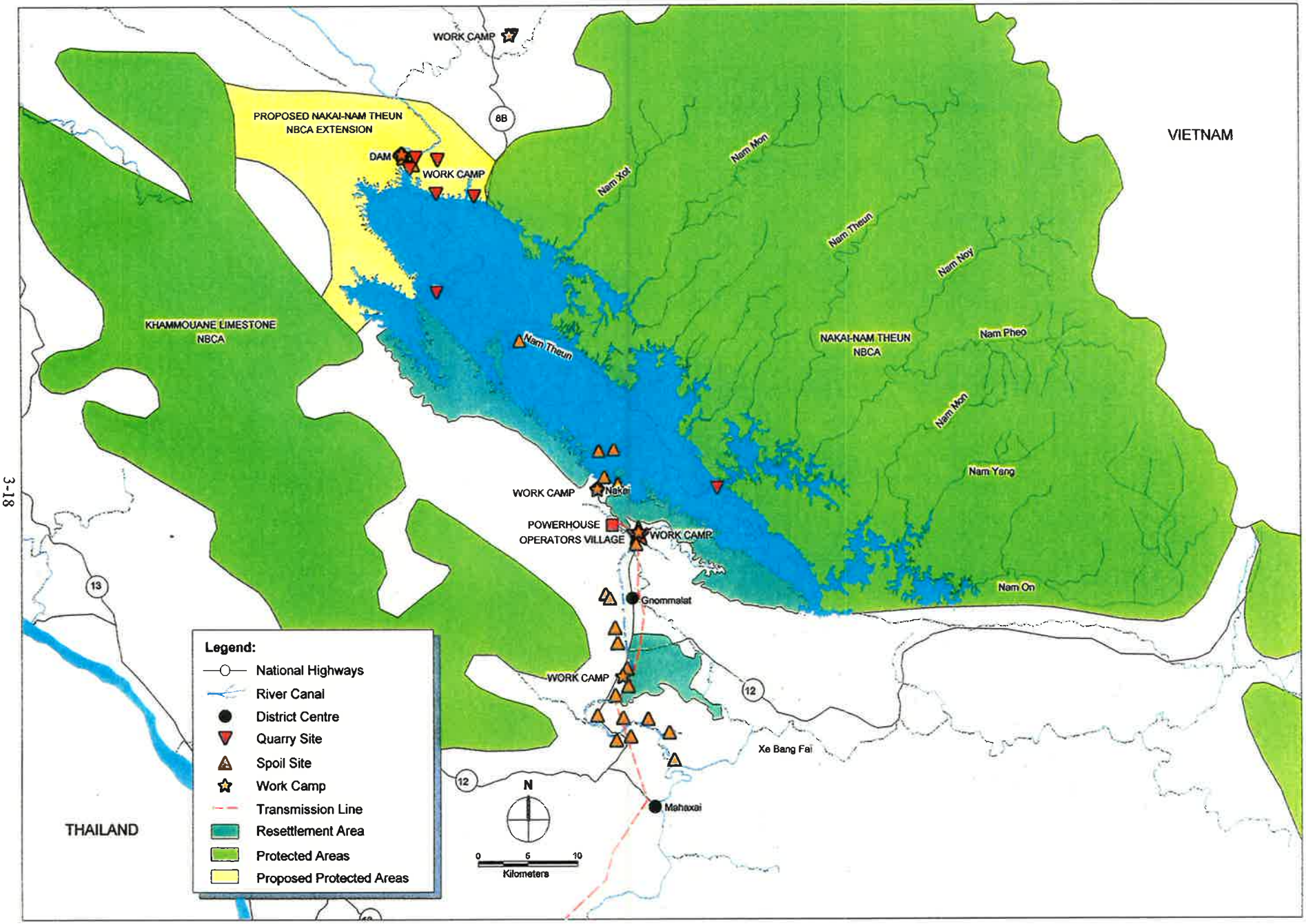
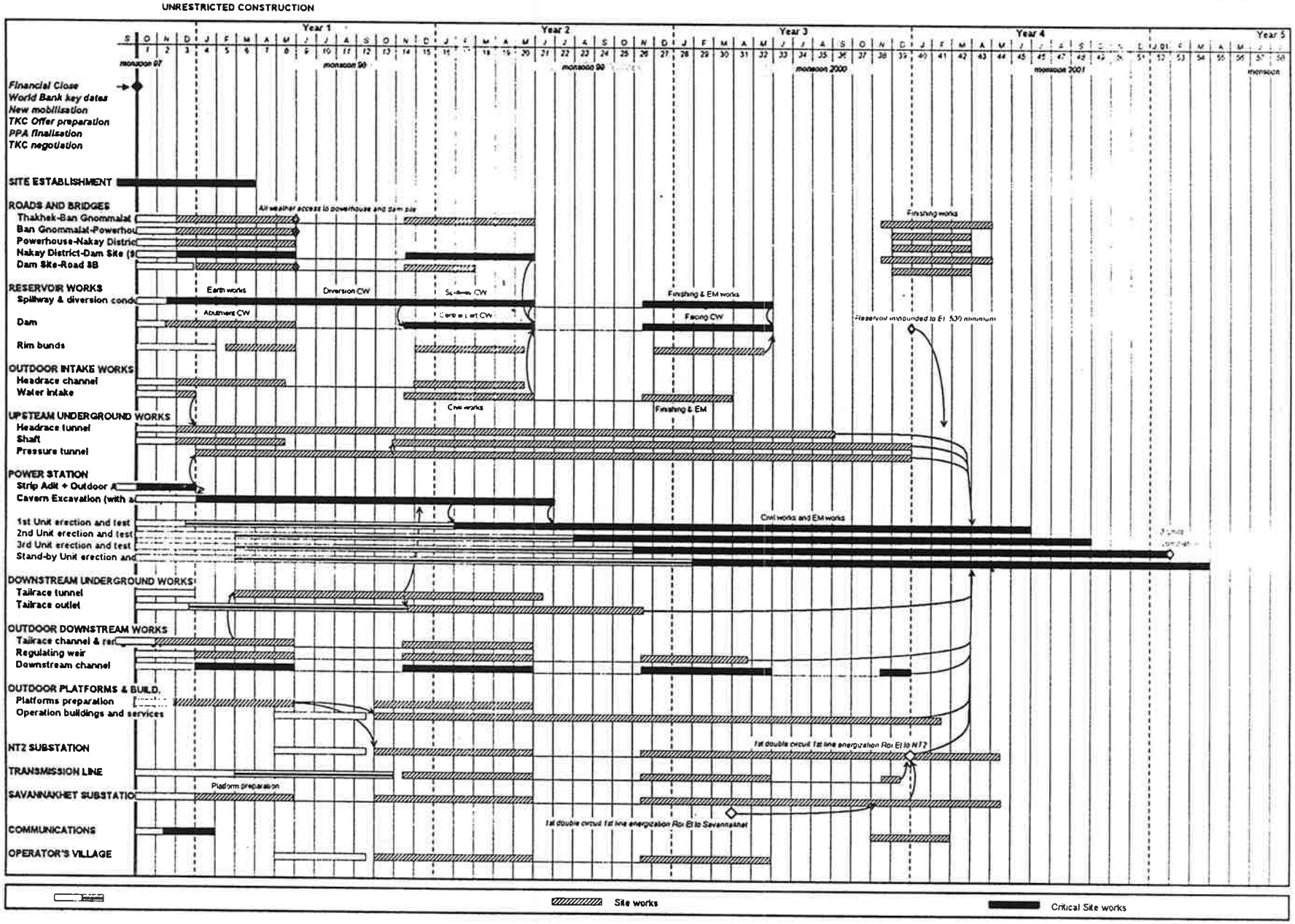


FIGURE 3-7 QUARRY AND DISPOSAL SITES

EDF - CNEH	FIGURE 3-8 : INDICATIVE CONSTRUCTION SCHEDULE	April 29th, 1996



3. Trucks - required to move materials. The truck size will vary for different work conditions and different sites. Large capacity off-road units used for heavy construction or mining will likely not be required.
4. Excavators - used to dig earth materials in the quarries, along the channels, in the ponds, at the dam and spillway site. The size will vary for different work conditions and different sites.
5. Rollers - employed to compact earth materials at all earth and RCC embankment construction locations. Typically, a 30 ton vibratory roller will be used for compaction.
6. A conventional drill and blast boom jumbo will be used for tunnel excavation. Jumbo scooptram rubber tired loaders will be used to remove the excavated rock from the tunnels.
7. Vehicles for equipment and labour transport.
8. Auxiliary equipment including concrete batch plants, RCC pug mixers, aggregate process plants, dam and tunnel grouting and vehicles for administration and supervision staff .

3.4 PROJECT ENVIRONMENTAL COMPONENTS

The Project environmental components refer to the measures, including design features that will be incorporated in the pre-construction design, construction and operation stages of the NT2 Hydroelectric Project to minimise any environmental impact from the Project, and at the same time enhance the environmental value of the resource.

Both the NT2 Project management and the Turnkey Contractor are key players in the implementation of the environmental components. The Senior Management and staff of the TKC are committed to complying with all specified environmental regulations and requirements as stipulated in the Turnkey Contract and Concession Agreement. The TKC will undertake a detailed environmental management and safety plan in order to achieve these objectives. This plan will be in accordance with all relevant Lao PDR regulations and as defined in the Concession Agreement

3.4.1 Design Phase

The design phase consists of the conventional three stages of conceptual, preliminary and detailed design. The conceptual design is substantively completed sufficiently for major costings to be completed and has included an iterative process which has minimised the projects environmental and social impacts. Preliminary and detailed design will reinforce this process. Some preliminary design has also been completed.

3.4.2 Construction Phase

The following environmental protection components will be incorporated into the construction phase of the Project.

3.4.2.1 Sedimentation and Erosion Control

Erosion and sedimentation will be carefully controlled during the construction of the plant. Areas of the site not disturbed by construction activities will be maintained in their existing condition. Any natural runoff from the undisturbed areas will be diverted away from the construction areas. The following measures are planned to control sedimentation and erosion :

(a) All soil erosion and sediment control practices will be installed prior to any major soil disturbance, or in their proper sequence, and maintained until permanent protection is established. Only areas intended for immediate construction activity will be cleared of vegetation and topsoil, in cognisance of the overall construction schedule.

(b) Any disturbed areas that will be left exposed more than 30 days and not subject to any construction traffic will receive a temporary seeding. Following initial disturbance or rough grading, all critical areas subject to erosion (i.e. steep slopes) will receive a temporary seeding in combination with straw or a suitable material.

(c) Dust control activities will be implemented on the construction site. Dust control will consist of the following activities or other methods.

- Stabilisation with temporary vegetation.
- Sprinkling with water until the surface is sufficiently wetted to suppress dust.

(d) Soil and spoil removed during the construction process will be stockpiled separately and stabilisation measures implemented. The stockpiles will be constructed with smooth slopes and free draining patterns. The height of stockpiles will be limited to 3 meters, and topsoil stockpiles will be deep ripped to provide for moisture retention and regrowth. Drainage and erosion from the stockpiles will be controlled by locating them in areas away from drainage lines. The erosion of the base of the dump will be prevented by providing a diversion bank uphill to prevent any runoff from reaching the pile, and at the same time constructing a silt fence to contain any runoff resulting from the pile.

(e) This will involve water management plans to meet the appropriate standards, and include development of drainage works, sediment traps, diversions, culverts and other structures designed to treat water to an acceptable quality before discharge into natural water courses. All these structures will be constructed prior to commencement of earthworks. Regular inspection and maintenance will be conducted to monitor their efficiency. The volume of turbid water will be kept to the minimum and the discharge regulated. All runoff from the construction areas will be directed to the sediment settling areas.

(f) Catch drains, diversion drains, table drains, windrows and associated drop-down drains will direct site runoff to established water courses. These will be inspected regularly for any damage caused by scouring, sediment deposition, channel obstruction, and loss of vegetation cover. Non-erodible segments will be established along the slope lengths through temporary banking for diversion to stable outlets at non-erosive velocities, with adequate capacity to manage runoff from high intensity storm flows. These outlets will be located along the natural drainage lines.

(g) Sedimentation controls will be implemented in the form of silt trap fences and sedimentation basins where appropriate depending upon the size of the catchment, and other physical and environmental constraints. The silt trap fences will control sheet flows along minor drainage lines, whereas the sedimentation basins will be utilised for removing sediment laden runoff from the construction areas. These will be built prior to the start of the activity and will be maintained until the completion of that activity. The basins will be designed for adequate storage and it will be regularly desilted when the basin capacity gets reduced by approximately 30 percent.

(h) All storm and construction water runoff will be confined to construction areas by containing it in concave shaped excavation and fills.

3.4.2.2 Noise Control

The primary construction noise sources will be from the diesel powered construction equipment for land preparation and clearing purposes and explosives used for open excavation and tunnelling. However most of the construction sites are very remote from areas of human settlement, and noise levels are not expected to be of any nuisance value. In construction areas

close to villages and settlements, the construction hours will be restricted and engine noise control devices on construction equipment will be adequately maintained. All construction workers will be provided with adequate hearing protection.

3.4.2.3 Air Emissions and Fugitive Dust Control

Construction phase activities having the highest potential for generating fugitive dust include land clearing, excavation, and vehicular movements at the site.

The primary control measure for suppressing fugitive dust generated during construction activities will be water spraying. Water sprays will be employed as necessary to control dust on unpaved construction roads and in areas of major earth excavation. In addition to water spraying in active earth disturbance areas, other measures that may be used to control fugitive dust emissions include controlling the speed of haul trucks and application of water to haul roads and embankment areas. All areas disturbed during construction will be either surfaced or revegetated to control erosion and fugitive dust emissions.

No specific controls are planned for any construction equipment emission as a result of diesel fuel combustion, as these will be minor, however suitable ventilation will be provided for underground construction sites. Any burning of construction waste and garbage will be conducted according to relevant guidelines and regulations.

3.4.2.4 Solid Waste Management

All solid waste generated from construction will be collected in waste bins to prevent any proliferation and escape from the site, and will eventually be burned or buried..

3.4.2.5 Spoil Disposal

Construction spoil will be disposed at the following sites :

(a) If possible, below minimum water level in the reservoir near the dam and intake works;
(b) On top of the escarpment for some of the tunnel works;
(c) At the escarpment base for the rest of the underground works; and
(d) In depressions and other areas along the alignment of the downstream channel.

The disposal areas are shown in Figure 3-7. The following table gives the expected volumes of spoil from excavations.

Site	Volume of Excavated Waste (million m^3)
Dam and Spillway	0.2
Headrace Channel	4.0
Underground Works	0.3
Tailrace Channel and Regulating Pond	0.2
Downstream Channel	12.5

All spoil will be transported to the disposal sites by trucks or scrapers. Any loose material capable of generating fugitive dust will be wetted and compacted. The spoil will then be stockpiled and stabilised and erosion measures introduced as described earlier in this Section.

3.4.2.6 Forest Clearing/Human Activities

All land and forest/vegetation clearing activities will be carried out with utmost restraint and care. Forests areas not ready for clearing will not be disturbed, except that early removal of merchantable timber will precede general clearing. Construction and land clearing activity will

be phased so that disturbance is confined to limited areas. Prior to construction commencing a vegetation clearing program will be developed as part of the environmental management plan.

Further, efforts will be made by the Environmental Manager to prevent any environmentally unfriendly activities by the construction workforce like fishing by explosives, hunting and firewood gathering, that harms the terrestrial and aquatic habitat.

Stabilisation of disturbed areas will commence as soon as possible. This will include the spreading of topsoil, grading, seeding by either conventional or mechanical means. Wherever possible native plants species will be preferred for planting. The process of seeding and fertilising the seeded areas will continue on a regular basis as the final landform is achieved.

3.4.2.7 Construction/Work Camps and Squatter Settlements

Camp Description	Peak Workforce Expected
Power Station Site	1100
Dam Site	400
Nakai	300
Phu Phako	50
Pha Thung	150

Figure 3-10 : Location of Work Camps and Operator Village, shows the location of these work camps.

The base camp will consist of living facilities with housing, mess, shower and sanitary facilities. First aid facilities will be provided. Portable fire extinguishers will be provided within the housing facility for fire protection. Insecticides will be sprayed within the camp periodically to control the spread of insects and outbreak of any disease. Water of potable quality will be supplied by chlorination of the construction well water, or will be transported from offsite sources by truck and stored on site and distributed to each housing facility. Adequate sanitary and sewerage facilities and solid waste disposal facilities will be provided to serve the construction camp facility, a packaged sanitary treatment system will be installed to collect and treat sanitary wastes. On completion of the construction stage activities, the work camps will be dismantled for reuse of any possible material and equipment.

The current TKC estimate for peak construction worker numbers is 2,000. Based on actual productivity rates achieved and the eventual level of mechanisation adopted there is some possibility that the actual peak numbers could be doubled or more. The TKC is committed in this eventuality to increasing camp and service centre community infrastructure at constant quality standards in proportion to any such increase.

In addition to the approximate 2,000 Project construction workers, and their family members who will accompany perhaps a third of the workers, there will be immigrants who will provide informal services in the area, which will require proactive and vigorous management measures. Construction and work camp site locations do not appear to require any relocation of communities. The Project will undertake elaborate protection and containment measures through detailed site selection, and design in efficient management of these areas. Camps will be located as far away as possible from permanent human settlements.

NT2 plans to incorporate ample screening and control measures for construction workers. Control over camp followers, however, is less easy to exert effectively. The NT2 Project has proposed development of "service centre communities" for allowing the Project and/or an appropriate Government agency the ability to monitor and control inhabitant's activities. Any

immigrant who wishes to offer informal services will have to rent space in specified areas delineated by the Project. These areas will be off main roads, but with easy access to the worker's camps. These areas will be provided with drinking water supply, and solid waste disposal facilities.

3.4.2.8 Power Plant and Associated Facilities Construction

Detailed pollution control measures will be developed during the construction stage by the TKC for the various facilities under construction including (i) dam, (ii) reservoir saddle dams , (iii) headrace channel, (iv) water intake structure, (v) tunnels and shafts, (vi) tailrace channel and weir, (vii) downstream waterway, (viii) transmission lines, (ix) roads and bridges, (x) power house and (xi) operator's village. These will include measures for runoff control, noise control, dust control, waste management, and rehabilitation.

The major effort at construction sites for the Project will be management of erosion of excavated surfaces especially during the wet season when the volume of runoff is expected to be high. A manual of Best Management Practices will be prepared for use at all the construction sites as part of the Environmental Management Plan for construction, that will include environmental management and pollution control techniques for all these areas of activity including drainage measures for underground works.

Provision for the temporary release of riparian flow will be made during the construction period during the closure of the diversion tunnel and until the time the water reaches the level of the permanent riparian outlet works (El 524.5), to maintain continuity of flow.

3.4.2.9 Construction Traffic

All construction traffic will be regulated and directed in an orderly fashion. There will be safe sighting distances and appropriate directions/signs at various locations on the site to direct the traffic. All road surfaces and shoulders of site access roads will be maintained per the appropriate design standards with regular maintenance inspections. Adequate parking and garage space will be provided for all classes of vehicles traversing the site.

3.4.2.10 Archaeological and Heritage Site Protection

All the sites of archaeological and historical significance as identified in field surveys will be flagged and strict directions issued to all construction staff of the need for their maintenance and protection. Disturbance of any such site will only proceed after consultations and agreement with experts and local/national authorities, and on obtaining such permission.

3.4.2.11 Chemical Waste/Spillage Management

All refuelling of heavy equipment and machinery will be undertaken by a service vehicle, with appropriate safeguards and protection measures to prevent any spillage or contamination by chemical wastes or maintenance oils, lubricants etc. All the fuel and hazardous material storage will be adequately bonded to alleviate any spillage problems.

3.4.2.12 Environmental Management and Safety

An environmental management and supervisory organisation will be instituted as part of the Turnkey Contractor's contractual obligations. This organisation will be instituted from the beginning of the design and the construction stage.

Figure 3-11 : Environmental Organisation Structure, illustrates the hierarchy of the organisation. The following table discusses their assigned responsibilities towards maintenance of environmental standards and quality.

Position	Responsibility
Consortium Manager	• overall responsibility and review of environmental management
Consortium QA Manager	• implementation and overview of the quality assurance plan
Project Managers	• conduct and review environmental protection measures for their respective projects, and approving corrective action reports
Construction Manager	• implementation of environmental protection measures in accordance with regulations and procedures • review and approval of technical procedures • approve disposition of non-conformance • participation in management review
Quality Assurance Managers	• review and approval of test plans for projects • conduct process quality audits • identify the corrective measures and modes of implementation • participation in management reviews
Environmental Manager	• ensures compliance with all aspects of the environmental management plan and necessary technical procedures • assisting in resolution of non-conformance • identify and recommend corrective actions • preparation of monthly environmental report
Design Manager	• ensures compliance with all statutory regulations, design practices and codes, ordinances and requirements of authorities
Site Engineers	• assessment and preparation of technical procedures • preparation of the inspection and test plans (ITPs) • monitoring environmental controls • documenting non-conformance and implementation of resolutions
Foreman	• implementation of environmental controls and technical procedures under the supervision of the Site Engineer • monitoring environmental control and identifying non-conformance

In addition to this the Turnkey Contractor will provide the services of Environmental Specialists to offer expert advice from time to time on various aspects of environmental management. This will include site inspections, meetings with the site construction and environmental organisation staff, particularly the Project Manager, the Quality Assurance Manager and the Environmental Manager.

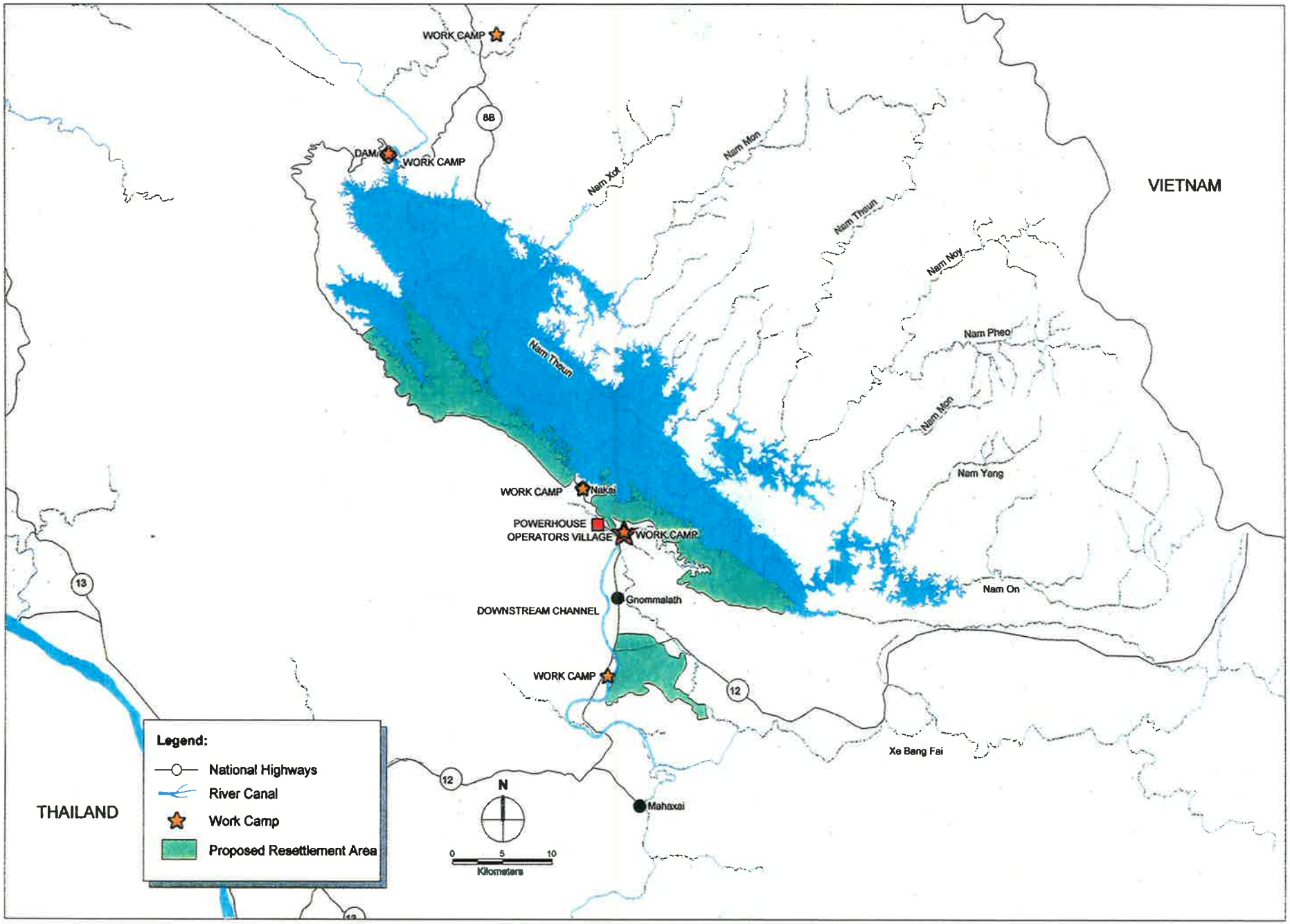
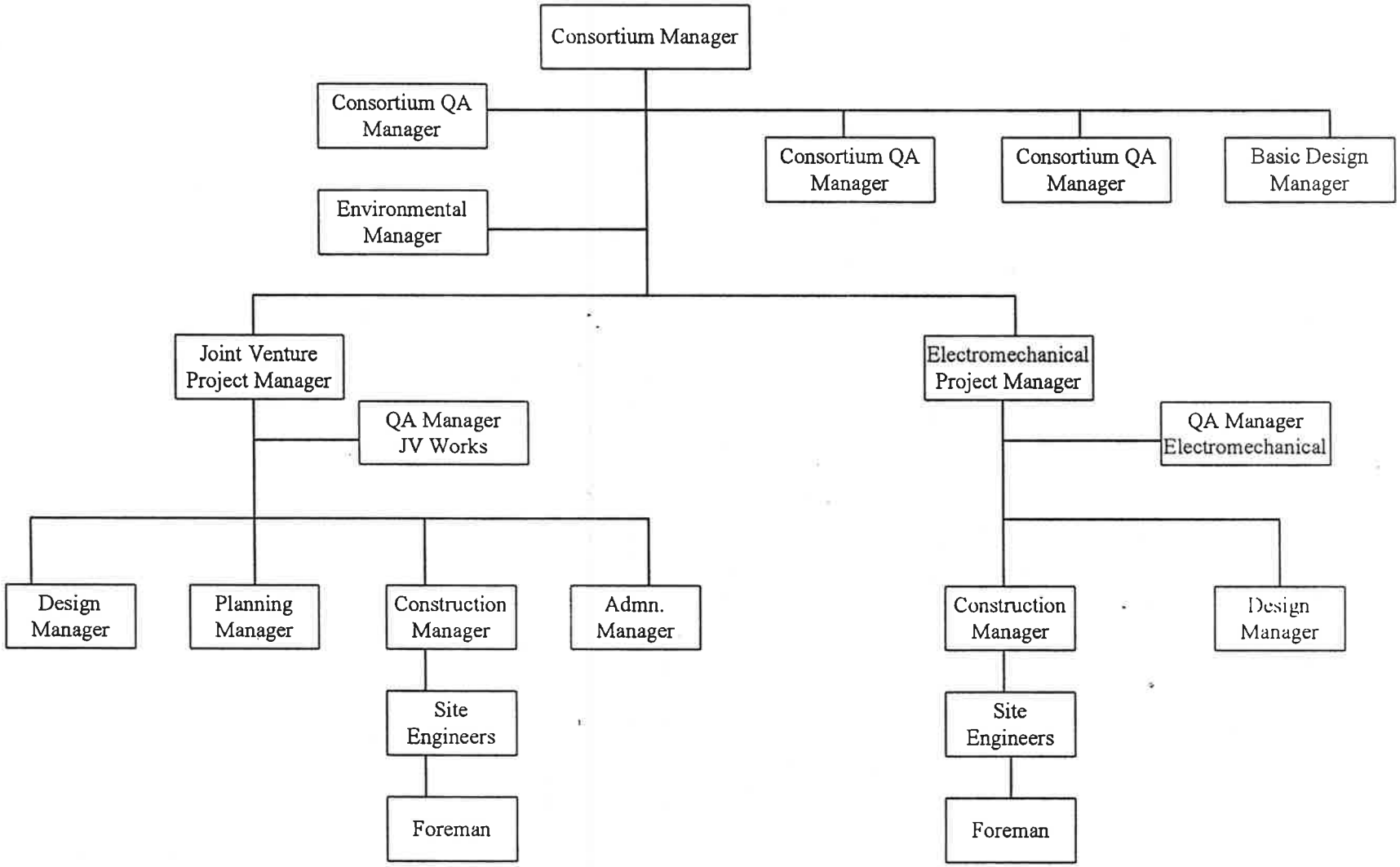


FIGURE 3-9 **LOCATION OF WORK CAMPS AND OPERATOR'S VILLAGE**

FIGURE 3-10 : ENVIRONMENTAL ORGANIZATION STRUCTURE



Source : TKC, 1997

Detailed documentation, inspections and reporting will be conducted for efficient environmental management of all the construction stage activities. The Site Engineers will prepare inspection and test plans including details on the environmental controls for each of the construction activity. The Environmental Manager will prepare the inspection and test plan for environmental monitoring, and the Quality Assurance Manager will conduct process quality audits, and produce an audit report. A Non-Conformance Report shall be prepared in instances where site inspection reveals a potential for an environmental impact, on resolution of the non-conformance a Corrective Action Report will be prepared. The Environmental Manager will prepare the monthly environment report, that will include evidence of EPM implementation, special site investigations, results of environmental monitoring. It will also include details on any approvals or permits required for construction.

A detailed "Workplace Health and Safety Manual", will be prepared for implementation by the Turnkey Contractor. Construction safety will be managed and controlled by the Work Place Health and Safety Officer and staff. The main areas of responsibility for this task will include :

- Monitor the enforcement of safety rules and regulations on the Project.
- Provide safety program communications to all sub-contractors.
- Maintain liaison with construction management, Govt. of Laos safety personnel, turnkey contractor and sub-contractors.
- Monitor contractor enforcement of personnel wearing appropriate personal protective equipment.
- Assist the contractors in posting of safety signs in hazardous locations.
- Enforce the requirements of the site safety manual.

3.4.3 Operation Phase

The following environmental components will be incorporated in the operational schedule of the Project.

3.4.3.1 Hydrology

During the times when the reservoir is full, spillway releases will be made to maintain the reservoir level at the Full Supply Level (El 538) during the passage of floods.

3.4.3.2 Water Quality

Minimum Guaranteed Release

NTEC guarantees that an average of two (2) m^3/sec will be released continually through the dam to augment dry season flows that enter from tributaries along the middle reach of the Nam Theun. Additional flow will be released during the wet season of the year depending on the amount of water needed at any given time to fill the reservoir. The minimum guaranteed release, generally referred to as a riparian release, will provide the minimum amount of water for protection of various ecological values found in the riparian environment below the dam. Since there are no people permanently inhabiting the stretch of river between the proposed Damsite and the upper end of the headpond of the Theun Hinboun, the direct impact on beneficial use by humans is minor.

The riparian water will be taken from a multi-level intake in the reservoir, transported along the spillway wall in a steel pipe and released through a cone control valve into the spillway stilling basin. The water will be well aerated with the cone valve spreading the water in an ever increasing hollow-cone shape, providing a large area of turbulent contact with the surrounding air, before falling into the pool below. It is anticipated that the dissolved oxygen level can be

increased by up to 5 mg/l, depending upon the oxygen demand in the 12-km reach of the Nam Theun River. Thereafter, this riparian release will mix with Nam Phao River water. Computer simulation of the reservoir dynamics has been able to predict accurate levels of water quality in the reservoir at the level of the riparian intake which generally indicate high quality of water.

The ecological values that are of importance in the riparian environment below the dam, and that are potentially affected by the quantity of water released over the dam, include the following:

- *Water quality.* This is a fundamental value that affects the aquatic habitat if allowed to deteriorate. Water quality can also affect other beneficial uses, if the water is used directly by people. Initial evaluation of flow rates through the various pools below the dam showed that water quality factors, in combination with flow quantity, can be significant in maintaining some ecosystem values. For instance, nutrient loads above critical threshold levels are approached in some areas of the reservoir, as indicated by the elevated chlorophyll 'a' concentrations that are predicted by the reservoir water quality model. Retention time is a factor in slow moving pools under the minimum release regime, since during night-time periods oxygen levels may drop. NTEC has agreed to vary the release rate under conditions that cause night time dissolved oxygen levels to drop. NTEC has agreed to monitor water quality at indicative locations to determine whether these effects are occurring.

- *Fisheries* The diversity and productivity of fish populations below the dam are affected both by water quality and quantity in combination. Also, diversity will decrease as a result of the physical presence of the dam, an effect that cannot be easily separated from effects brought about by water quality deterioration. Productivity is expected to increase as long as sufficient dissolved oxygen is present. Productivity is not expected to be seriously affected by a release rate of two m^3/sec, if dissolved oxygen levels are not allowed to fall below 40 percent of saturation concentration which the water quality report says will not happen and which the cone valve will further improve by providing aeration.

- *Wildlife.* Some species of wildlife depend on the stock of fish as a source of food. These include various raptor birds and a native species of otter. As long as productivity is maintained in the fish population, these animal populations are not expected to be altered under the guaranteed release regime.

- *Riparian Forests* High canopy forests can be found in isolated locations within minor floodplains along the river. The configuration of the gorge makes their occurrence uncommon. Trees within these isolated areas can be affected if the groundwater table lowers below the root zone of the trees. The effect is difficult to predict; however the judgement of specialists holds that the phenomenon will not occur within a short time frame. Over ten to twenty years, alterations in vegetation of various types can be expected.

- *Aesthetic Values* Another ecological value found in the riparian strip has to do with the appearance of the river and adjacent habitat under minimum flow conditions. Some aesthetic values will be lost.

Aeration Sills

In the Downstream Channel which will carry turbined flows to the Xe Bang Fai River, specially designed aeration sills will be constructed where is it desirable to drop the invert of the channel. These will add oxygen to the water in amounts much greater than the normal transfer through the water surface. The air so added will be beneficial for all users of the water, both in the channel and in the downstream river.

Nam Kathang

The low flow of the Nam Kathang River will be capable of being increased during the dry season with additional turbined flow released at the Regulating Weir, through a channel to be excavated on the left side of the regulating pond. This will provide more water for various beneficial uses including irrigation, fish habitat, and all other human uses.

3.4.3.3 Sedimentation

The backwater effect of the reservoir will cause sedimentation in the tributaries where they enter the reservoir. However the sediment load from the catchment being low and the tributaries being steep, this effect will develop slowly over time and for a short distance upstream.

Under existing catchment conditions, the sediment load to the reservoir is not expected to be high. In addition, studies (Norplan A.S., 1995) indicate that the amount of fine sediment that could move in the reservoir to the riparian outlet or to the Power House Intake is minimal. The development of the NBCA will protect the Nam Theun catchment from increases in sediment production and resulting decrease in reservoir volume.

The inorganic sediment load supplied to the Xe Bang Fai River is not expected to change significantly because of the Project. Much of the bed profile is controlled by rock outcrops and the river bends between hills of rock formations, so its bed profile and general plan will not change. During periods when there are no floods or only small ones in the Xe Bang Fai,, the river bed will become coarser and the sand bars smaller. However, large floods will replicate the former features. The addition of the turbined flows will not significantly increase the concentration of suspended sediment so the water quality will remain unchanged in this respect.

3.4.3.4 Immigration

All Project related immigration in the form of informal service communities and other people migrating to the Project for employment and engagement in other splinter commercial activities will be carefully monitored. These measures implemented during the construction stage for this development will also be followed up in the operation stage. They will be guided by sound social and economic planning, co-ordinated by a skilled Government entity with active co-operation from the NT2 management, to protect the area's human, terrestrial and aquatic environment while, at the same time, bringing social and economic benefits.

3.4.3.5 Resettlement

Approximately 900 households (or about 4,500 people) from 17 official and 6 "other" settlements will be relocated from the inundation area. Figure 3-12 shows settlements in the reservoir area and the proposed location of the resettlement areas. The NT2 Resettlement Committee carried out initial field surveys in 1995 to identify sites for resettlement. Four broad criteria were used to select seven preliminary sites: (i) land suitable for agriculture, (ii) easy accessibility, (iii) year around water supply and (iv) proximity to the reservoir area. The last criterion was proposed by potential relocatees.

A Resettlement Action Plan (RAP) has been prepared and includes all the activities needed for relocation and resettlement of affected people. Relocatees will be provided with assistance during relocation and resettlement villages will be provided with all the required amenities, housing, health clinics, and other community facilities. In addition, a livelihood packages for economic rehabilitation of relocatees have been developed. Land capacity studies are being updated to clarify further the land use potential of the resettlement zones. The RAP includes studies investigating village administration and infrastructure, carrying capacity (groundwater,

soils, irrigation potential, livestock and agriculture), natural forest and plantation forest recourses and agroforestry options for natural forests.

3.4.3.6 Operator Village

As described in Section 3.2 the operator village, covering an area of 24-ha will be built to accommodate approximately 125 employees and their families near the Power House..

In addition to the requisite public utilities, adequate wastewater treatment and sanitation facilities will be provided including a water treatment plant, sewerage treatment plant, a fire fighting unit, a solid waste and disposal system, power supply, roads and drainage network. Any runoff from the operator village will be collected in a detention basin prior to discharge to Nam Kathang. Adequate security will be provided by way of an enclosed fence around the operator village. Public health facilities will be provided through a well equipped clinic/dispensary. There will be adequate green cover provided for the area for aesthetics.

3.4.3.7 Manpower Sources and Technology Transfer Process

In order to ensure a successful startup and long-term operation of the Nam Theun 2 Hydroelectric Project, pre-commercial training program will be provided. The training will include the following, i.e. orientation, safety, environmental control, scheme operation, scheme maintenance, and management systems. The training will be in the form of classroom and on the job training. The training will be attended by selected personnel of the NT2 Project. This will be part of an elaborate technology transfer program to help in giving Lao workers skills in rebar/carpentry/concrete placement areas.

3.4.3.8 Power Transmission Lines

As detailed in Section 3.2.8, the Project will construct 144 km of twin double circuit 230 kV transmission line to deliver electricity from the Power Station to the transfer point on the Lao-Thailand border near Savannakhet, on to the Mukdahan switching station linking it with the foreshadowed EGAT 500 kV system in the area. The two parallel lines will be about 60-100 m apart, suspended on steel towers spaced at around 300-400 m intervals. The towers will be supported on concrete piers or rock footings depending upon the foundation material.

The alignment will not affect houses or divide communities. Most of the land is forested and only very small amounts of agricultural land (about 2-3 ha of paddy) will be affected. The route will be cleared of tall vegetation to prevent contact with the conductors. Low vegetation will not be affected Latest research and studies have not shown any evidence of harmful effects of the electromagnetic fields generated by power transmission lines.

3.4.3.9 Dam Safety

The major issues involved in the safety of hydroelectric dams similar to the NT2 are the operation of the spillway and the stability of the foundation conditions.

Intensive training will be given to the gate operators for correct and efficient management of the spillway operation. Emergency power supply will be provided from a generator supply for the operation of the gates as backup. The Shift Supervisor will closely monitor the spillway gate operation such that the operators open and close the gates at the appropriate times.

The NT2 roller compacted dam can withstand overtopping by the Probable Maximum Flood (PMF) should it occur or in the event of any incorrect spillway gate operation.

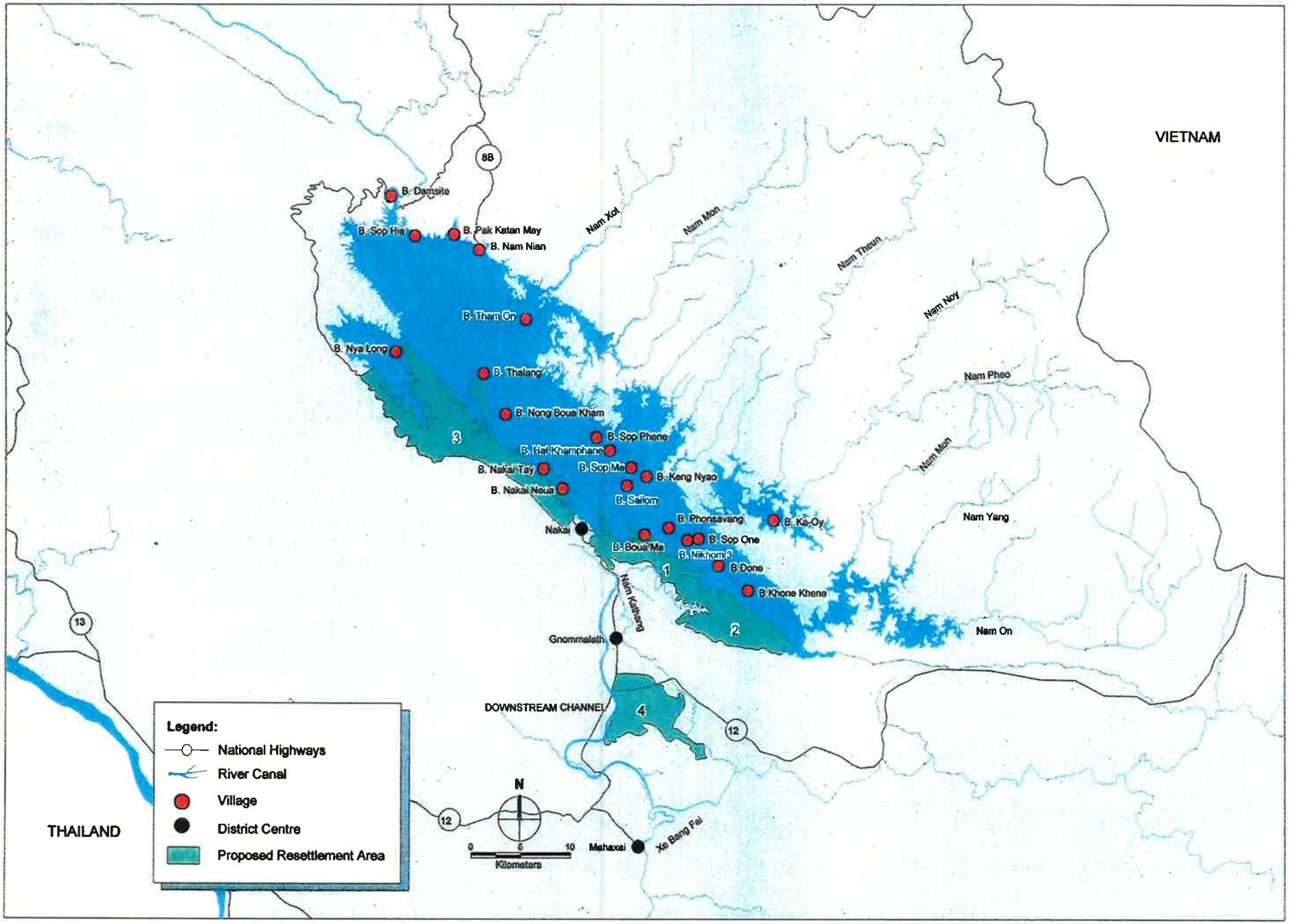


FIGURE 3-11 **RESETTLEMENT AREAS AND SETTLEMENTS IN THE RESERVOIR AREA**

The dam foundation has been investigated in detail by the process designer The dam structure will be built to withstand all the forces of nature such as storms, floods and earthquakes which may occur in the area in accordance with accepted design practices with due consideration to all the relevant factors of safety, preventing failure even under the most extreme situations. The World Bank will institute a Dam Safety Review Panel for review of all safety related issues.

3.5 PROJECT AMENITIES

The Project intends to undertake activities that enhance the environmental resources of the area by their sustainable utilisation and in the process also furthers the socio-economic level of the Laotian population residing in the area. Most of the employees of the operating company will be Lao.

The expat workforce will consist of 40 for the first year of operation. As Lao expertise increases the expat population will drop to 5 personnel in year five.

A major undertaking in that direction is the implementation of the Nam Theun Social and Environmental Project (NTSEP) by the World Bank. NTEC intends to work in close co-operation with the GOL, the provincial authorities of Khammouane and Bolikamxay, and BPKP towards achieving the objectives of this Project.

> "The effectiveness of this four sided partnership will depend on all working towards the same fundamental objectives of the NTSEP: sustainable development of the natural resources in the NT2 Project Area for the benefit of the Lao people and economy; long term protection of the forested watershed of NT2 and adjacent areas; mitigation of environmental and social impacts of NT2 construction and operation; and support for community development and poverty reduction in the Project area." (World Bank, 1996a)

The following components have been identified for the NTSEP : (WB, 1997a)

1. Watershed Management including the institutional and management set-up for the NNT-NBCA through the preparation of an Environmental and Social Action Plan (ESAP).
2. Resettlement and Community Development including the Resettlement Action Plan (RAP).
3. Downstream Environment including water quality and watershed management studies.
4. Public Health including malaria and sexually transmitted disease prevention.
5. Construction Management.
6. Irrigation and Infrastructure.

4. ENVIRONMENTAL SETTING AND BASELINE VALUES

CHAPTER 5

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TABLES

5. ENVIRONMENTAL IMPACTS

5.1 INTRODUCTION

This chapter presents the findings of the EA study on the potential environmental impacts expected to result from construction and operation of the Nam Theun 2 Hydroelectric Project. It presents the essential findings of the EA process, namely (i) delineation of the significant environmental issues, (ii) evaluation of each of these for an assessment of the potential for an environmental impact, and (iii) identification of opportunities for implementation of mitigatory measures, offsets and enhancements.

The environmental issues are each evaluated as a subsection of this Chapter. Each evaluation includes: (i) reference to information available from earlier (or ongoing) studies, (ii) a background of the approach used by the EIA team for making the assessment, (iii) description of links between the various environmental issues and other sectors of assessment, and (iv) presentation of results and recommendations including a final section on "Summary and Conclusions".

The critical environmental issues that are evaluated include the following :

- hydrological impacts evaluation, which includes investigation of extreme events like flood, drought and typhoon conditions
- water quality impacts evaluation including both the Project's impact on water quality and the impact of these changes in water quality on beneficial uses
- evaluation of terrestrial habitats that form an essential environmental resource in the project area, and the assessment of impacts including the study of impact on forests, forest biodiversity and wildlife
- the evaluation of impact on aquatic habitat including the evaluation of physical impairment of the habitat in terms of temperature and DO, and its consequent impact on aquatic life and fisheries
- a comparative analysis between NT2 impacts on forests, woodlands and landcover with analogous habitats unaffected by the Project
- evaluation is also provided on the threats to the forest resources in the absence of the NT2 Project
- impact evaluations have been made for various other activities associated with power plant construction by conducting sub-EAs for quarry sites, transmission lines, roadways, construction camps, and resettlement sites.

The Chapter presents to the reader where applicable, the impact scenario for various environmental issues with or without the project. This is particularly relevant for the terrestrial and biodiversity resources which are expected to undergo rapid and systematic depletion by way of logging and accompanied encroachment by sundry human activities without the Project. In addition impacts to landuses from frequent floods in the Xe Bang Fai will continue to happen with or without the Project. Further, other environmental resources including fisheries and wildlife will be continuously threatened with increasing population influx and environmentally hostile activities such as explosive fishing and hunting. The NT2 Project introduces an element of sustainability in resource utilisation.

Wherever possible effort has been made to draw linkages between various sectors of assessment for providing a comprehensive picture of environmental assessment, and to lay the ground for mitigatory measures, compensations or enhancements. Mitigation measures are provided in Chapter 6.

5.2 IMPACTS ON GEOLOGY AND LANDFORMS

5.2.1 Seismotectonic Study and Calculation of Site Dependent Spectrum

The seismic risk assessment was performed using a deterministic approach, consistent with ICOLD recommendations on dam design regarding seismicity. Because the seismic history in the Nam Theun 2 Project area is not completely documented, conservative values were developed for some of the assessments.

The Maximum Credible Earthquake (MCE) was selected as the seismic event for use in design studies. The MCE is defined as the largest reasonably conceivable earthquake that appears possible along a recognized fault or within a geographically defined area under the presently known or presumed tectonic framework.

Based on a review of available references (listed in Annex A), including catalogs of historical earthquakes, specific potentially active faults and definable source-zones in the region were identified and an MCE was assigned to each of these structures. The ground shaking produced at the site by each of these MCEs was estimated and compared to the site effects caused by the other MCEs. The critical MCE was selected to be the one that was expected to cause the most severe shaking at the site, based on these comparative studies. In this manner, the critical earthquake event was identified as a magnitude 5.3 event occurring in the site area source-zone, directly under the site at a depth of 13 km.

A specific site response spectra was developed from the critical MCE described in the above paragraph. The data are plotted as Pseudo-acceleration versus frequency in Hz. The results showed that for 5percent damping (a normal value being used in current seismic engineering practice), the site specific response spectrum for horizontal motion plotted slightly below the target curve in which the spectrum is anchored at 0.15 g at 25 Hz and above and peaks at 0.42g between 4 and 5 Hz (a period of 0.2 to 0.25 seconds). Vertical motion was estimated at 2/3 of horizontal; accordingly the target spectrum was anchored at 0.1g .

The seismotectoninc study and site dependent spectrum calculations associated with the critical MCE did not indicate the possibility of any damage to the dam or associated structures.

5.2.2 Reservoir Induced Seismicity

The risk of reservoir induced seismicity must also be considered. A synthesis of worldwide available data on this topic in 1991 showed that this risk is generally associated with the combined effects of a large reservoir (over 1 x 10^9 m^3) and a high dam (over 100m). Experts agree that reservoir impoundment alters the stress regime within the crust by increasing the shear stress due to the weight of the water and reducing the shear strength by increasing pore-water pressure. Further, it is agreed that these changes are not sufficient in themselves to create failure in unfractured rock. It is possible, however, that faulted rock with a high ambient stress level may be brought to slippage by the additional effects of reservoir impoundment.

Although the maximum reservoir volume of 3.18 x 10^9 m^3 exceeds the volume criteria mentioned in the paragraph above, its average depth is only 7.1m due to a surface area of 450 sqkm and active storage volume is 2.7 x 10^9 m^3 with an operating range of about 10m. The Nakai Dam does not exceed 40m above natural surface with a maximum reservoir depth which is very localized within an initial relatively short gorge interval.

Moreover, a theoretical approach of the mechanical and hydrogeological conditions which would favor reservoir induced seismicity showed that the most susceptible sites are those under an extensive tectonic regime and with vertical stress exceeding the maximum horizontal stress.

In the Nakai Plateau area, it is likely that the maximum stress component is approximately horizontal, close to a north-south strike. The general site areas has a notable lack of faults (See Section 5.2.3) upon which induced movements could occur.

In view of the above discussion it can be said that the probability of reservoir induced earthquake can be considered as low, and no significant impacts are expected from the reservoir loads.

5.2.3 Potential Local Faults

A regional study based on satellite imagery shows that the folded structures forming the Nakai syncline are repeated in the older underlying sedimentary rocks, including permo-carboniferous limestones.

The Nam Nhuong (= Nam Gnouang) fault, which exists very close to the dam site (Roberts, 96), is part of a series of faults paralleling the Red River Fault which run through Central and Southern Laos. These run in a NW-SE direction on each side of the Nam Theun reservoir. The main faults in this series are outside the proposed NT2 reservoir area. No evidence of recent activity has been observed along these faults (EdF, 1996-97). They do not pose any threat to the stability of the area.

Several lineaments trending approximately N 140 E were observed and two of which were interpreted as faults, in the vicinity of the Nam Kathang and the edge of the reservoir basin . The lineaments were investigated by a drill-hole (DD6) which did not indicate a measurable displacement on either side. The splayed fault above the Nam Kathang basin which cuts across the tunnel alignment was studied in the 1995 investigation. It was determined to represent a rapid transition of bedding orientation from the tabular structure of the Nakai Plateau to the steep structure of the Nam Kathang rim. The transition does not represent faulting which was later confirmed by a bore hole across the interpreted fault location which found only a few bedding shears zones of 2 to 20 cm thick.

The scarcity of such major discontinuities is confirmed by the field observations of very large and extensive outcrops of the Phra-Wihan sandstones without any such features. This can be explained by the large thickness of Mesozoic sediments (up to at least 2,000m) and their partially plastic lithology (mudstone + siltstone).

No known or interpreted faults or lineaments which have been identified from the investigations undertaken for the Project, have significant impacts.

5.2.4 Reservoir Water Tightness

The geological factors representing potential leakage of the reservoir (pool El. 538) are:

A. Hydraulic relationship between the surface and the underlying permo-carboniferous limestones. Direct connection by outcrops of permo-carboniferous formations through the Jurassic and Cretaceous formations. Hydraulic links along major discontinuities such as faults.

B. The local narrowness of the lip separating the Nakai basin and the Nam Malou basin from the adjacent lower catchment basins of the Nam Hinboun and Nam Kathang Valleys, with local passes (topographical lows) the elevation of which require the construction of complementary little dams.

C. The unfavorable groundwater table and permeability conditions within the Nakai Dam right abutment, as the first investigations showed a relatively flat water-table and high values of Lugeon tests.

These different factors are addressed below.

5.2.4.1 Relationship Between the Reservoir and the Underlying Limestones

As stated in Section 5.2.3 above, the geological layers forming the base of the reservoir are folded in a large syncline formed by a series of sandstones, siltstones and mudstones of Jurassic and cretaceous age, over an important thickness; about 2,000m over most of the reservoir area and at least 1,100 m from the dam to 2km upstream and including the connection between the Nam Malou sub-basin and the Nakai basin.

Within these series, some of the layers (mainly siltstones and mudstones), can be guaranteed as watertight. The powerhouse and pressure tunnel exploratory adit was excavated a total distance of 566m into the Plateau massif near the tunnel alignment including a 215m branch along the powerhouse axis. The maximum single water inflow was estimated to be 0.1 l/s at about 490 m into the massif. Other inflows are only drips, all occurring in the more fractured areas. Although these were measured at the end of the dry season, the seasonal ground water variation is insignificant when compared to the depth of the adit below the water table. These water arrivals indicate an extremely low rock mass seepage rate and extremely water tight conditions of the rock formations which were 85percent sandstone in the 200m interval of the maximum inflow location.

Therefore the potential for hydraulic connections between the reservoir and the underlying Permo-Carboniferous limestone can rely only :

- on the existence of limestone pinnacles which would cut through the Jurassico-cretaceous overburden and could so constitute drains (worst scenario imagined in early reports: SMEC 1984, Ewert 1988), or,

- on permeable faults across the overburden.

A. From the study of the geological map drawn by SMEC, it is evident that the existence of limestones under the whole reservoir is not reasonable. On the contrary, for a great part of it, it was demonstrated that the Jurassico-Cretaeous series lie directly on the basement or on devonian series with a stratigraphic unconformity. The Devonian series is similarly impervious. This observation reduces the potential leakage factor to limited areas, mainly in the western and southwestern part of the reservoir.

B. From the examination of the karstic regions surrounding the Project (Thakhek region), it can be observed that the maximum height of the remaining pinnacles is about 400 m. If one imagines an ante-Jurassic topography on the reservoir site, with pinnacles even higher than present ones, it is unlikely that the peaks belonging to the karstic paleorelief could be high enough to cut through the whole thickness. It can be estimated that, in this southwest part of the reservoir, they are covered with up to 1,000m of watertight formations.

C. During the beginning of the Jurassic sedimentation, all the remnant karstic features which would affect the Permo-Carboniferous limestones would have been sealed with Mesozoic clay-rich sediments: there is more than 60m of marine calcareous mudstone at the base of the Phu Kradung formation near Ban Gnommalat where it overlays the limestone. Moreover, observations made close to this village show that the basis or Jurassic sediments

contains cherts showing that the Jurassic transgression reworked the top of the paleotopography, probably resulting in a removal of the karstic limestones.

D. The hypothesis of the existence of regional fractures crossing the whole Mesozoic series has also been studied. Of the few local inferred faults, the one with any potential to directly affect the Project was investigated and the only discontinuities found were bedding shears on the order of tens of cm. The apparent surficial feature expression constituted a transition of the Mesozoic series bedding from tabular to near vertical. These were discussed in Section 5.2.3 on Potential Local Faults

In conclusion, potential leakage of the reservoir toward some underlying limestones, can be discarded, and thus does not pose the possibility of any impact. No further investigation is required for this concern.

5.2.4.2 Watertightness Between the Reservoir and the Adjoining Catchments

This question is a classical one to be examined when a reservoir level reaches or slightly exceeds the elevation of the watershed with adjacent catchments.

Investigations indicate that piezometric levels (drill holes DD4 and DD9, respectively) (natural water-table) found during the dry season is close to the future Normal Supply Level or a little higher (534.5 and 541), respectively. Test pits and borings at several locations requiring saddle dams indicate that foundations and abutments consist of clayey soils and are underlain by mudstones and siltstones all of which are relatively impervious. The embankments themselves will consist of a homogeneous section of similar impervious materials.

So, it is anticipated that there will be no significant leakage from the reservoir in these areas, thereby minimising the possibility of any impact.

5.2.4.3 Unfavorable Groundwater and Permeability Conditions in the Nakai Dam Right Abutment

An initial concern regarding a depressed water table and high permeability in the right abutment massif and adjacent saddle has been resolved. A more detailed investigation with specific piezometer installations indicated that the dry season water table in the area of the right abutment massif exceeded that of the future reservoir level and had relatively low Lugeon values. The adjacent narrow saddle area (the thin area of the horseshoe bend in the river and beyond the right abutment massif) has a maximum groundwater elevation 8 m below future reservoir level and average Lugeon values of 3.6 l/m/min. This is not an unusual condition and does not pose any construction or operational problems. It can be remedied effectively with adequate conventional treatment to assure seepage control in this area.

5.2.5 Relationship of the Reservoir With Underlying Evaporites

In previous studies, some authors cite the possible existence of evaporitic layers within the Mesozoic formations. The field investigations confirmed by regional geological studies showed that this hypothesis can be discarded.

The only evaporitic layers existing in the bedrock of the reservoir are in the Maha Sarakhan formation. This formation extends over a limited area (up to 6km x 38km) and is totally geometrically contained within the upper Khok Kruat formation which is rich in fine, impervious sediments (mudstones). It is without any hydraulic link with any other underlying formation or with formations outside the reservoir or its catchment.

Therefore, this formation poses no problem of watertightness of the reservoir. Nevertheless, as it contains soluble rocks, the possible consequences on the salt content of the reservoir water in the future or on reservoir floor behaviour under the effects of the dissolution were examined.

This formation was investigated by 6 boreholes in order to establish its stratigraphy and to compare it with a well known similar formation in northern Thailand.

The stratigraphy can be summarized as follows:

- Clay occasionally varved, containing salt crystals and gypsum nodules
  maximum thickness: 92.5m (boring DD1)
  minimum thickness: 9.5m (borings DD2 and DD3)

- Evaporitic layer
  1.5m gypsum (DD3)
  92m (DD1), including:
    4 m gypsiferous bed at the top
    85 m halite (NaCl) with flow texture
    3 m gypsum-anhydrite at the base

Gypsum anhydrite does not pose any potential risks of acidification, if anything the water pressure will take it into the lower layers of soil and rock and if any quantity does get dissolved it will be quickly diluted. The Project water quality monitoring program as described in Annex E will periodically monitor the pH levels in the reservoir.

In summary, the only borehole where an important thickness of soluble rocks was found is DD1 where it probably corresponds to a salt pillow or ridge.

Elsewhere (boreholes DD3, DD5, DD7), the salt bed has most likely been removed by dissolution, leaving the less soluble remnant gypsum-anhydrite.

In DD5, the gypsum bed (from 22 m to 25.5 m deep) contained saline artesian water.

An outcrop of crystalline gypsum with clay veins characteristic of a caprock (less soluble residuum after the halite was dissolved) was noted on the left bank of the river, 7 km upstream of Ban Signo Bridge, reflecting the fact that the underlying salt (halite), if it remains, is situated immediately below this caprock.

The sensitivity of the halite to migration by flowing and to dissolution explains the existence of the main depressions observed in some parts of the reservoir central area:

- Nong Niam: Dissolution Observed in DD5

- Nong Boto: Dissolution Observed in DD7

The origin of the Nong Boua large depression (DD1 and DD2) is not as clear. Radiocarbon dating of the thick alluvium (56 m, which corresponds to 40 m lower than the present alluvium bed level of the Nam Theun) overlying the salt, shows that the subsidence was gradual from Pleistocene (40 m in 40,000 years or 1mm/year).

In conclusion, this study shows that even if it has no direct incidence on the watertightness of the reservoir, the dissolution of the halite contained in this formation (which has occurred

gradually since pleistocene ages) will continue, probably with a low rate as it is more or less protected at its top by clayey sediments (Cf artesian flow from boring DD5).

While dissolution can be expected to continue there is no reason that the rate of dissolution will greatly increase after the filling of the reservoir, provided soluble rocks, currently covered with impervious material do not become exposed during construction, as these formations are already under the water table and have been in the past under lacustrian conditions as evidenced by varved clays. Moreover, the rate of dissolution is not such as to make the reservoir saline.

The headwater channel excavation will be monitored so that any soluble rocks exposed during construction can be identified, overexcavated and covered as necessary with impervious material to minimize any potential changes to the current global dissolution rate within the reservoir area.

Nonetheless, baseline water salinity will be established and reservoir water salinity monitored through conductivity measurements as part of the project water quality monitoring program as detailed in Annex E .

With the above mitigation activities carried out as necessary there would be no change to the reservoir's salinity

5.2.6 Nakai Plateau Massif In Situ Stress Condition

Hydrofracture testing of pre-existing fractures was performed in three inclined borings drilled from the exploratory adit to determine the in-situ stress conditions of the rock mass. These measurements were performed to verify that the internal water pressure at the termination of the steel lined tunnel section will not exceed the minimum stress in the surrounding rock thus risking hydrofracturing the massif. As a minimum such an event would cause excessive unacceptable seepage losses from the tunnel, requiring extensive work and on occasion has caused a failure of the works.

The test location was at the upstream end of the adit (about 545m from the adit portal and 150m upstream of the powerhouse) towards the previously proposed location of the end of the steel lined section. Results indicated that the minimum rock stress would be significantly exceeded at this location for a concrete lined tunnel. The steel lined tunnel segment was increased by about 400 m to a point where the rock stress has a sufficient factor of safety to accommodate the resultant internal water pressure from a concrete lined tunnel. The precise location of the end of the steel lined tunnel segment will be verified by future in-situ stress measurements during pressure tunnel excavation.

The current design proposal should ensure that hydrofracture does not occur.

5.3 Impacts on Climate

5.3.1 Potential Micro-climatic Changes

The great lakes of the world have a dramatic influence on the climate surrounding them, providing heat when it is cold and coolness when it is hot. Lee shores have different climates than upwind shores. Precipitation patterns are different over the lake and onshore. The temperate climate Lake Michigan (43°N latitude) and the tropical Lake Victoria (2°S latitude) are two such examples; however, their effects are due in the most part to their great size; Lake Michigan has a surface area of 58,000sqkm, and Victoria 69,500sqkm.

The replacement of 450sqkm of mainly forested and some seasonally flooded land with the NT2 reservoir will result in some changes to the air temperature and relative humidity over the water and around the shore. Any changes will be modest in comparison to the influence of the great lakes noted above on their adjacent land climates.

The major determinant of the temperature of the water in the reservoir, is the inflows from tributaries and, to a much lesser extent, the rainfall on the reservoir. Together, these bring 7.4 km^3 of water to a reservoir that can hold not even half that amount. Thus, the temperature of the rainfall accompanying the SW monsoon is the chief factor for the summer season. In the winter, with its NE monsoon, there is very little rainfall so radiation to and from the body of water becomes the ingredient for change. In addition, the volume and surface area of the reservoir will change greatly from summer to winter affecting the degree to which any micro-climate influence may exist.

The assessment of available data and results for macro-climatic changes analysis are presented in Annex F.

Some potential exists for the reservoir to change the rates and intensity of occurrence of haze, fog, increased downslope winds, and cloud base creation or suppression. The magnitude of the changes will be small and not particularly noticeable because of the comparatively small forces created by the reservoir in relation to the dominant impacts of the seasonal monsoons. It should also be noted that the NT2 reservoir when full will occupy 40% of the area of the Nakai Plateau and will shrink annually to about 15% of the plateau. The plateau forest will still influence the local climate, at times almost exclusively. The SW monsoon overpowers what could be locally caused climate variations by its persistence and by the 2,000 to 3,000 mm of rain it brings to the catchment in a little over five months. The body of water will moderate the daily air temperature and relative humidity around its shores. On a seasonal basis, the water and air temperature will rarely differ more than 2°C. Tropical lakes do not differ much in temperature and humidity from the forests they displace. Furthermore, any change to the local climate is not likely detrimental to its environment.

In summary only minor microclimatic changes, if any, are expected as a result of the project.

5.3.2 Greenhouse Gas Emissions

The impact of the NT2 Project on greenhouse gases emissions is discussed in detail in Section 5.24, Global Warming.

5.4 IMPACTS ON HYDROLOGY

The creation of the large reservoir on the Nakai Plateau and the diversion of 6.7 km^3 of water per year from the Nam Theun to the Xe Bang Fai are major changes to the hydrologic and river regimes of the two rivers. These impacts are addressed by region: Nakai Plateau (ESA Zone 1), Downstream from the Dam (Zone 4), Gnommalat Plain (Zones 7, 8 and 9), Xe Bang Fai (Zones 10, 11 and 12), and Mekong River (Zone 15). The magnitude of the changes in hydrologic regime have been assessed in reservoir simulations studies and are based on the following operating criteria :

- 2 m^3/sec of riparian flow
- 3 turbines operating until reservoir levels reach 528 masl
- 2 turbines operating between 528 masl and 527.5 masl
- 1 turbine operating from 527.5 masl and ceasing at 527 masl

The same simulated hydrology is used for water quality modelling. The unregulated streamflow record for the damsite from June 1953 to December 1995 was employed. This covers 43 wet seasons and 42 complete years of monthly flow. The maximum turbined flow was taken as a nominal 210 m^3/s. The natural flows at all sites on the Nam Theun and Nam Kading Rivers are determined from the Ban Signo record by ratio of catchment area

There is some uncertainty regarding the capacity of the reservoir. The difficulty arises in establishing the vertical control for aerial photographs over the reservoir area. Three capacities have been established; the largest possible, the most probable, and the minimum considered possible. The simulated operations calculated for the assessment have adopted the minimum considered possible.

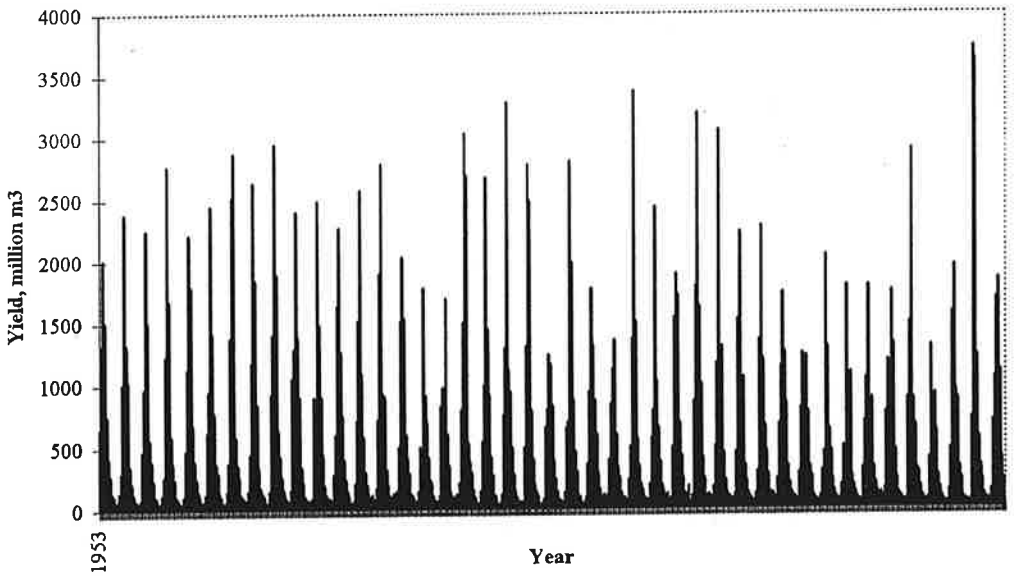
5.4.1 Nakai Plateau (Zones1 and 3)

5.4.1.1 Annual Flows

The water yield from the catchment upstream from the Dam will be slightly modified by the existence of the reservoir. The evaporation from the reservoir surface will be at dry-season more than the evapotranspiration from the land it has submerged, and during the wet season it will be less. In addition, the inundated area will change from a maximum of 450 sqkm to a minimum of 164 sqkm in some years. The amount of evapotranspiration from the 286 sqkm which becomes exposed by reservoir drawdown is not completely established. On the basis of information collected at the Nam Ngum reservoir and with Vientiane pan evaporation data, it was estimated that there will be an increase in water yield of 50 to 100 million m^3/year at Nam Theun; that is, 0.6 to 1.4 percent. Then, for the catchment and the reservoir, the yearly average water yield may increase to 7,460 million m^3.

Monthly inflow to the Nam Theun Reservoir for the period of simulation is shown below.

Catchment and Reservoir Yield



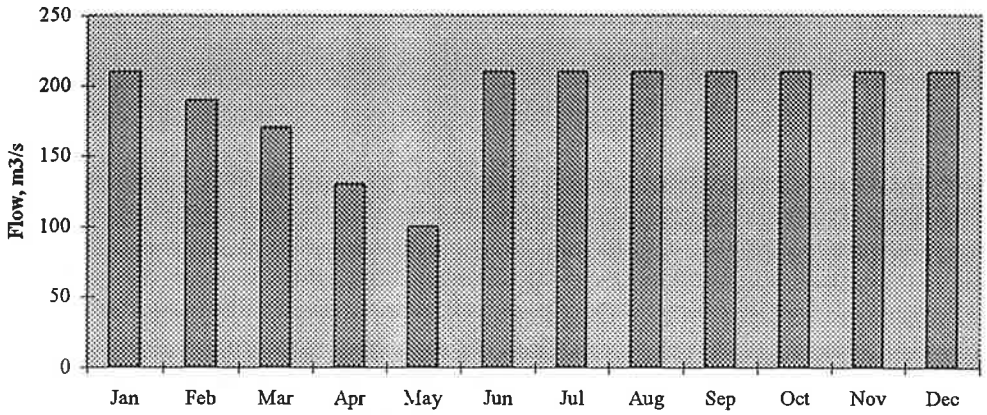
With a plant capacity of 681MW a maximum of 6,620 million m^3/year will be diverted from the reservoir to the powerplant and beyond to the Xe Bang Fai River.

5.4.1.2 Monthly Flows

Based on 43 years of records, turbined flows were simulated to obtain the discharges from the powerhouse into the Nam Phit in Xe Bang Fai river.

Mean monthly turbined flows from the reservoir to the Xe Bang Fai are indicated below (under revision).

Turbined Flows



The reservoir fills 36 of the 43 years of simulation. Once filled, the excess water must be passed through the spillway to the Nam Theun River downstream from the dam. There are no spills from December through June, and in all years but two, there is spill in the month of September. The simulations show the following :

Spillway use in the wet season months.

Month	Number of Years of Spills	Maximum Spillway Flows m^3/s/month	Average Flow in Years of Spill m^3/s/month
Jul	1	310	310
Aug	22	1150	302
Sep	34	906	332
Oct	35	290	96
Nov	1	27	27

All months not listed have no spills.

Throughout the year, the level of the reservoir water surface will vary as much as 10 m.

5.4.1.3 Flow Patterns

The flow patterns in the reservoir were initially estimated on the basis of a compartmentalisation of the reservoir into sections based on morphology. These are the upstream and the downstream part separated by a narrow neck at Ban Signo. The intake will be in the upstream part, and the spillway discharge and riparian releases will be from the downstream part. The findings were:

- In June, the inflow into the upstream part is a mixture of mostly water from tributaries and a little water from the downstream part. The water arriving in the downstream part is only recent inflow. Reservoir contents are increasing.

- From August to October, the upstream part of the reservoir is filled only by recent inflow, and the downstream part is filled by water from the upstream part and recent inflow from the local tributaries. Reservoir contents are increasing.

- From November to May, inflow is very low and the plant runs on water stored in both parts in the previous months.

The more recent and elaborate mathematical modelling undertaken by the Centre for Water Resources of Western Australia (CWR), Imberger et al. (1997) has recently been completed. The details on anticipated reservoir hydrodynamics determined by new mathematical modelling is presented in the Water Quality section as it is the concentrations of substances in the water leaving the reservoir and its affect on downstream aquatic life and human use that is of interest. As far as the turbines are concerned, the quality of water is not an issue, unless the pH is far from neutral, which the CWR studies show not to be the case.

5.4.2 Nam Theun River below Dam (Zones 4 and 5)

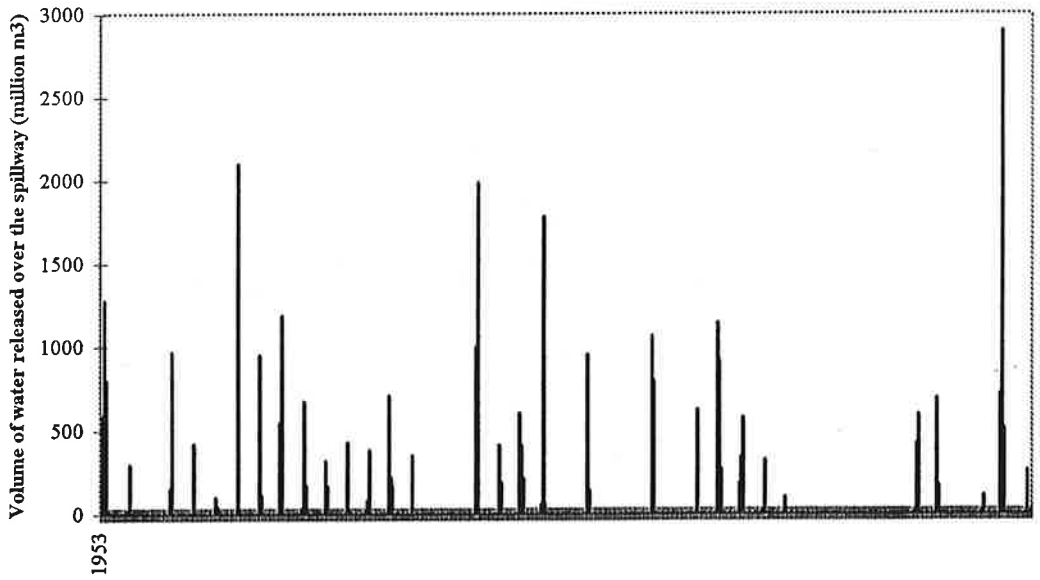
5.4.2.1 Annual Flow

The anticipated annual amount of spillage from the Nam Theun 2 reservoir to the river downstream is 745 million m^3, equivalent to an annual rate of 23 m^3/s. In 16 percent of the years, there is no spill, when the only flow will be the riparian release. The mean annual flow in the Nam Theun River immediately below the damsite will be reduced to 38 percent of its former level.

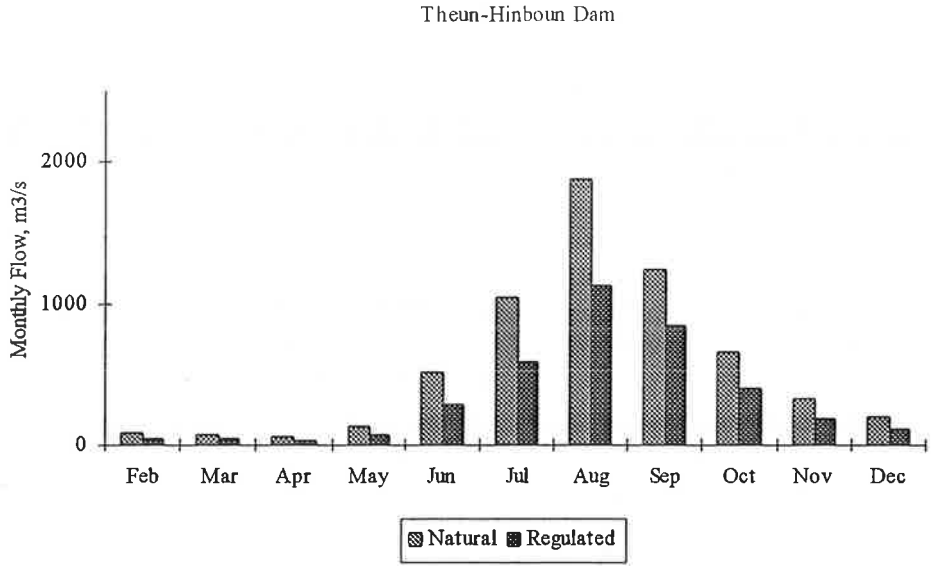
5.4.2.2 Monthly Flow

The mean monthly flows immediately downstream from the dam are shown below.

Magnitude of spills with NT2

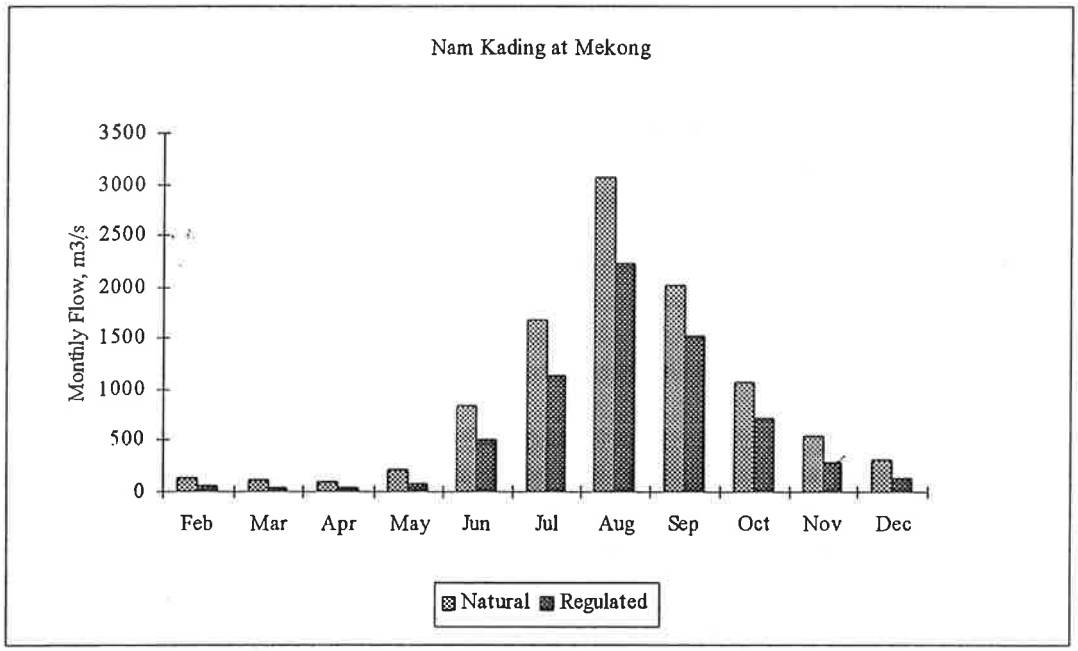


Flows at the Theun-Hinboun dam are likewise affected but to a lesser degree because of the moderating effect of the two large tributaries, Nam Phao and Nam Gnouang. Because the Theun-Hinboun flows had been estimated on the basis that the runoff (in mm) is the same as at Ban Signo, the annual flow is reduced to 59 percent of its unregulated flow.



Both regulated and natural flows in the Nam Kading at its confluence with the Mekong are small during the dry months. The greatest effects of the two trans-basin diversions are seen in the wet season when the runoff is being diverted at the Theun-Hinboun dam and stored and diverted at Nam Theun 2.

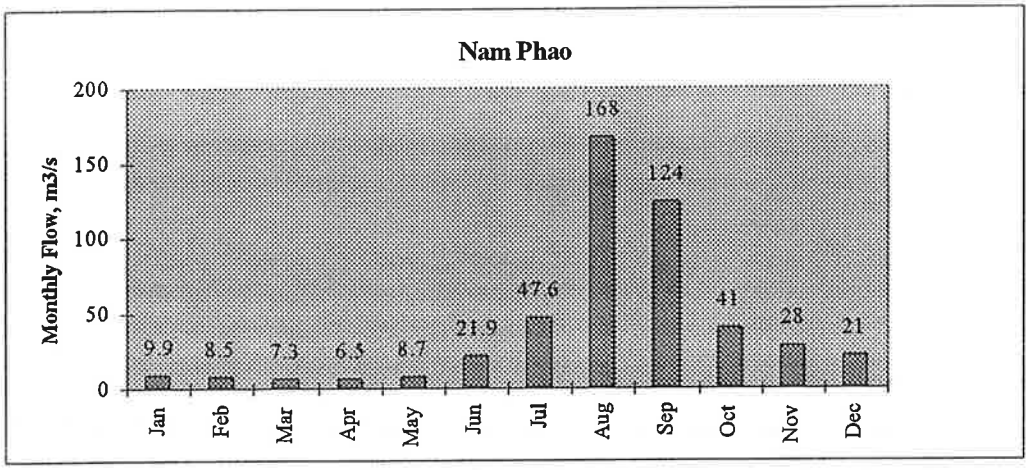
Natural and Projects regulated flows in Nam Kading at the Mekong



5.4.2.3 Low Flow

In the 12-km reach of Nam Theun between the dam reach and the Nam Phao, the stream will be primarily dependent on riparian releases at the dam for its streamflow during the dry season. Spillway releases occur in only 93 of the 511 months of simulated reservoir operation, and this 18percent of the time is mainly during the months of August, September, and October during, the wet season. The local tributaries in this reach are very small because the small contributing catchment area is only approximately 56 sqkm. Inflow in March and April is extended to be a maximum of 0.3 m^3/s and during August, an average of 10 m^3/s of local inflow can be expected.

At the Nam Phao confluence, the Nam Theun picks up contributions as listed below. During March and April, the flow in the Nam Theun downstream of the Nam Phao will be on the order of 7 m^3/s plus the minimum guaranteed release, of 2 cum./sec to the headwaters of the Theun-Hinboun reservoir. Here, flows are diverted out of the Nam Theun basin through the powerhouse into the Hinboun Basin.



Downstream from the Theun-Hinboun Dam, the Nam Theun becomes the Nam Kading. The low flow in this reach will be that amount passed through the Theun Hinboun dam and the amount picked up from local tributaries which have a combined catchment area of 5,713 sqkm. The Theun Hinboun Dam Project has agreed to a minimum release of 5 cum/sec into the Nam Kading. The contributing tributaries will add substantially to this. For the month of April, the average regulated flow in the Kading at its confluence with the Mekong is estimated at 42 cum./sec.

The impacts from the reduced flows in the Nam Theun between the damsite and the Theun Hinboun dam are limited to impacts on riparian vegetation and wildlife. There were no permanent residents on this reach of the river and there are no impacts on human related activities.

5.4.2.4 Floods

The Nam Theun reservoir will have a profound effect on floods, restraining them in 7 of the 43 years simulated and attenuating them in some other years. The peaks will be much less. However, the "big" flood will still be possible as can be seen for August 1994, from the Annex G. The reservoir has been filled in July so all of the runoff, except what the powerplant can use, for the wettest month of August must be passed through the spillway. That is 2,900 million m^3, or 80 percent of the August inflow. The other year presenting the same flooding opportunity (the reservoir filled July) is 1953. Most of the downstream floods will come in September because the reservoir is completely filled in August in one-third of the years and monsoon rainfall is still high in September.

Monthly simulation gives the correct view of the change in the frequency of occurrence of flooding but the magnitude must be undertaken on an hourly or daily time frame. The simulations for the period 1986-1995 was undertaken by SMEC in 1996 for the 681 MW plant using a maximum flow of 210 m^3/s. The regulated flood peaks are only half those of the unregulated river.

5.4.2.5 Effect of Nam Theun 2 regulation on maximum daily flood peaks.

Floods at the Theun-Hinboun Dam will be affected to a lesser degree than at the NT2 Dam because the large tributaries, Nam Phao and Nam Gnouang, add in their considerable

influence. For the same 10-year record, Theun-Hinboun floods were reduced by about one-third that of their unregulated peaks.

Month	Peak Inflow m^3/s	Peak Outflow m^3/s
NT2 Dam		
August	2,675	1,266
September	2,122	906
Theun-Hinboun		
July	5,947	4,099
August	5,958	4,194
September	4,789	2,571

Flooding will be reduced though it is not a significant problem currently for the population living on Nam Theun/Nam Kading.

5.4.3 Gnommalat Plain (Zones 7, 8 and 9)

The NT2 power plant is in the escarpment base at the edge of the Gnommalat Plain. The 210 m^3/s maximum flow from the power plant will discharge from the Tailrace Tunnel into the reconstructed Nam Kathang Noi and then to the Regulating pond. This Tailrace Channel will still carry the Kathang Noi waters (it is designed to carry 210 m^3/s plus the 2-year flood) and will be connected to the new Kathang bypass channel at the head of the Regulating pond. See Figure 3-5.

Created by a weir, the function of the Regulating Pond is to dampen the flow variations during the startup of the turbine. This reduces the rate of change of the flow and water level in the Downstream Channel. To keep the flows separate, the Nam Kathang flow will be carried around the pond in an excavated channel designed for up to the 2-year flood. Larger floods will utilise in part the pond for passage as well. Over time, the excavated bypass channel will take on some of the appearances of the original river in this area. Gravel and cobbles will become deposited and riparian vegetation (willows) will establish a shadier bankline.

During the dry season, the Nam Kathang will be supplied with some turbined water to the degree that this water will enhance the environmental, social, and economic features of the Nam Kathang. This amount is to be determined by requirements and requests from the local population and by monitoring for water quality and river response to changes in low flow.

The turbined flow will be carried from the Regulating Pond to the Xe Bang Fai in the excavated Downstream Channel, designed to carry the local 2-year flood plus the 210 m^3/s without freeboard. For larger floods, the water will spread out and flow towards the river as before. The water to be taken for agriculture and other purposes is discussed later in this chapter. The effect of aeration sills to increase the oxygen content of the turbined water if not already saturated, is discussed in the Water Quality section which follows.

The beneficial effects of the water in the Downstream Channel include raise of the groundwater table about one to two meters in the vicinity of the channel. To the east, this seepage will join the regional groundwater flow to the rivers in that direction. To the west, the groundwater must travel in the same direction as the channel. Local dry-season ponds will have more water than before. Some local depressions will become wetlands. The water level in all the wells will rise and improve water availability in the local villages.

5.4.4 Upper Xe Bang Fai (Zone 10)

The Downstream Channel follows the course of the Nam Phit to its junction with the Xe Bang Fai, approximately 10 km upstream from Mahaxai. The effects of addition of the nearly continuous turbined flow of 210 m^3/s to this river are numerous (SMEC 1996). On the basis of data from the stream gauging station at Mahaxai and the 1996 SMEC Report, impacts can be estimated.

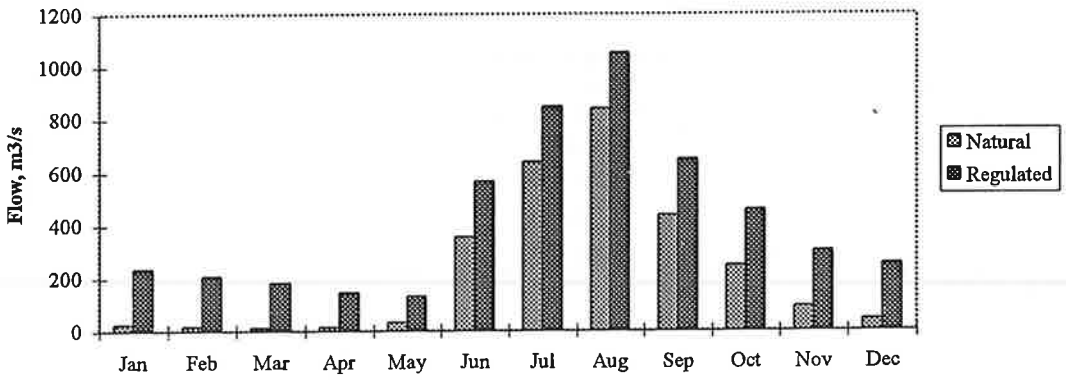
5.4.4.1 Annual Flow

The turbined water will almost double the annual volume of water flowing in the Xe Bang Fai at Mahaxai from 7,290 million cum. to 13,910 million cum.

5.4.4.2 Low Flow

During the low flow periods of the years the addition of 210 cum./sec to the average flows of between 3 and 60 cum./sec will have very significant impacts. For example, the lowest discharge in the 10-year stream guage record at Mahaxai was 3 cum./sec. This could increase to 213 m3/sec with full power plant production. The corresponding increase in river water level will be approximately 3.5m.

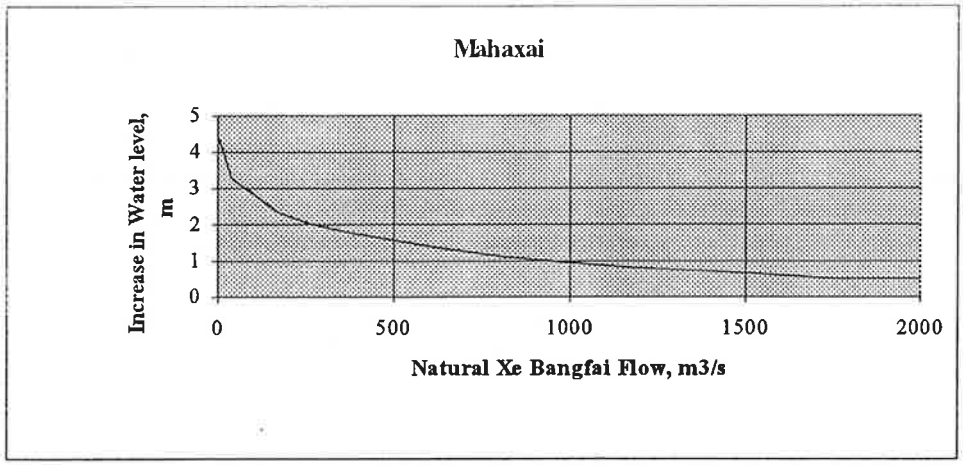
Natural and Regulated Flow at Mahaxai



5.4.4.3 River Level

If the additional 210 cum./sec were to be added to a very low natural flow at Mahaxai, it would cause the water level to rise greatly, approximately 3.5m higher if the natural flow is 5 cum./sec. As the natural flow increases in the wet season, the effects of the turbined flow become less. When the natural flow and turbined flow sum to the bankfull discharge (2,000 m^3/s), the increase is approximately 50cm.

There are significant impacts on the ability of the local population to cross the river in the dry season caused by the addition of the turbined flows.



If it is assumed that water could never spill from or enter the Xe Bang Fai channel and the Downstream Channel, the straight line extrapolation of the graph above indicates that the increase for higher flows would be approximately 50 cm. In the real case however both the river and the Channel will spill water onto their floodplain, decreasing the water levels. If it is assumed that the Downstream Channel discharges some of its water in the Xe Bang Fai and the rest flows downstream on the Xe Bang Fai floodplain next to the channel, SMEC's overbank rating curve gives this lesser increase as follows:

Increase in flood stage at Mahaxai caused by turbined flows.

Return Period years	Natural Flood Peak (m^3/sec)	Natural Stage (m)	Increased Stage Due to Project (cm)
2	2,070	15.00	50
5	2,410	15.80	43
10	2,610	16.60	37

(SMEC, 1996)

Duration of Flooding

The addition of turbined flow to the Xe Bang Fai River system will increase the duration of flooding. There are two factors; one has been addressed SMEC (1996). That is the increase in time that the river stage will be above flood level in the main channel itself. This was estimated by adding the turbined discharge to the natural flood hydrograph. The increase is smaller for larger floods.

The increase in water level away from the river and on the floodplains of the tributaries depends on circumstances leading to the flood. Sometimes, the main river may flood when the local tributaries do not. Sometimes all tributary flood water can get directly to the mainstream because the latter is not yet at flood stage. When the mainstream does rise to flood stage, the flow in the tributaries is affected, and they themselves spill. The flooding mainstream causes backwater effects in the tributaries and raises their levels.

The effect of turbined flow on future flood levels in the Xe Bang Fai and on its and tributary floodplains downstream will vary according to circumstances. However, the conclusion can be reached that the turbined flow will increase the flood level in the Xe Bang Fai river at Mahaxai by 50cms for smaller floods and approximately 40cms for floods that overtop the banks of the river.

Increase in duration of overbank stage at Mahaxai due to 210 m^3/s of turbined flow.

Return Period years	Natural Duration of Overbank Flooding (hours)	Increased Duration due to Turbined Flows (hours)
2	-	0
5	63	36
10	93	24

(SMEC, 1996)

The above durations are valid for sites on the Xe Bang Fai floodplain next to the river. They are a good indication of what to expect at the town of Mahaxai. Back from the river on the floodplain, the flood waters drain more slowly. The small drainage systems are not as efficient as large ones, and because the flow is shallow, it moves slowly. As with flooding levels away from the Xe Bang Fai, the duration is difficult to determine. There are different ways that flooding can occur here, so an observation program must be necessarily extended over a suitable number of years to sample all types of events. To compute such phenomena requires topography of the finest detail and at least two different types of events to calibrate. No estimate has been made, but for at least some floods, the flooding duration must be longer than that given for the mainstream.

Bigger floods are less exacerbated by the additional flow than smaller floods. Maximum height increases range on an average from about 40cms for large floods (1m in 10 yrs) to 50cm for smaller floods (1m in 2 yrs). The duration of flooding will be extended as discussed.

The impacts on the hydrology can be summarised as follows : the return period for a given size of natural flood will be essentially halved by the addition of the Nam Theun projects discharge into the Xe Bang Fai. For example, flood studies and surveys undertaken by NTEC indicate that a natural flood with a 5 year return period will inundate 16,000 ha of land in the Xe Bang Fai river valley between the Nam Phit confluence and the Say Phou Xoy gorge. With the 210 m3/sec from NT2 this flood could be expected to occur every 2 to 3 years.

Flooded Area

The large floods (1-5 years and above) in the past have flooded almost all of the lands that can be reached. Any increase in flooding level will not increase significantly the flooded area.

Frequency of Flooding

The turbined flow will increase the frequency of flooding. Natural floods with peak discharges between 1,990 and 2,270 m^3/s did not flood Mahaxai in the past but will with turbined flows. None of these have occurred in the guage history (9 years). For this short period, there are three years in which the Project would have caused more flooding. For the other six years, the turbined flows would not have forced the Xe Bang Fai to spill overbank.

5.4.4.4 Middle Xe Bang Fai (Zone 11)

Approximately 25 kms downstream from Mahaxai, the Xe Bang Fai river passes through a range of limestone mountains. The narrow and steep grade through the rock essentially isolates the Upper Xe bang Fai from the Middle Xe bang Fai.

Low Flow

In the absence of other developments, the low flow in the Xe Bang Fai River at Bridge 13 will increase by the same amount as at Mahaxai. In May this amount is 62 cum./sec on the average. In other low-flow months, the amount will be more.

The low flow in the Xe Bang Fai River at Bridge 13 will increase by a maximum of 210 m^3/s due to the addition of turbined flow. The effects of turbined flow on flooding have been determined by SMEC (1996) in the same manner as for Mahaxai. The findings are also

basically the same; larger depth of flooding, longer duration, area flooded almost unchanged, and flooding more often.

However the increase in the flood level due to the turbined water is predicted to be lower than in the middle reach, at a maximum increase of 30 cm.

With the addition of the turbined water the duration of overbank stage on the river at Bridge 13 will be approximately 30 hours longer than for the natural condition

5.4.4.5 Lower Xe Bang Fai

The flat region downstream from the bridge to the Mekong is normally flooded (without Project) every year due to the influence of the Mekong and the natural flooding of the Xe Bang Fai.

In the 36-year gauge history at Bridge 13, the Xe Bang Fai spilled overbank in 31 years (under natural conditions. With the turbined flow added, this number will increase to 33 years. However, because of the reservoir's flood routing effects onMekong flows, there is a fall of about 15cms in the Mekong during flood events. The net effect for the zone will be that there will be no change in the flood levels as a result of NT2.

5.4.5 Mekong River (Zone 15)

5.4.5.1 Annual Flow

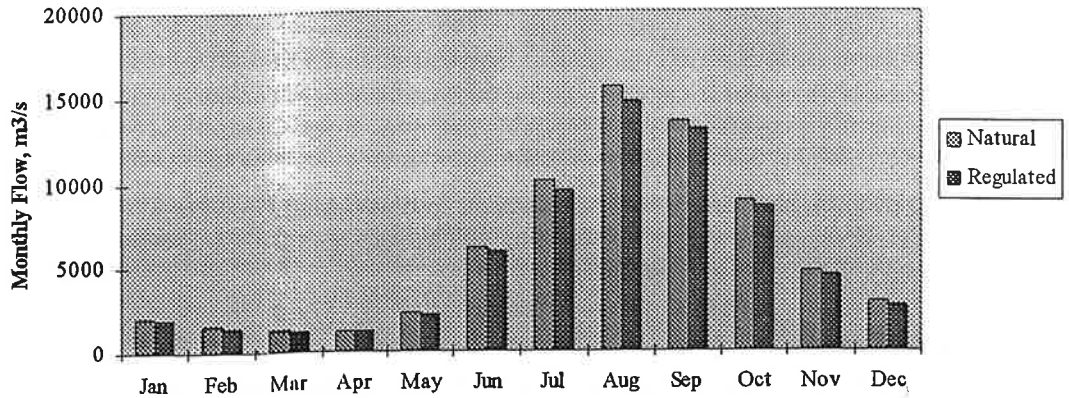
The annual flow in the Mekong river over a distance of 183 river kilometers will be affected by the Project. The Nam Theun 2 Project in conjunction with Theun Hinboun Project will decrease the amount of flow in the Mekong reach from the confluence of the Nam Kading to the confluence with the Hinboun River. The amount of decrease will be essentially the same as the total volume of water diverted for power generation by these hydroelectric plants. From the Hinboun to the Xe Bang Fai confluence with the Mekong, the Nam Theun Project alone will be responsible for the decrease. The NT2 Project will divert 6,700 million cum./year which is extremely small compared to the long term average for this Mekong reach of 185,000 million cum./year. Even when combined with trans-basin diversion of 100 m^3/s from the Nam Theun to the Hinboun, the effect is not significant within the time frame of a year. Unregulated, the Nam Kading contributed about 27,000 million m^3/year to the Mekong. Trans-basin diversion from both Projects will reduce this by 11,000 million m^3/year

Downstream from the Xe Bang Fai confluence, the annual Mekong flow yield will be essentially unchanged. Neither Project has a consumptive use of water that could be detected in the annual flow of the Mekong.

5.4.5.2 Monthly Flow

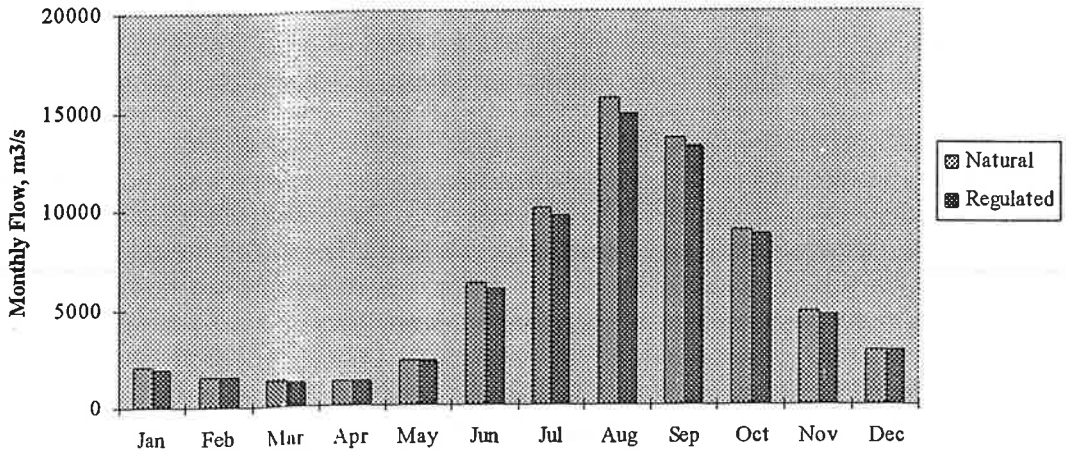
On a monthly basis, the low-flow in the Mekong is slightly affected. The flows in the Mekong at its junction with the Nam Kading before and after both the Nam Theun and Theun-Hinboun diversions are given below. For the driest month, April, there will be a four percent reduction in flow due to the two Projects, at this confluence. There will be significant no impacts because of this small reduction.

Mekong Downstream from Nam Kading



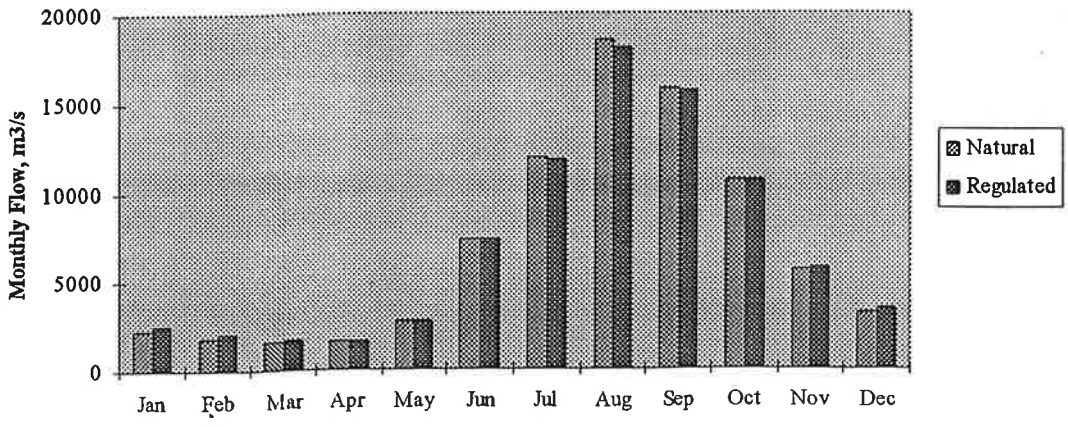
The Hinboun River brings back to the Mekong the Nam Theun water diverted at the Theun-Hinboun dam. This return contribution increases the flows in the Mekong again after they have been reduced in the Nam Kading by both Projects.

Mekong at Nakhon Phanom



Downstream at Mukdahan, the Xe Bang Fai will bring back the turbined flow to the Mekong, increasing slightly the low flows.

Mukdahan



5.4.5.3 Floods

An appreciation of the influence of the Nam Theun reservoir on flooding in the Mekong is obtained by studying the changes caused in maximum daily flow resulting from the operation of NT2. For the simulation period from January 1986 to December 1995, the Mekong daily hydrographs are shown in Figures 5-1 and 5-2. There is a reduction in flood peak for all but one annual peak and reductions for many peaks at Nakhon Phanom (Thakhek). At Mukdahan, four of six peaks are increased by the two Projects, chiefly because of the turbined flow in the Xe Bang Fai. The increase in low flow is also apparent in all years. SMEC (1996) estimated the 2-year flood peak at Thakhek would be reduced 17 cm and also reduced at Mukdahan by about 14 cm. This decrease in wet season flooding will shorten the period of flooding at the Xe Bang Fai confluence i.e. a positive project impact.

5.4.6 Extreme Events

Extreme floods with a frequency of occurrence of 0.01 or less (return period greater than 100 years) will overshadow the regulation effects of the Nam Theun reservoir and the addition of power station releases to the Xe Bang Fai. For example, the natural 100-year flood level at Mahaxai would be increased on the order of 30 cm by the full tribute of turbined flow.Typhoons which come in September and October may occur when the reservoir is already full. Their water will pass though the reservoir and on downstream slightly attenuated, but for practical purposes, essentially unabated. Likewise, the addition of turbined flow to very large floods in the Xe Bang Fai will cause only a small increase in flood level and duration, but because flood damage will be extensive or complete for these large natural floods created by typhoons, there can be very little, if any, increase in damage. The perception of adding water to an already badly flooding river may be different from what an engineering analysis indicates.

Extreme drought events will be an economic risk for energy production and for continued passing of mitigating flows downstream from the reservoir. The power plant cannot generate electricity without risk once the extreme minimum operating level of 527 masl is reached. Riparian releases can be made until the reservoir drops approximately 5m below minimum operating level but this would be done only in extreme circumstances.

5.4.7 Summary

In summary, the Nam Theun 2 Project will have a profound effect on hydrology of the Nam Theun and the Xe Bang Fai, and a very small effect on the Mekong river. In the Nam Theun river downstream from the damsite, all flows-low, intermediate, and flood will be decreased in all or most years to a small fraction of their former values. The impact of the Theun-Hinboun project farther downstream adds to the impact on the Nam Kading river. In the Xe Bang Fai, all flows will be increased significantly, the impact on floods and low flow being the most significant. Because the Mekong river is so large the two trans-basin diversions do not change the Mekong flows directly. The effects of these hydrologic changes on people, their agriculture and infrastructure and fish and wildlife are discussed in the following sections. Recommended mitigation measures are referenced in the relevant sections, and are discussed in Chapter 6.

5.5 Impacts on Water Quality

The water quality characteristics of the Nam Theun 2 Reservoir were simulated using the one-dimensional water quality model (DYRESM-WQ) for averaged long-term predictions of water quality and a two dimensional model (ELMO-WQ) to assess the longitudinal variation in water quality along the reservoir over the critical first few years of operation. The I-D DYRESM - WQ model developed by the Centre for Water Research, University of Western Australia has been previously applied to predict the dynamically behaviour and water quality of many storage in Australia and the world. Both the 1-D and 2-D models simulate the vertical density stratification generated by variations in water temperature and salinity as well as a range of

water quality parameters including dissolved oxygen, algae suspended solids, nutrients and metals.

Calibration of the 1-D model was based on a review of literature describing ecological parameters for tropical and sub-tropical lakes. The ecological parameters derived from calibration of the 1-D model was then adopted in the 2-D model with allowance made for the different model formations. The 1-D model was used to predict the quality of water to be stored in the Nam Theun 2 Reservoir from 2002 (commencement of reservoir inundation) through a period of 3500 days when the reservoir water quality was considered to be independent of initial filling conditions.

5.5.1 Prediction of Reservoir Water Quality (Zone 1)

The water quality characteristics at three points within the reservoir were determined

- turbine offtake RL 523.5 m.
- spillway discharges at the reservoir wall
- minimum guaranteed release from surface waters at the dam wall.

A number of different operating scenarios have been modelled for the NT2 Reservoir. Comparisons of the water quality at the turbine offtake, spills at the dam wall and environmental flows for each of these different offtakes are discussed in Annex H for combinations of :

- 10 year periods of high flow - HP
- 10 year periods of low flow - LP
- three (3) turbines operating -3T
- four (4) turbines operating - 4T
- vegetative biomass within the impounded area (70 tonnes/ha)- A
- vegetative biomass within the impounded area (57 tonnes/ha) -B

Biomass removal rates are represented by likely scenarios estimated by Prosser (1997). The residual above ground biomass in the reservoir will be approximately 70 tonnes/ha by the close of the 1999/2000 logging season (April, 2000) through logging scenarios only. A further reduction to an overall average of about 57 tonnes/ha of residual biomass for the reservoir will occur if effective harvesting of forest resources and present land clearing patterns by local communities continue and proposed clearing of Project workshops occur during construction. Mitigation measures for reservoir biomass clearing, the optimisation of salvage logging, and firewood gathering from the inundation area are discussed in Chapter 6, Section 6.2.2.

The above ground carbon biomass is assumed to be 40percent of residual biomass (French National Scientific Research Centre in Prosser, 1997). The above ground carbon biomass is estimated to be 28 tonnes based on 70 tonnes/ha of biomass by the close of the 1999/2000 logging season. An estimate of below ground carbon biomass was obtained from soil samples. A complete description of the model inputs, scenarios and results are contained in Annex H.

5.5.1.1 70t/Ha Biomass, High Period Flows, and Three Turbine Operations

A summary of water quality characteristics at these sites within the Reservoir is presented below for the scenario - 70t/Ha Biomass, High Period Flows for Three Turbines Operation.

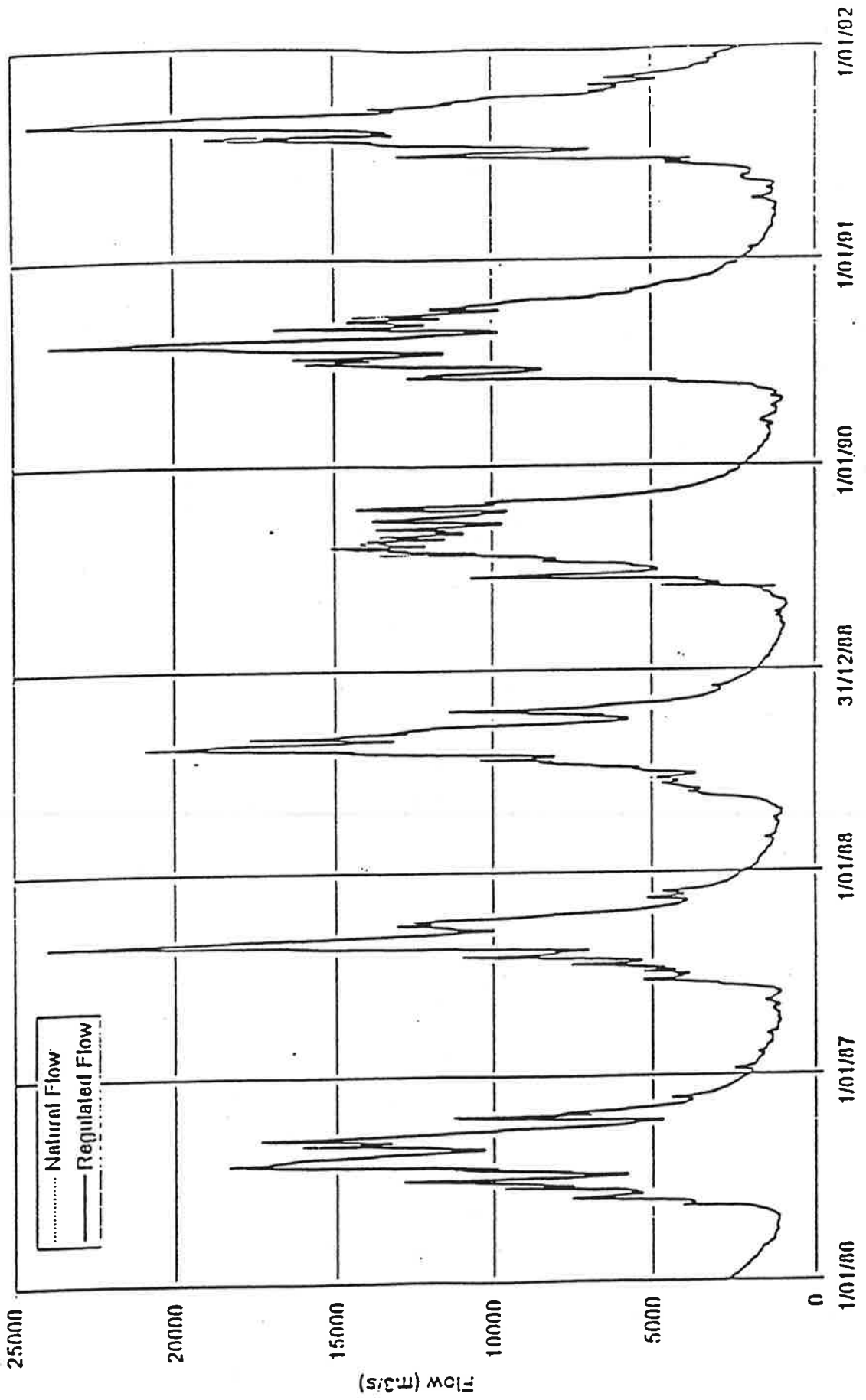


FIGURE 5-1 MEKONG HYDROGRAPH FOR THAKHEK

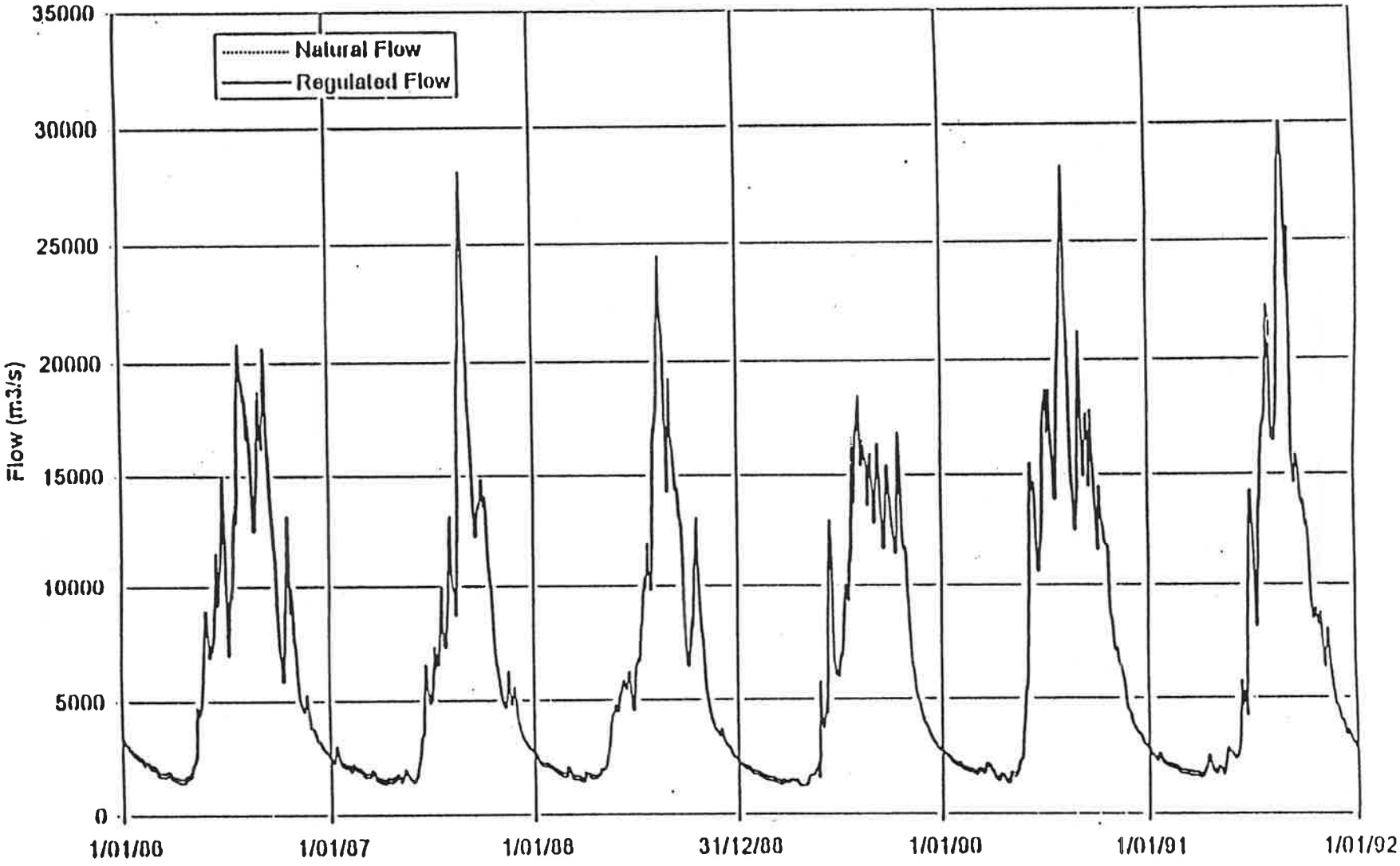


FIGURE 5-2 MEKONG HYDROGRAPH FOR SAVANNAKHET

Turbine Offtake Water Quality Water temperatures during the wet season are as high as 30 deg C, some 12 deg C higher than the dry season water temperature and consistent with observed temperatures in the rivers. The dissolved oxygen concentration of water drawn into the offtake was predicted to be between 5 and 7 mg/l for the first 5 years then increases for the remaining five years. BOD concentrations at the turbine discharge are low; in all cases less than 1 mg/l. Nitrate concentrations are between 80 and 100 µg/l in the wet season, and drop to less than 10 µg/l in the dry season. Ammonia concentrations are highest during the wet season (25 µg/l) before dropping to less than 20 µg/l in the dry season. Total nitrogen concentrations are low (250 µg/l) at the turbine offtake. Dissolved reactive phosphorous (DRP) concentrations (40 µg/l) peak in the second wet season. The average wet season DRP concentrations for years three to ten are less than 20 µg/l. Average concentrations of DRP during the dry season are 10 µg/l or less. More details on nutrient levels analysis and graphs are provided in "Predictions of the Water Quality Characteristics of the Proposed Nam Theun Reservoir System", April 1997. The total phosphorous concentrations vary seasonally from upper values of 75-90 µg/l during the stratified period (wet season) before falling to 50 µg/l in the dry season, with a marked decline over the ten year period. Chlorophyll a, concentrations vary seasonally with maximum concentrations in the wet season of 20 µg/l with average dry season concentrations less than 10 µg/l.

The turbine water is of good quality when released. The organic load is low with high DO concentrations.. Nutrient concentrations will support moderate plant growth in receiving waters.

Water Quality of Dam Spills The reservoir spills periodically. During periods of high flows, the reservoir spills annually, while during periods of low flows, spills will occur only occasionally throughout the 10 year period. Water temperatures will be in the high twenties during both low and high flow periods, and dissolved oxygen concentrations will be between 5 and 8 mg/l. BOD concentrations are low (< 1mg/l) and a reflection of the low phytoplankton numbers and organic matter in dam spills. Nitrate concentrations range in value between 20 and 40 µg/l, and ammonia concentrations are low (<20 µg/l). Total nitrogen values are generally between 150 and 200 µg/l. Initially, DRP concentrations were 20-30 µg/l before decreasing on average to 20 µg/l. These values reflect the very low inflow concentrations of runoff waters into the Reservoir. Total phosphorous concentrations are on average 60 µg/l, and Chlorophyll a concentrations in the dam spills are on average 10 µg/l.

The water quality during dam spills is very good. The characteristics of dam spill water is similar to that of both environmental flow releases and turbine water quality at the offtake.

Environmental Flows Environmental flows or the minimum guaranteed release are of the order of $2m^3/s$ as discussed in Section 5.9.1 and are drawn from surface waters at the dam wall. The water temperature of the environmental flows will vary seasonally from a high of 30 deg C to a low of 18 deg C. These water temperatures are of a similar magnitude to those found in the downstream Nam Theun. Dissolved oxygen concentrations are consistently between 5 and 8 mg/l during both low and high flow periods. BOD concentrations are low (< 1mg/l) and will not exert a significant oxygen demand on the downstream Nam Theun. Nitrate concentrations are in the order of 100 µg/l during the wet season with lesser values expected in the dry season (40 µg/l). Ammonia concentrations are low (max. concentrations of 25 µg/l), and total Nitrogen concentrations show a strong seasonal trend with wet season flows in the order of 250 µg/l and dry season flows markedly less between 20 and 120 µg/l. DRP concentrations are highest in the first dry season peaking at 40 µg/l. A gradual decrease in these concatenations occurs over the next 10 years with concentrations of 20 µg/l found in the discharge waters. Total phosphorous concentrations are higher during the wet season discharges (max. 90 µg/l)

and lower during the dry season (average 50 µg/l). Chlorophyll a concentrations are on average 10 µg/l with short sharp peaks up to 25 µg/l during the wet season. The nutrient concentrations presently in the Nam Theun are similar to the values predicted in the downstream releases from the reservoir (see Chapter 4). Any increase in nutrient concentrations is a natural progression from a free flowing riverine system to a lotic system where there are internal nutrient loadings.

The water quality of the riparian release will be good having low organic loads and high in dissolved oxygen concentrations. Nutrient concentrations will support moderate aquatic plant growth in the downstream Nam Theun.

5.5.1.2 Water Quality Characteristics for Other Operating Scenarios

Turbine Offtake Water Quality For the two scenarios considered the amount of vegetative biomass remaining in the impoundment has little impact on turbine offtake water quality, nor does the use of three or four turbines. The biomass remaining in the reservoir has been estimated with considerable accuracy and both "high" and "low" estimates are quite low compared with many reservoirs that flood tropical forests. For the low flow scenario there are periods under both turbine options of insufficient water for release to the turbines. There are differences in nutrient concentrations between turbine 3 and turbine 4 operation in low flow periods, however these differences are minor. Total Phosphorous (TP) and DRP increase by 10 percent under the higher biomass content. After the first year, nitrate concentrations are similar for both turbine scenarios with markedly higher concentrations in the wet season. Chlorophyll a concentrations tend to be higher in the low flow period for the 10 year period. These concentrations reach a maximum of 20µg/l. There are differences in nutrient concentrations between 3 turbine and 4 turbine operation in low flow periods. These differences are minor throughout the 10 year period. Dissolved oxygen concentrations are less in the first year during the low flow period than during the high flow period. The dissolved oxygen concentration is approximately 3 mg/l during a thirty day stretch in lowest one percent of the reservoir's volume. Total phosphorous concentrations tend to be higher in the high flow period (5-10 µg/l) with concentrations similar in latter years for both periods. Ammonia concentrations are higher in the high flow period (15-20 µg/l) than in the low flow period (10 µg/l) for the first 5 years. Dissolved oxygen concentrations are low in the first year during low flow periods for a period of 30 days during the operation of four turbines.

The water quality generally is very good at the turbine offtake. High dissolved oxygen concentrations and low BOD concentrations are predicted. DO concentrations at the offtake are low for short periods (less than 30 days). Nutrient concentrations will support moderate aquatic life.

Dam Spill Water Quality The amount of vegetative biomass remaining in the impoundment and the operation of 3 or 4 turbines, under either high or low flow scenarios has almost no impact on water quality during dam spills . The surface water released downstream into the Nam Theun has adequate dissolved oxygen concentration. DO concentration in the reservoir is high at the surface as the oxygen demand by decomposing vegetative biomass is met by elevated DO in inflowing waters and photosynthetic oxygen production within the reservoir. The water quality generally is the same for both high and low flow periods.

The water quality again is very good with elevated DO at the surface. Moderate levels of nutrients will be available for downstream plant growth.

Water Quality of Environmental Flows The amount of vegetative biomass remaining in the impoundment and the operation of 3 or 4 turbines and under either high or low flow periods has little impact on environmental flow water quality during . DRP concentrations show some initial variation between the 3 and 4 turbine scenarios. For the remaining ten year period DRP concentrations are similar for both scenarios. Chlorophyll a concentrations are 5-10 µg/l greater for the 4 turbine operation year 1. Concentrations of Chlorophyll a are similar for the remaining years. Ammonia concentrations for the first 4 years for the turbine 3 scenario are 5-10 µg/l higher than for the turbine 4 scenario. The use of 3 or 4 turbines during low flow periods does not have a significant impact on environment flow water quality. Low and High flow periods during the operation of three turbines produce similar environmental flow water quality. Spills occur only during high flow periods and the EAMP is based on this.

The environmental flow water quality during the operation of the four turbines during low and high flow periods is different between the operating scenarios. Higher ammonia and Chlorophyll a concentrations are present in the environmental flows from 4 turbine high flow periods. These changes in concentrations may significantly increase primary production in the downstream Nam Theun, with greater algal growth, phytoplankton and invertebrates, but not necessarily implying eutrophication in the river. However, NTEC's intention is to proceed with the 3 turbine configuration and the EAMP is based on this scenario.

5.5.1.3 Impacts of Logging on Water Quality

Up to 50percent of logging within the catchment could cause an increase of 25 times the present sediment load from the undeveloped catchment, which would also lead to an increase in nitrogen and phosphorous entering the Reservoir. This 25 fold increase in sediment load was based on a literature review undertaken by SMEC (1991) and a study in New Zealand where logging with no protective measures resulted in increase of sediment yield by factors of 24-27 times (Graynoth, 1979). The scenario with high biomass (A), 3 turbine (3T), and high flow period (HP) was modelled.

Turbine Offtake Water Quality DRP concentrations on average increase to 600 µg/l during the wet season. In the dry season, DRP concentrations substantially decrease to less than 100 µg/l. These are significant phosphorous concentrations which will promote high algal productivity. Chlorophyll a concentrations on average are 10 µg/l greater in the potentially logged catchment model than when the catchment remains undeveloped. BOD concentrations remain the same i.e. less than 1 mg/l. Total phosphorous concentrations are 20 times greater (2000 µg/l) in both the wet season and dry seasons (1000 µg/l) in the model when the catchment is partially logged. Both Total Nitrogen (600 µg/l) and Ammonia (60 µg/l) concentrations in the wet season from a logged catchment model are on average three times the total nitrogen and ammonia concentrations from an undeveloped catchment. Models of logging in the catchment leads to elevated concentrations of phosphorous and nitrogen in the Reservoir which in turn doubles the algal biomass to 20 µg/l. This argues for conserving the catchment.

The increase in Chlorophyll a suggests that some algal species, particularly blue-green algae, may dominate when nutrient concentrations are elevated. This enrichment of the reservoir may also encourage the proliferation of exotic plants particularly if no natural predators are present.

Dam Spillway Water Quality The dam spillway water quality has nutrient levels peaking at the wet season but within acceptable limits. The impact of increased nutrient concentration in the downstream Nam Theun will be limited to a more productive system.

The impact of increased nutrient concentrations in the downstream Nam Theun will lead to a more productive system, with increased algal biomass within the rivers.

Environmental Flow Water Quality The dam spillway water quality is the same as that found at the turbine offtake for a partially logged catchment. The major difference is in peak Chlorophyll a concentrations in the environmental flows where Chlorophyll a may be as high as 40 µg/l compared with 20-25 µg/l at the turbine offtake.

The doubling of algal biomass as indicated by increased Chlorophyll a concentrations may lead to domination of blue-green algae. This domination could lead to some toxicity in the waters though generally the aquatic ecology of the reservoir will not be affected.

In summary, if the catchment is partially logged this will lead to large increases in phosphorous and nitrogen and a doubling of algal biomass in the upper portions of the Reservoir. The water quality of the turbine offtake, dam spills and environmental flows are very similar for the partially logged catchment. Catchment logging and increased nutrients in the Nam Theun will lead to higher primary productivity in this river and possibly increased fish productivity not counting sedimentation, turbidity and changed hydrology. Recommended mitigation measures are discussed in Chapter 6 for the prohibition by RAP of land clearing and shifting cultivation in resettlement areas (Section 6.2.4), development by GOL of a watershed management plan, and prohibition by GOL of logging above FSL (Section 6.2.7).

5.5.1.4 Reservoir Limnology

The Nam Theun 2 Reservoir mixes readily because of its shallow bathymetry and relatively short residence time. There is weak stratification during the wet season. The decomposing vegetative biomass remaining in the reservoir does not lead to excessive enrichment of the water column in the first two years as predicted by Chlorophyll a.

These vegetative biomass levels result in low dissolved oxygen concentrations in the first two years at lowers depths. For short periods, in the order of 30 days, anoxic water may be passed into the turbine offtake during the first two years. There are patches of anoxia which extend from the bottom (509masl) to 516m ASL as the reservoir fills in the first year. In the first 120 days, these areas of anoxia increase in volume to 524m ASL as the reservoir continues to fill in the wet season. After this time, dissolved oxygen concentrations at the surface (538m ASL) to 516m ASL; 7.5m below the turbine offtake level, are 4 to 5 mg/l. For the remaining ten year period dissolved oxygen concentrations throughout the main basin are predicted by the model to be high, resulting in elevated levels of nitrate and low levels of ammonia. DRP concentrations are low and in association with the elevated nitrate concentrations and the mixing characteristics of the dam will favour a diverse range of phytoplankton genera, resulting in greater and diverse range of species. Chlorophyll a peaks in the wet season with concentrations of 20 µg/l with lower concentrations of 10 µg/l in the dry season therefore not signifying bloom conditions.

The low nutrient and high dissolved oxygen concentrations of the inflows from the catchments effectively dilute the nutrient and metal (Iron and Manganese) inputs from the decomposing vegetative biomass and sediments. These factors in turn give raise to more nitrate than ammonia and relatively low phosphorus in the water column. There are sufficient amount of these nutrients, light and elevated water temperatures for algal biomass to be in the order of 10-20 µg/l Chlorophyll a. These concentrations of Chlorophyll a are indicative of moderately enriched lotic systems.

The reservoir has a weak thermal pattern and subsequently mixes easily. The dissolved oxygen concentrations in the reservoir is generally high. Nutrient concentrations are sufficient to support a moderate level of algal productivity.

5.5.1.5 Vegetation Decay and Reservoir Recovery Time

For all the scenarios modelled, the water quality parameters were characterised by two stages of development:

- for the first two years, quality of stored and discharged water was dominated by the decomposition of submerged biomass with low DO concentrations at greater depths.
- from two years onwards, the quality of stored and discharged waters became increasingly influenced by inflow water quality as well as physical and biogeochemical processes within the reservoir.

Overall, the 1-D water quality simulations showed that the reservoir dynamics were dominated by the poorly stratified conditions in the wet season and the well mixed conditions in the dry season. Stratification occurred in April through to September before mixing took place in October through to March. Anoxia conditions began to develop in April beneath the thermocline for a period of 180 days in the first year.

The fundamental results derived from modelling of the dynamics and water quality of the Nam Theun 2 Reservoir may be summarised as follows:

Short Term Operations: Up to 2 years

- Oxygen consumption associated with decomposition of organic matter from flooded biomass resulted in depletion of oxygen in the hypoliminon for short periods of time with the surface layer remaining aerated. The short anoxic periods in the reservoir do not deteriorate the water quality.
- Suspended sediment concentrations remain below the thermocline as a result of wet season inflow. The lack of suspended sediment in the upper levels of the reservoir encourages good light penetration and moderate algal growth. Inflows with high DO are brought in at depth supporting oxygen replenishment of the hypoliminion.
- Low nutrient concentrations are found throughout the reservoir. Nitrate concentrations are elevated in comparison with ammonia because of the high dissolved oxygen concentrations and low internal organic matter loading within the reservoir. These low to moderate levels of nutrient should support a diverse range of phytoplanktons.

Long Term Operations: 2 years - onwards

- Dissolved oxygen concentrations generally increased with time throughout the reservoir. There is sufficient DO within the surface waters of the reservoir for fish survival and production. These elevated DO levels are found within the reservoir during initial filling. These concentrations are maintained throughout the filling and operation of the reservoir.
- Suspended solids concentrations continued to flow at depth below the thermocline.
- Nutrient concentrations remained low within the reservoir.

5.5.2 Potential for Proliferation of Water Weeds

A number of species of aquatic macrophytes have been recorded in the Nam Theun River and Nan Kading as shown in the Table below.

Aquatic Vegetation	Nam Kading	Nam Theun
Submerged Plants		
Hydrilla	+	+
Najas	+	+

Ceratophyllum	+	+
Potamogeton	+	0
Ottelia	+	+
Utricularia	+	0
Vallisneria	+	0
Chara	+	+
Floating Plants		
Wolffia	+	0
Lemna	+	0
Spirodella	+	0
Azolla	+	0
Salvinia	+	0
Pistia	+	0
Eichhornia	+	+
Emergent Plants		
Nelumbo	+	0
Nymphaea	+	0
Nymphoides	+	+
Spread Marginal Species		
Ipomea	+	0
Marsilea	+	0
Jussiaea	+	+
Stand Marginal Species		
Sagittaria	+	+
Colocaisa	+	+
Typha	+	0

Source : Dept. livestock and Vet., Burapha Ltd., 1992, in Norplan

Under conducive conditions, aquatic macrophytes can develop into nuisance proportions according to their growth form and habitat. Nutrient enrichment may cause mass development of aquatic plants. Introduced plants with no natural predators or diseases also may proliferate. However excessive growth sometimes results after hydropower development even in ologotrophic conditions. Such changes are mediated by alteration of the flow hydrograph which enables aquatic macrophytes to persist in an actively growing state for a prolonged time. The potential areas for proliferation of aquatic weeds as a result of this Project are the fringing edges of the reservoir, the surfaces waters of the reservoir and the downstream channel.

Possible candidates to become weeds on the reservoir are the free floating species such as *Azolla, Wolffia, Salvinia, Pistia* and *Eichhornia*. Only *Eichhornia* has been recorded on the Nam Theun River. Generally these plants which originate in tropical areas will grow rapidly in nutrient rich and warm waters.

The Nam Ngum Reservoir, Lao PDR was filled in 1972, before being raised in 1977. A report completed on the Development and Management of Fisheries in Nam Ngum Reservoir (1984) found only once was there dense growths of *Azolla, Salvinia, Pistia* and *Eichhornia* in several embayments in the reservoir during the four year study period.

The low nutrient concentrations in the Nam Theun and the cooler water temperatures of the proposed reservoir in comparison to those found in the Nam Ngum Reservoir suggests that the proliferation of exotic weed species is unlikely to occur in this impoundment.

Other potential weeds are the submerged macrophytes *Hydrilla* and *Ceratophyllum*. *Hydrilla verticillata* in the Nam Ngum Reservoir grew abundantly in the shallow reaches 3-5m from the shore and up to 4m depth. This plant could hamper fishing and navigation in the shallower regions of the reservoir (Development and Management of Fisheries in Nam Ngum Reservoir 1984). These plants also like the submerged plants described above are capable of rapid spread in nutrient rich waters.

It is likely some submerged aquatic plants will become established in the Nam Theun Reservoir; however the 10m vertical fluctuation of the drawdown zone will limit submerged and emergent macrophyte growth to a certain degree, and a balanced population could improve fish production by providing refuge and forage habitat.

Following hydropower development and diversion to the Xe Bang Fai, changes in vegetation community structure, species composition and biomass quantities are likely to occur in the downstream Nam Theun and the Downstream Channel. In the downstream Nam Theun, the macrophyte communities are likely to be similar to those communities presently in the river. The submerged macrophytes, *Hydrilla* and *Ceratophyllum* and the emergent macrophytes *Sagittaria*, *Typha* and *Colocaia* are likely to become established in the Downstream Channel.

Monitoring for the detection of nuisance aquatic plant growth should be employed by NTECo to control the proliferation of water weeds and is included in the recommended mitigation measures discussed in Section 6.2.6 on downstream surveys.

5.6 Impact of Water Quality Changes

5.6.1 Beneficial Uses

Each waterbody may have a number of beneficial uses, including recreational use, potable water supply, ecosystem protection and irrigation that need to be measured in order to test that they are being protected. Water quality criteria or reference values provide the means to make such measurements. The water quality management approach involves:

- identifying the environmental values of particular water bodies that are not protected
- establishing the objectives that will achieve the required level of protection. These objectives are established in terms of key indicators of quality (physicochemical and biological) using the collated scientific information relevant to each indicator and each environmental value
- establishing water quality management strategies (e.g. policies covering receiving water, effluent, non-point source and catchment) that will provide the instruments for achieving the objectives
- developing and initiating a monitoring and surveillance program to ensure that the water quality objectives are being maintained
- initiating a research program to understand the unknown factors and to refine the scientific information relating to each particular aquatic ecosystem

Sets of key indicators of water quality are presented in Annex H to provide a means of identifying and measuring change in each beneficial use. Three types of environmental quality indicators can be identified:

- those indicators that are normally present in the water and that can be usually monitored for a change in concentration, quantity or quality, some or all of which can be linked to a change in the conditions affecting the water body;

- those indicators that are not normally present, but if detected in certain concentrations or quantities can be used to identify a change in the conditions affecting the water body;
- indicators that are normally present but the absence of which reflects a change in an environmental value.

The aquatic ecosystems described in this chapter will be highly modified aquatic ecosystems. The recommended water quality criteria or reference values are necessary to maintain the beneficial use values of each water body after modification. The beneficial uses in the Nam Theun Reservoir (Zone 1), the Nam Theun River below the dam (Zone 4) and the Downstream Channel - Gnommalat Plain (Zones 7, 8 and 9) to be considered are listed in the Table below.

Beneficial Use	Nam Theun Reservoir	Downstream-Nam Theun River	Downstream Channel-Gnommalat Plain
Protection of Aquatic Ecosystems including fisheries	✔	✔	N/A
Stock Watering	✔	✔	N/A
Navigation	✔	✔	N/A
Primary Recreation	✔	✔	N/A
Water Supply	✔	✔	N/A
Industrial water supply	N/A	N/A	✔
Irrigation	N/A	N/A	✔

5.6.2 Water Quality Criteria

5.6.2.1 Protection of Aquatic Ecosystems

The water quality guidelines for aquatic ecosystems are based on the ecologically sustainable development philosophy where the goal is to protect biological diversity and maintain ecological processes and systems, i.e. to maintain the 'ecological integrity' of each modified freshwater resource. An indicator of ecological integrity is the degree to which ecosystems have been altered from their natural state. This degree of alteration is measured by a combination of biological and physiochemical parameters. A description of the water quality monitoring program designed to measure these parameters is provided in Annex E.

Mitigation through NTECo's compliance with water quality standards and guidelines is addressed in Sections 6.2.6. Guidelines are listed in Annex I and are drawn from the Australian Water Quality Guidelines (1992). These guidelines are based on a review of the international criteria documents, particularly those produced by the United Sates (USEPA 1986), Canada (CCREM 1991) and the World Health Organisation (WHO 1980, 1984).

The Reservoirs' seasonal nature and the differing sediment loads of the inflows will lead to changes in colour and clarity of the water column. These changes can be marked so no guideline values are listed until the natural range in the dam has been established. Similarly this approach has been adopted for suspended solid concentrations and turbidity. These water quality guidelines are applicable to the Reservoir (Zone 1), downstream of the Powerhouse (Zones 7, 8 and 9), and below the Dam in the Nam Theun River (Zone 4).

There will be two release points from the reservoir. Water will be released through the turbines continuously. Minimum guaranteed release from the dam will be drawn through a multi-level offtake to the Nam Theun. The water drawn through this offtake will be from, or near the surface. The following water quality parameters have been predicted from an extensive water quality model of the proposed reservoir.

Dissolved oxygen concentrations are estimated to range from 5 mg/l up to 7 mg/l down to a depth of 20m on most occasions. Under certain flow conditions it is possible that dissolved oxygen will be less than 3mg/l for about 30 days during the wet season in the first year of operation from low level water that may flow to the turbine. The "guideline value" in the reservoir for dissolved oxygen is more than 6 mg/l or 75% of saturation level. NTEC will monitor this situation.

Iron and manganese concentrations in the water column will be elevated in the anoxic hypolimnion; as these metallic compounds stabilise and mix into the epilimnion, they will be precipitated as particulate. Surface iron and manganese concentrations will be less than 100 µg/l. The guideline value for iron is less than 300 µg/l and for manganese is less than 100 µg/l.

Inflow conductivity of the Nam Theun River are very low (2-90 us/cm). Predicted conductivity values in the reservoir will be between 100 and 500 us/cm. The guideline value for conductivity is less than 1500 us/cm.

pH values in the euphotic zone of the reservoir are predicted to be between 7 and 8. Lesser values of pH in the order of 6 to 7 are likely to occur in the hypolimnion. The guideline value for pH ranges between 6.5 and 9.

The inflowing waters are from almost pristine catchments and associated nutrient concentrations are in the order of 20 µg/l for total phosphorous and 10 µg/l for total nitrogen. In the early stages of impoundment (that is, the first 2 years), internal nutrient loading from decaying biomass increase these nutrient concentrations. Predicted maximum total nitrogen concentrations are 250 µg/l and total phosphorous in the order of 90 µg/l. At these concentrations, primary production in the reservoir is expected to be moderate. Corresponding chlorophyll a concentrations integrated over the photic zone reach a minimum of 20 µg/l. The guideline concentrations suggest total phosphorous should be in the range of 5 to 50 µg/l, and total nitrogen in the range of 100 to 500 µg/l. At these concentrations, chlorophyll a is expected to be between 2 and 10 µg/l.

In the hypolimnion, hydrogen sulphide may be generated due to the anoxic conditions that will exist in this area of the lake in the first two years. There are periodic episodes of anoxia (less than 2µg/l) that occur under thermally stratified conditions. High oxygen concentrations (approx. 9mg/l) occur each year as the reservoir cools and homogenises. Precipitation of sulphide with iron is a common process and negates the production of gas in the hypolimnion. If gas is formed in the hypolimnion it will be converted rapidly as it diffuses into the epilimnion. The guideline value of 0.2 µg/l of H_2S will be met at the surface offtake.

Riparian releases into the Nam Theun River are from near the surface of the reservoir. Thus dissolved oxygen concentrations will be high, soluble iron and manganese concentrations will be low, pH values will be the same as those present in the lake, and there will be no hydrogen sulphide in these riparian releases to the Nam Theun. Water temperatures will follow the seasonal trend found in the reservoir and will match closely water temperatures in the Nam Theun.

Dissolved oxygen concentrations, pH, salinity, iron and manganese, hydrogen sulphide and temperature will meet the guidelines for protection of aquatic ecosystems in the Nam Theun River. Nutrient concentrations in streams tend to be lower than those for lakes. The greater assimilative capacity of streams for nutrients than in lakes undoubtedly has much to do with the free flowing nature of streams and rivers. Therefore the nutrient concentrations that will

enter the Nam Theun River by way of riparian releases meet the guidelines for protection of aquatic ecosystems.

In summary, water quality guidelines for downstream discharges and lake water quality will be met because the Nam Theun 2 Reservoir will exhibit cool, well-mixed conditions high in oxygen and low in nutrients for about four months of the year following the cessation of the wet season rains. During the wet season, the reservoir will be thermally stratified and brief (less than 15 days) episodes of low oxygen deep water are expected to occur. The decomposition of drowned vegetative biomass does not lead to excessive enrichment of the water column in the first two years.

Assumed vegetative biomass levels will however result in low dissolved oxygen concentrations in the first two years at depth. Throughout the ten year period, dissolved oxygen concentrations throughout the main basin are high resulting in elevated levels of nitrate and low levels of ammonia. DRP concentrations are low and in association with elevated nitrates concentrations and the mixing characteristics of the dam will favour a diverse range of phytoplankton. Chlorophyll 'a' peaks in the wet season with concentrations of 20ug/l with lower concentrations of 10 µg/l in the dry season.

The water quality modelling shows the water quality guidelines for protection of aquatic ecosystems are met within the reservoir and in the downstream Nam Theun. These guidelines can be met by NTECo's implementation of the water quality monitoring program as described in Annex E and recommended in Section 6.2.6 in Chapter 6.

5.6.2.2 Recreational Water Use

Water quality guidelines to protect recreational water use for such activities as swimming and boating and to preserve the water's aesthetic appeal are distilled from the literature cited. Recreational water use is discussed here but will be controlled by GOL based on the higher ranking requirements for protected area management and fishery. Similar consideration will apply to the area downstream of the dam which will form part of a protected area corridor.

The water quality characteristics relevant to recreational use are listed in Annex I. These guidelines are applicable to the Nam Theun 2 Reservoir (Zone 1), below the Powerhouse (Zones, 7, 8 and 9), and the downstream Nam Theun River (Zone 4).

Biological factors that influence the recreational value of surface waters include those that endanger the health or physical discomfort of people and animals and those that render water aesthetically objectionable. In the first category are non-biting midges, caddis flies and mayflies which can emerge in large numbers and cause serious nuisance to people camping or living near the shoreline. More serious are biting insects that cause irritation from their bites, respiratory allergic reactions or disease. Common diseases transmitted by aquatic invertebrates are encephalitis, malaria and schistosomiasis.

Excessive growths of aquatic plants can also cause problems in recreational areas. Rooted or non-rooted macrophytes can entangle swimmers. If the growth is very dense, boating and fishing may also be restricted. Dislodged or free-floating plants and debris (eg. logs, branches) may also drift onto beaches, decay and cause objectionable odours as well as provide breeding areas for nuisance organisms. There are likely to be accelerated growths of aquatic macrophytes during the wet season as the reservoir fills and rehydrates the littoral zone . These macrophytes may make swimming and navigation extremely difficult and even dangerous. Harvesting is the only viable control mechanism for macrophyte control in the reservoir.

The microbial levels in the reservoir will meet primary recreational water quality guidelines of less than 150 faecal coliforms per 100 ml. The exception to this is where bacterial contamination occurs by animal defecation and/or inflow points draining domestic and agricultural land use mainly the resettlement zones areas during the wet season.

There will be no toxic chemicals within the reservoir since the catchment does not support industrial activities. There may be localised hydrocarbon spillage from fishing and recreational boats however these generally do not cause restrict recreation in reservoirs. On the whole normal recreational guidelines values will be met.

There will be little or no faecal coliforms (less than 150 per 100 ml) in riparian releases and spills from the reservoir to the Nam Theun River. Small pockets of aquatic macrophytes may become established in the river, particularly when low flow conditions exist in the first 12 km. These plants would inhibit navigation and swimming in this stretch of the river; however as this stretch is not navigable and will have restricted access being part of the protected area wildlife corridor this is not an issue. Given that toxic substances and hydrocarbons are unlikely to be present in the reservoir, these substances are unlikely to be found in the river. The recreational guidelines will be met in the river.

A comprehensive programme for long term water quality monitoring should be implemented by NTECo to ensure that downstream water quality standards are maintained.

5.6.2.3 Raw Water for Drinking Water Supply

The guidelines described in Annex I apply to raw water that is not treated prior to consumption apart from the removal of coarse debris. Water is boiled prior to consumption. These guidelines are applicable to water drawn from the Nam Theun Reservoir (Zone 1), below the Powerhouse (Zones 7, 8 and 9), and the downstream Nam Theun River (Zone 4).

Raw water is traditionally gathered from water courses and dams and boiled for consumption. The raw water from the reservoir will have low total dissolved solids concentrations (less than 500 mg/l), high dissolved oxygen concentrations (greater than 6 mg/l), pH values between 6.5 and 8.5, low iron and manganese concentrations (less than 0.1 mg/l), and low concentrations of nitrate (less than 100 µg/l). Bacterial contamination may occur by wallowing animals and/or inflow points draining domestic and agricultural land use areas throughout the year. The practice of boiling water provides a substantial level of protection from bacterial contamination. Therefore the guidelines for drinking water from the reservoir will be met.

Given that the water quality guidelines will be met in the reservoir, and that this water will be released into the Nam Theun River downstream of the reservoir, as well as below the Powerhouse, guideline values for drinking water supply in the river will also be met.

5.6.2.4 Agricultural Water Use

Water will be available to be drawn from the Downstream Channel for irrigation in the Gnommalat Plain. The water quality guidelines in Annex I list the parameter concentrations required for irrigation. This water has passed through the turbines at the powerhouse before entering the Downstream Channel. The water quality in the downstream channel is therefore suitable for irrigation. The salinity will be less than 100 mg/l, sodium, chloride, and magnesium concentrations are all less than 10 mg/l and metal concentrations will be less than irrigation guideline values.

5.6.2.5 Industrial Water Use

Water may be drawn from the Downstream Channel for industrial purposes although this is unlikely in the medium term. The water quality guidelines in Annex I list the parameter values required for these purposes. The most likely industrial process to draw water from the channel is the pulp and paper industry. On the Gnommalat Plain there may be established a medium density fibreboard factory. The water quality requirements for this factory are for pH to be between 6 and 8, colour to be less than 100 units, turbidity less than 20 NTUs, cations less than 12 mg/l, and anions less than 25 mg/l. These guideline values will be met.

5.7 SEDIMENTATION AND EROSION IMPACTS

5.7.1 Reservoir Sedimentation

The estimate of the Nam Theun reservoir sedimentation rate under catchment quality and current sediment load is 13 million m^3 in 50 years or 260,000 m^3 per year (SMEC, 1991). As the total capacity below Minimum Operating Level (MOL) is calculated to be in excess of 490 million m^3, the sediment yield from the catchment is theoretically of no consequence to the reservoir or its functions for a very long time under current watershed conditions and based on normal events. There is capacity for over 1850 years of sediment accumulation below MOL. Unfortunately, estimates of erosion in catchment areas are often lower than those observed after the dam is built. If the erosion rates averaged twenty-five times the SMEC estimate, the consequent 325 million m^3 over 50 years would be approximately 66percent of the "dead space". Such a rate would allow, for example, the current background rate to increase twenty fold (to 5.2 million m^3 per year) and for annual "special events" such as 40 land slips, each 30m wide, 200m long and 5m deep also to be deposited in to the reservoir. The water quality study has used such a twenty-five fold increase in erosion to ascertain the sensitivity of water quality parameters to a less effectively managed watershed. Such increases in erosion rates have been measured in New Zealand logged areas.

Of course not all eroded material deposits' in the "dead space" of the reservoir. When the reservoir is full, the coarse sediment (sand, gravel, and cobbles) brought in by the tributaries will be deposited in the storage pool, building up a small delta where each enters the reservoir and aggrading a short section of tributary channel upstream from the full supply level due to changes in river gradient locally. When the reservoir is drawn down, flows will move this deposited sediment deeper into the reservoir, mostly into dead storage below El 528.

Gradually over time, the tributary deltas will grow and the beds will aggrade for some distance upstream. Water levels in the aggraded reach will be higher than in the natural state. Some tributaries are very steep (up to 20 m/km) with waterfalls in the drawdown section. If there is any aggradation upstream in these, it will not extend far. The flattest tributary is the Nam Xot, about 0.7 m/km in the drawdown zone. Aggradation and increased flooding will extend farther upstream on this river.

Some of the coarse sediment will be in active storage with some in the aggradation zone and some reaching the dead storage. Some fine sediment (silt and clay) will be deposited in the backwater areas above and in active storage indicated by the spidery configuration of the reservoir where the tributaries enter as shown in Figure 3-3 (Reservoir Plan). The majority will be transported to dead storage. Some of the clay may reach the dam wall in turbidity currents, especially from the lower tributaries. This would be a small amount because there is a long flat stretch of reservoir bottom between the largest tributaries and the dam.

Provided the amount of sediment deposited in the Nam Theun 2 catchment is near to that predicted above, the impacts described above are not of serious consequence to the function of

the reservoir, either for energy production or environmental loss. The creation of the NBCA should ensure that mitigation measures to control erosion and sedimentation are implemented and insure that sediment yield will remain at the current estimated low level.

The issue is how to ensure that the reality is as close as possible to the predictions. The key to this is the management of activities in the watershed, particularly the steeper slopes. These are purely in the NNT-NBCA and without management could be subject to logging and slash and burn agriculture. From an economic and environmental perspective it is therefore important that prohibition of logging in the NNT-NBCA be enforced rigorously and that slash and burn activities be limited to and preferably reduced significantly from their current levels . To assist in achieving these objectives NTEC is proposing to contribute $1million annually for 30 year to the management costs of the NNT-NBCA, as outlined in Chapter 6.

5.7.2 Degradation

5.7.2.1 Downstream from Dam (Zones 4 and 5)

Because most, if not all, the products of catchment erosion and other sources of inorganic sediment will be deposited in the reservoir, the Nam Theun channel downstream from the dam will not receive its former supply of these materials. The small tributaries will bring but a fraction of the former sediment load. As a result, flows from the spillway, and to a lesser extent riparian releases, will erode and retransport the sand bars and finer sediment from the bed leaving the 12km reach of river slightly deeper with a coarser substrate and with smaller and fewer sand bars.

The Nam Phao River, which joins the Nam Theun 12 km downstream from the damsite, carries an appreciable load of sand. Beyond this confluence changes due to sediment load will be smaller than upstream. However, in order to minimse loss of fine benthic substrate and present sand bar configuration, aquatic habitat below the proposed Damsite, river basin management planning is proposed for the Nam Phao tributary in Section 6.2.2.

Erosion of river banks in downstream sectors of the Nam Theun will not be a major problem as there are considerable lengths of rock zones involved and bamboo will tend to encroach in other zones.

5.7.2.2 Conveyance Channels (Zones 7, 8 and 9)

The design velocity for flow in the reservoir intake and power station tailrace channels, and in the Downstream Channel is less than 1.0 m/s. The banks and bed of the excavated channels will be naturally free from erosion from the turbined flows, except at few localised places where the soil properties are inferior. These areas should be protected with riprap to control erosion of the banks and degradation of the channel bed. The EAMP recommends that the situation be monitored by NTECo as described in Section 6.2.6 and rectification works carried out if needed. These measures are discussed in Section 6.2.3.

5.7.2.3 Xe Bang Fai(Zones 10, 11 and 12)

The total inorganic sediment load currently supplied to the Xe Bang Fai River will not change because of the Project. However, as a result of the sustained power station releases of largely sediment free water, sand and finer sediment will be removed from the bed and bars in the channel of the Xe Bang Fai below the confluence with the Downstream Channel. Much of the bed profile is controlled by rock outcrops and the river winds between hills of rock formations, so its bed profile and general plan will not change. There may be stretches of weaker bankline that will erode because of larger and occasional low flows. This situation will be monitored as described in Section 6.2.6and if such erosion is of consequence remedial action will be

completed by the NT2 Project and the bank will be protected by rip-rap or other suitable river bank stabilisation works (Section 6.2.3).

During periods when there are no floods or only small ones in the Xe Bang Fai, the river bed will become coarser and the sand bars smaller. However, large floods will replicate some of the former features. Again, after large floods, the slow removal of the finer inorganic sediments will take place. The addition of the power station releases will not significantly increase the concentration of suspended sediment so this aspect of the water quality will remain unchanged.

The response of the Xe Bang Fai will be different than that in the downstream Nam Theun because in one the sediment load to the reach will be almost stopped and in the other it will remain unchanged. These changes however are not expected to be in any significant proportion.

5.7.3 Erosion Due to Construction

Most of the erosion from construction results from removal of vegetation including changes in sediment yields which have frequently been observed after vegetation has been removed and catchment areas have been converted to other land uses, (Brooks, 1993). Change in landuse is another factor contributing to erosion and sediment yields. The proposed NT2 Project will undertake several construction activities for power plant facilities and support infrastructure such as roads and bridges. All measures as discussed in Sections 3.4.2.1 and 6.2.3 should be undertaken to minimise the impacts from erosion and sedimentation in construction of all facilities. These measures should form an integral part of the Turnkey Contractor's environmental management plan and should be incorporated in the contractual agreement between the TKC and NTEC.

Erosion impacts associated with quarries (Annex L), transmission lines (Annex M), roadways (Annex N), and construction camps (Annex O) are addressed in the relevant sections mentioned. Resettlement sites are addressed in the RAP.

Erosion impacts due to construction are not expected to be significant with implementation of adequate mitigation measures and good monitoring practices as discussed in Sections 3.4.2.1 and 6.2.3. Implementing mitigation measures, following best management measures, and maximisation of working in the dry season will help minimise the erosion impacts. Special care will be needed with road construction and excavation work at the damsite.

5.8 Impacts on Forests, Forest Biodiversity and Wildlife

Project impacts on forests, forest biodiversity and wildlife occur both during the pre-construction, construction and operations phases, and are characterised as both direct and indirect impacts. Direct impacts are related to the clearance, degradation or disturbance of forests and forest biodiversity as a result of Project construction and operations. Impacts on floral and faunal biodiversity are closely interrelated since forests make up many of the habitats for wildlife. Indirect impacts may occur from increased human population, loss of livelihood among some of the area inhabitants, and improved access to forests occur and are allowed to increase pressure on forest resources. There is also the possibility of positive indirect impacts as a result of improved management, and increasing the living standard in the area, thereby reducing dependence on forest resources. Clearly it is desirable to intervene to achieve the second scenario. The RAP includes measures to ensure that resettlers have a fiscal incentive to become forest guardians in the resettlement area. The NNT-NBCA management plan is also intended to deal with these issues.

5.8.1 Impacts During Pre-construction and Construction Phases

5.8.1.1 Logging

Commercial logging commenced on the Nakai Plateau, mostly but not solely in what is now known as the inundation zone, in the early 1980s. The GOL had instructed BPKP to develop the central mountainous area of Lao PDR and authorised it logging rights over an extensive area which included all the Nakai Plateau and what is now the NNT-NBCA. Quantities of logs extracted appear to have increased steadily towards 200,000 to 300,00 m^3. p.a., as equipment and access roads were acquired and built.

A Forestry Report for the NT2 Hydropower Project (MGP 1996), provides details regarding the forest ecotypes and their tree species composition below FSL. As of May 1996, more than 50 percent (25,000 ha) of the forest in the inundation zone had already been logged. Some of this area categorised as 'Temporarily Unstocked' includes agricultural land and wetlands. The remaining forests are described as 60 percent Mixed Deciduous, 32 percent Broadleaf/Conifer, 0.5 percent Dry Dipterocarp, and 0.2 percent Conifer (*Pinus merkusii*).(MGP 1996) Intensive logging over the prior 3 years has focused on removing pine and much of the area defined as Temporarily Unstocked was previously under Conifer or Broadleaf/Conifer forest.

> "Most of the Plateau area which contains forests of *Pinus merkusii* has been or is being logged and some of it has been subjected to shifting and other cultivation. Apparently hunting and collection of non-timber forest products has been intense. Other than a few pockets of pine or mixed broad forests and possibly some riverine strips most of the Plateau is considered to be substantially modified by human activity and from a biodiversity standpoint substantially degraded from its original status"
>
> *Report of the International Environmental and Social Panel of Experts - 1997*

Prosser (1997) estimates the expected volumes of timber removed -- and biomass remaining -- in the inundation area. Proposed mitigation involves removal of sawlogs and continuing shifting cultivation in the inundation area up to time of submergence (Section 6.2.2), and the removal of trees and biomass for firewood (Section 6.2.2), and optimization of salvage logging for Project works (Section 6.2.2), including the dam, saddle dams and intake channel structures. This level of clearing will remove a total of 1.1 million m^3 of commercial pine and hardwood, representing virtually all of the commercial volume in the inundation area. Assuming this level of removal is achieved, the economic loss from inundation expressed in terms of un-harvested timber is not significant.

5.8.1.2 Inundation of Land

If the NT2 Project proceeds, 450 sqkm below 538 masl will be submerged. All existing vegetation habitat types in the inundation zone will be inundated and their economic values lost.

While the area has been intensely logged since early 1980s, if the Project does not proceed, sustained yield silviculture may otherwise be applied, enabling selectively logged forests to regenerate. Sustainable yield losses are calculated based on harvesting 1.5 percent of the total current amount of marketable timber in the inundation area over an indefinite future period. Using a stumpage value of \$80/m^3 and a five percent discount rate, the present value is \$26 million. It is assumed in making this calculation that the existing forested areas are managed over an indefinite period in a sustainable fashion. In addition to the potential loss of

sustainable forestry, subsistence values (e.g. imputed income from harvesting NTFPs by local people) and wildlife habitat values also are lost due to the inundation.

In 1993 GOL made two decisions which have had a bearing on BPKP's approach to logging. An "in-principle" decision was made to construct NT2 and the NNT-NBCA was also declared. BPKP was directed to focus its logging activities within the inundation zone because the commercially valuable Pine would not survive inundation. BPKP ceased logging in the area destined to become the NNT-NBCA. The NBCA was defined as occurring down to the highwater line of the NT2 reservoir (more recent proposals would extend the NBCA to include all the reservoir).

Forest biodiversity is comprised of the floral and faunal components of the forest ecosystem, and relates to the diversity and patchwork of associated forest ecotypes. There has never been a complete inventory for either flora or fauna in the Plateau or adjacent NBCA. It is impossible to say categorically, therefore, that all plant and animal species found in the Project impact area exist in other parts of Laos or elsewhere; however not one of the preliminary biological studies and observations suggests any terrestrial plant or animal species is unique to the Plateau (WCS 1996). Similar environmental investigations undertaken in the past have reached similar conclusions (SMEC, 1991, TEAM, 1995)

Most of the old-growth stands of *Pinus merkusii* in the Project area have been impacted by salvage logging, though substantial areas remain above the inundation zone at several sites on the Northeast bank of the Nam Theun River and in the southernmost sections of the Plateau (See Figure 4-6 and 4-9). NTEC and GOL are making a good faith effort to ensure that remaining stands above the inundation level are conserved. When it was discovered recently that old-growth pine was being illegally logged, NTEC, GOL and BPKP came to an agreement to place all old-growth pine stands lying outside the demarcated salvage logging zone Northeast of the Nam Theun River under strict conservation. NTEC, GOL, and BPKP seek to impose a total ban on logging outside the inundation zone as mitigation (Sections 6.2.4 and 6.2.7). This will be strictly enforced prior to actual filling of the reservoir, pending agreement on which selected areas in the vicinity of the resettlement villages will be sustainably harvested (Section 6.2.4) and which will be declared part of the NBCA. NTEC working with the Khammouane Provincial Forestry Office has put into place a monitoring system which enables immediate notification of infractions, followed by stiff penalties. Current controls appear to be effective, but the value and location of remaining old-growth *P. merkusii* stands, (mostly near the N.E. shoreline of the proposed reservoir), put them in jeopardy; however their protection over the long term will be a priority for the Management plan for the NNT-NBCA. Detailed conservation measures are provided for *Pinus merkusii* in Section 6.2.7.

> "The terrestrial ecosystems of the 40percent of the Plateau to be inundated are substantially degraded"
>
> *Report of the International Environmental and Social Panel of Experts - 1997*

5.8.1.3 Construction and Resettlement Areas

Dam and Dam Area Work Camp

The dam and associated work camp will be located in an area of early to late secondary succession forest dominated by mixed deciduous with small areas of dry evergreen adjacent to the Nam Theun River. Some of this area has been cleared of vegetation to conduct geological studies. Settlement, prior occupancy sites and shifting cultivation have altered the original vegetation. Approximately an additional twenty hectares will need to be cleared to construct the

dam and camp. About 25 percent of this area is degraded, and the remainder is forest in good to excellent condition. The camp will house 400 workers during the four year (dry-season only) construction period and a much smaller crew during the operational phase. Based on experience from other dam construction projects, an 'informal' population of merchants is likely to enter the area during the construction phase, some of whom may try to settle permanently. These spontaneous resettlers activities will be regulated by construction phase mitigation measures to be undertaken by the TKC as advised in its environmental management plan as detailed in Annex J. While the needs of workers formally employed by the Project will be met mostly by their terms of contract, the informal population will meet their housing, fuel, food and health care , at least partially, from the forest. Damage to area forests may occur from scavenging these materials from the forest. A large market for bush meat could develop in the area. Higher population and activity levels will create an increased risk of forest fire. Clearing for construction will create abundant material that could be used for temporary housing and fuel, and direct reliance on forest resources should be held to a minimum. The sub-EA on Work Camps in Annex O fully addresses impacts and mitigatory measures.

Powerhouse, Switching Station, Regulating Pond, Weir and Work Camp

This area is located below Nakai Village on the west face of the Plateau escarpment adjacent to Route 8B. It is under early to mid- secondary succession mixed deciduous and dry Dipterocarp forest. Much of the forest directly adjacent is degraded by road construction in addition to upland agriculture. Switching station construction will require clearing an additional two to three ha of secondary succession mixed deciduous forest. The regulating pond and weir below the powerhouse will be excavated for a maximum of two kilometres through areas, not exceeding 391,000 sqm., consisting of degraded mixed deciduous and semi-evergreen forest already degraded by exploitation by residents of the Gnommalat area. Detailed design may reduce the height of this weir and hence the extent of the pond. Nearly the entire work camp area proposed is already a cleared area and damage to forests as a result of construction will be minimal.

The principal threat to forests is from potential indirect impacts. Eleven hundred workers will be housed in the work camp. Based on experience from the Theun Hinboun Hydropower Project, an additional 4,000 people could enter the area as merchants, temporary and informal workers including their families. This major settlement concentration with attendant needs for food, housing and fuel could impact significantly on nearby forests, many of which are in good to excellent condition The recommended mitigation and monitoring measures are provided in Annex O and Annex J, construction related mitigation measures.

Limestone Quarry

Forests in the limestone quarry area between Lak Sao and the Damsite have long been under agricultural use. The karst outcrop from which the aggregate will be quarried has some sparse scrub and tree vegetation typical of karst formations in the area. Quarry site impact on forests is negligible. The sub-EA on Quarry Sites in Annex L gives complete details on impacts and mitigation measures.

Downstream Channel, Spoils and Drainage

The downstream channel, spoil disposal sites and drainage are located in agricultural areas bounded by scrub vegetation. Direct impacts of the Project on forests in these areas is therefore negligible. Indirect impacts could be significant, however. They could occur were loss of livelihood activities associated with the affected areas (agriculture, fishing, wild food collection) inadequately compensated by substitution income. Families would likely seek to compensate these income losses from a limited number of alternative available sources, including forests. The RAP deals with compensation for directly and indirectly affected persons

Road Construction and Improvement

Project road works entail mostly upgrading existing logging and other tracks on the Northeast between the reservoir and Lak Sao and in the Southwest from Thakhek through Gnommalat to Nakai District center. Direct impacts on forests from these improvements are negligible. A new road is planned on the upper rim of the western Plateau escarpment. This road would extend from Nakai town to the Damsite, cutting through an area of relatively undisturbed mostly upland mixed deciduous and dry Dipterocarp forest.

The road will serve three purposes :

- it replaces the existing route 8B that links Gnommalat to Lak Sao but which will be inundated
- it provides an all weather route and emergency access from the operators village to the dam and spillway gates
- it will be used by the resettled villagers to access forest products, including logs, on a sustainable basin within their village boundaries (which are outside the proposed corridor extension of the NBCA) as described in the RAP.

The road will pass through an extension to the NNT-NBCA from midway along the Nam Malou basin, across the dam and then to where it will rejoin the existing route 8B just outside the N.E. boundary of the Reservoir. One option under examination by NTECo and GOL is to make this section of the road of limited access, particularly during night hours. The road crosses the proposed wildlife corridor and the corridor would better fulfill its purpose if there was no regular traffic at night. This would also help convey the protected nature of the area.

Including shoulders and estimated borrows and spoils, this road would require removal of, or otherwise damage, 325 hectares of the two forest types. Indirect impacts from the construction of this road are potentially more significant. At present, the area is relatively unaffected and the routing of a roadway through rich forest could facilitate human intrusion resulting in illegal logging, intensive hunting and NTFP collection, and forest fires. It could facilitate entry by shifting cultivators seeking to capitalise on rich forest soils, ease of access and transport. Recent small-scale outside economic investment in the Nakai area is increasing, particularly by Thakhek entrepreneurs who hire poor farmers on the Plateau to raise livestock. Unless monitored and controlled access to new forest areas could facilitate the spread of similar explotive practices with associated negative impacts on forests; however it is an integral part of the RAP to address this through land allocation and implementation of an effective surveillance program . The length of the road within the expanded NNT-NBCA should be subject to the same management rules as applied elsewhere in the NBCA. The sub-EA on roadways in Annex N gives complete details on impacts and mitigation measures.

Transmission Line

The transmission lines extend from the powerhouse below Nakai Village, 140 km to the Mekong River about 5km north of Savannakhet Provincial Capital. Routing has been designed to minimise the need for forest cutting. Most of the line traverses agricultural or scrub land, however about 25 km passes through mid- to late secondary succession mostly mixed deciduous forest. Assuming the need to cut a 5m wide access track through these forests, a total of not less than 12.5 ha would be removed.. These forests are already used for hunting and gathering by area villages. Improved access and regular maintenance should not result in any significant additional resource pressures. The sub-EA on transmission lines in Annex M gives complete details on impacts and mitigation measures.

Resettlement Area

The proposed resettlement areas are on the left bank of the reservoir looking downstream, adjacent to the Plateau escarpment forests. A portion of the proposed resettlement area is located in or near to forests above the western shore of the reservoir.

The precise location of resettlement housing, agriculture and forestry areas will be determined in consultation with local villagers and selected to minimise the need for forest clearance. Most of the resettlement areas so far proposed have been cleared or degraded to varying degrees by upland agriculture and logging. Resettlement plans include reforestation and sustainable timber harvesting from forests adjacent to the resettlement sites. These forests will need to be declared Production Forests under the new Forest Law. Income and revenues from forestry activities will contribute to resettlers' livelihoods. Adequate forest remains in the resettlement area so that each of the approximately 1,000 resettled families could obtain income from controlled cutting and sale of several trees per year (dependent on size and value) without threatening forest sustainability. This aspect and control of indirect impacts is discussed in detail in the RAP, as noted above. Appendix E of the RAP gives complete details on impacts of the resettled people on the natural environment, as well as associated mitigation measures .

5.8.1.4 Comparative Analysis

This section compares NT2 Project impacts on forests, woodlands, and land cover in the inundation and construction areas with analogous habitats unaffected by the Project yet within the defined Environmental Study Area (ESA), primarily the NBCA (Zone 2). Forest and woodland plant communities and land use types on the Nakai Plateau up to the Southwest escarpment and Northeast dividing hills are characterised as comprising 13 ecotypes. This mosaic of habitats once housed an outstanding density and diversity of wildlife species which used to exist on the Plateau and in surrounding forests, but which have recently come under increasing pressure over the last 30 years from settlement expansion, logging and hunting.

The Table below details the approximate area of these forest and land cover types, and the area of damage that will be incurred by each as a result of reservoir inundation and other Project direct impacts. The purpose is to compare damage to habitat types that would occur as a result of reservoir inundation and other Project direct impacts, with analogous habitats that would remain unaffected at elevations above the reservoir's full supply level.

Land cover types and comparative extent of damage resulting from the NT2 Project are :

Land cover	Total area (ha) including NBCA[1])	Destroyed by inundation (ha)	Destroyed/ Damaged in other areas[2]	Total damage (ha)	% unaffected
1. Dry evergreen	185,313	65	15	80	99.96
2. Mixed deciduous	95,866	5465	250	5715	94.04
3. Dry dipterocarp	3,940	725	15	740	81.22
4. Broadleaf/conifer	39,026	5035	125	5160	86.78
5. Coniferous	2,155	195	-	195	92.35
6. Lowland riverine	51	35	10	45	11.76
7. Riparian gallery	255	135	-	135	47.06
8. Savannah/ woodland	13,753	5860	225	6085	55.76
9. Grassland	3,060	1090	-	1090	64.38
10. Wetland	2,459	2070	-	2070	15.88
11. Lowland agriculture	3,848	1900	120	2020	47.51
12. Upland agriculture	4,475	160	-	160	96.43
13. Temporary unstocked[3]	56,075	22060	55	22115	60.56
TOTAL	**403,146**	**44795**	**820**	**45610**	**65.66**

(Compiled from data derived from: 1987 SPOT data analysis (SMEC 1991); 1989 Landsat data analysis (NT2 EAMP 1995) and NOFIP 1994 aerial photography (MGP 1996)).

The lowland riverine land type is spread over the areas of the eastern tributaries valleys and the Nam Malou basin; however primarily at the southern inundation zone extremity with additional small remnants primarily from midway between north and south extremities of inundation zone. Similarly the riparian gallery is distributed all around the dam site and upstream of it to the northern extremity of the inundation zone, so also in the valleys of the eastern tributaries and with some scattered remnants running upto midway between the northern and southern extremities of the inundation zone. The wetland areas are located mostly between the north and south boundaries of the inundation zone and running inland from the Nam Theun to the mid-point of the southern extremity.

Loss of riparian forests would be unavoidable, mitigation measures however are discussed in Chapter 6, by way of water quality studies for adjacent basins (Section 6.2.2) and possible development of wetlands downstream at the confluence with the Xe Bang Fai (Section 6.2.3).

The data collected to date facilitate consideration of two issues central to appraising the impacts of the NT2 Project on forests and forest-based biodiversity, and the acceptability of proposed mitigation measures and conservation trade-offs. The first has to do with whether sufficient areas of forest habitat analogous to those damaged or destroyed by the Project remain in nearby areas, specifically the N-NT NBCA, to support similar floral and faunal populations associated with these habitats. The second issue addresses whether the forest and biodiversity management for the NBCA will ensure adequate protection for analogous habitats in the NBCA (Zone 2) during construction and operation of the Project

The above table shows that with a few exceptions, analogous forest and land cover types adjacent to the inundation zone in the NBCA exceed significantly those that would be damaged

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[1] Estimates are based on habitat assessment reports from WCS (1995a and b), and visual inspection of the dividing hills at 7 locations on the east and west sides of the Nam Theun River.

[2] Estimate of damage at resettlement areas and construction sites including work camps, switching station, roads, downstream channels, and transmission line corridor.

[3] MGP 1996 (NOFIP 1994) data for temporarily unstocked disaggregated to capture rice field, grassland and savannah (See: SMEC 1991).

by the Project. The exceptions are lowland riverine forest, riparian gallery and the lowland savannah-wetland-grass mosaic, much of which has probably resulted from forest clearing.

While the extent of lowland riverine forest is small, its loss is significant since riverine forest in the adjacent NBCA is rare, being confined to small areas along several tributaries feeding the Nam Theun from the east. Likewise, wetlands associated with grassland and savannah are extensive on the Nam Theun floodplain but uncommon throughout the rest of the area, and in fact, nation-wide since most such areas have been converted to rice cropping (WCS, 1995). Despite the logging of the Plateau, small forest remnants remain associated with the five herbaceous and grassland cover types. Their association with larger forest areas at higher elevation makes the wider ecosystem extremely rich in terms of wildlife habitat value. Preferred wildlife foraging sites are also preferred hunting grounds so that the present habitats in the inundation area can no longer realistically be considered favourable for wildlife.

5.8.2 Impacts During the Operations Phase

5.8.2.1 Indirect Impacts on Areas Adjacent to the Inundation Zone

Considering that logging in the inundation zone would well have proceeded without the NT2 Project and that other sites to be affected are largely deforested, direct Project impacts on forests and forest biodiversity may be a lesser concern than potential indirect impacts during operations. Indirect impacts could come about as a result of:

- increased population on the Nakai Plateau;
- improved access and egress to and from the Plateau on the Northeast route (Lak Sao) and Southwest route (Thakhek);
- improved access and egress to and from the interior of the NBCA via the reservoir.

World-wide experience with the construction of large dams in remote areas of the tropics indicates that their potential indirect impacts should be considered a matter of utmost concern (Goldsmith and Hildyard 1991; Goodland 1992; McCulley 1996). Both the Project proponents and loan guarantor (The World Bank) are devoting enormous attention to these extremely complex issues. The Project will significantly alter human activities in the Project area and the alteration could have significant impact on nearby ecosystems. Human activities, if inadequately controlled, could expose forests and biodiversity in the adjacent first-class conservation area (NBCA) and in other sites bordering the Project's direct impact zone to significant threat of degradation, including in-migration and intensified use of the NBCA for settlement, shifting cultivation, fishing, fuelwood collection, collection of NTFPs, and illegal poaching of timber and wildlife resources. Were these threats to coalesce, the 'indirect' impacts of the Project on forests and biodiversity could exceed its direct impacts. Registration of resettlement families (Section 6.2.7) as mitigation measures are aimed at minimising the impacts of spontaneous development.

The management strategy, and more importantly, the ability to implement it effectively, is of primary importance for preventing the main potential for the destructive impact of the Project on forests and biodiversity. If human utilisation of project area environments is controlled effectively, the Project will enhance potential for conserving the endangered NBCA. The plan to achieve this is being developed by the World Conservation Union (IUCN), under contract from GOL, and will be available as a companion document to this Report in July 1997.

5.8.2.2 Indirect Impacts on Wildlife in the Dividing Hills (Zone 2)

Access to the nearly unmodified and somewhat remote Dividing Hills area of the NBCA will be improved during the operations phase. Although plant communities in the Dividing Hills are

apparently intact (with less than two percent in abandoned shifting cultivation succession forest or upland agriculture), the wildlife resource suffers year-round over-exploitation as in much of the rest of the Plateau and NBCA. Boat access made possible by the impoundment will be easier for many than that currently available by tracks and roads. In any case as described below it will be important to manage this aspect, and it is also being addressed in the above mentioned IUCN plan.

Chapter 4 describes the diversity and use of forest ecosystems of the Dividing Hills in the NBCA (Section 4.4). The Mixed Deciduous and Dry Evergreen vegetation types constitute 28 percent and 66 percent of the area, respectively. A large area consists of elements specific to the riparian zones which dissect these vegetation types . The three percent in bamboo is embedded within the deciduous, evergreen and riparian areas. The area is noteworthy for its lack of permanent habitation and human use, with the exception of intensive but dispersed, ephemeral hunting and gathering. Four species serve as indicators for deciduous forest habitat, a leafbird, two bats, and a rat. Indicator species closely associated with the dry evergreen forest include three birds, two bats, a macaque, and two rats. The globally threatened species likely to be found in both types of primary forest include elephant, tiger, gaur, marbled cat, clouded leopard, and Douc langur among the mammals, and hornbills, pheasants, and pigeons among the birds.

Access to the Dividing Hills is currently by a 10-20km boat trip up one of the major tributaries from its intersection with the Nam Theun, by a hike from the logging road which goes through Ban Nam Xot, or from the Nam Theun riverside through about three to five km of forest to the hills. At FSL the impoundment will flood the shallow rivers (such as the Nam Mon) which are difficult or impassable from January to June, making access easier during the wet season and early wet season. Elsewhere, the reservoir will allow access by boat to the Northeast shoreline at the boundary of the NBCA. Such access entails navigating across five to 12 km of the reservoir from the Southwest settled shore. A boat provides a relatively fast and easy way of bringing products of the forest or hunt to markets on the south shore.

The vulnerability of the Dividing Hills to hunting was assessed using a 'region of influence' analysis employing a geographic information system (GIS). Contours were plotted on a base map of the reservoir and hills and travel times based upon experience and interviews were assigned to local boats (five km/hr), and easy (two km/hr), difficult (one km/hr) and very steep hiking. The GIS model was used to indicate areas that could be accessed within a single day by boat from the reservoir and by walking. The area of influence is shown in Figure 5-3 (Hunting Travel Time).

About 203 sqkm, or one-half, of the Hills are vulnerable, and all of the area would be accessible if hunters camp for a night. Running a trapline requires an overnight trip (with increased risk of discovery), so most of the day-trip harvest would employ guns or rifles.

The analysis assumes that no new logging or logging roads will penetrate the area at the base of the Hills. As the location and value of habitat resources and areas of important animal use become better known, these areas can be intersected with the travel pattern. The use of a GIS to pinpoint the most important spots to deploy conservation officers or management interventions can give the most value for the investment in mitigation. In a previous similar application, only three percent of the total possible area of habitat needed to be actively managed and surveyed (Berwick *et al.* 1986). Preservation of wildlife values of the Dividing Hills portion of the NBCA depends on mitigating new access to these hills from the reservoir. The management plan for the NBCA should include the appropriate EPMs to minimise human encroachment into the NBCA for illegal hunting and gathering of NTFPs.

5.8.2.3 Impact on Riparian Forests and Wildlife Below the Damsite (Zone 4)

The Project will dam the Nam Theun River and divert most of its flow through the power station and into Xe Bang Fai River. The result will be a loss of most of the dry season base flow in the Nam Theun over a 12 km reach before it meets its confluence with the Nam Phao. Riparian forest soils in this area could become dry enough to cause demise of a number of moisture demanding tree species. This impact is not considered likely; though an adaptive management strategy is suggested that can anticipate the effect and provide counteracting measures (Section 6.2.6).

Minimum guranteed release of 2 cumec will be provided as discussed in Chapter 3 and will also form a part of the recommended mitigation measures as discussed in Section 6.2.6). The minimum guaranteed release will flow through this 12km stretch thereby ensuring the sustainable survival of any plant and tree species that are threatened from lack of moisture.

The impact on wildlife of the reduced base flow is not considered severe. Some impacts are possible as a result of a decrease in fish which provide food for some species of wildlife for instance otters, eagles etc., found in the riparian zone below the Damsite. There is a level of uncertainty associated with this outcome because the current standing crop biomass of fish is a fraction of what is expected, and may actually increase under the effects of the Project, as described in Section 5.9. The current nutrient-constrained system might benefit from the low flow-related eutrophication up to a threshold, after which declines will occur. Though the loss of rapids, reduced current, and elimination of migrants act to reduce production and particularly the diversity of fish species, the effect may be countered by increased nutrients and productivity. These are discussed in detail in Section 5.9.

Terrestrial vertebrates which depend upon the aquatic diversity and productivity of the Nam Theun have been described in Chapter 4. The key and indicator species are very diverse because the canyon has a diversity of habitats not seen in more uniform forested areas. Bird species of special concern are the Lesser fish-eagle, White-winged duck, Pied falconet, Coral-billed ground cuckoo, Grey headed lapwing and Brown hornbills. The mammal species include the Small-clawed otters. The intact riparian habitat is important for some such as the Pied falconet which nests in tree cavities and the Coral-billed ground cuckoo which uses the thick bamboo along the river. If the river is dried to the point of influencing riparian water balance (particularly bank recharge and water availability in the dry season) and the loss of elements of riparian vegetation occurs, these birds will suffer. River morphology below the dam may be modified by NTECo as mitigation if deemed appropriate by wildlife specialists to enhance wildlife adaptation. This is discussed in Section 6.2.2.

Another set of effects attend the change in prey for the lesser-fish eagle, and otters. It is possible that a slight increase in nutrients as water is reduced and warms in the dry season, would increase prey and benefit these species. The availability to otter and birds of fish, crustaceans, molluscs, reptiles and amphibians, would be greater than at present, particularly if hunting were controlled during the construction phase and later via mitigation measures of NBCA management, when the below-dam area is incorporated into the NBCA. Prey would exceed current levels which are diminished due to the current regime of heavy exploitation.

The dependency of key and threatened species of birds and mammals on the aquatic ecosystem is an important element of the Nam Theun canyon's biodiversity. The changes due to the reduction in dry season flows are difficult to predict, and could in fact go either way - i.e. to more diversity or toward ecosystem loss. Additional studies will be provided as mitigation, and are discussed in Sections 6.2.2.

The impact of workers at the Damsite is an immediate concern. Workers and others accessing the gorge from the Damsite (though very difficult) can travel down the Nam Theun to the Nam Phao (in Zone 4). To go further is a commitment to go all the way to the bridge at Highway 8 (about 50 km) as the rapids insure a one-way trip. Pressure on the resources of the first 12 km downstream of the dam will be focused on the river as the canyon precludes much extended travel beyond the riparian zone. The EAMP recommends that GOL place strict controls on hunting, fishing, and gathering in the gorge below the Damsite. A properly enforced ban on consumptive resource uses such as fishing and hunting will reduce current constraints to the wildlife populations, prevent over-exploitation by workers before the reservoir fills, and enhance the use of the area as a wildlife corridor.

Further baseline assessment is needed for preparing an adaptive management strategy for this zone which is recommended for reservation as a corridor zone between the Plateau and the Khammouane Limestone Protected Areas. The EAMP recommends that GOL monitor the impacts to fish and wildlife of the riparian releases and further assess these issues during the construction phase and during the early years of operation. The proposed mitigation measures are discussed in Chapter 6.

5.8.3 Special Wildlife Concerns

5.8.3.1 Impact on Wildlife Habitats

It is not the forests expressly, but rather the mosaic of forest types and diverse lowland ecosystems including riverine, wetland, grassland and scrub which comprise the area's special wildlife habitat qualities. Habitat loss can be significant if the habitat type is poorly represented elsewhere in Lao PDR and regionally. The most significant habitat loss in the inundation area is the riverine habitat.. In the current context, intense hunting pressure appears to have all but extirpated most wildlife species from much of the Plateau and its nearby environs (WCS 1996). It is inaccurate to characterise the Plateau as a favourable wildlife habitat (Marsh 1996, POE 1997). Depopulation of wildlife species is a direct impact of high intensity exploitation pressure, particularly at the (otherwise) best habitat sites.

The affect of the NT2 Project on wildlife habitats relates mostly to potential for indirect impacts from increased population of the Plateau (outside of the inundation zone) and its vicinity. If the impacts of people entering the area as a result of the Project cannot be controlled, or if resettled populations are unable to obtain adequate livelihoods, forest exploitation and degradation could increase. On the other hand, the Project could provide the impetus, legal leverage and resources required to regulate natural resource exploitation to keep it within sustainable limits.

Conservation measures have been designed by GOL/NTEC to strengthen forest and habitat management, so that the area's overall ecological status will improve compared to pre-Project (or 'no-Project') conditions. Analysis of environmental costs, benefits and trade-offs related to the NT2 Project indicate that a positive scenario is more likely to unfold if the Project proceeds, as opposed to without it (WCS 1996; Chape 1996).

Tables 4-1 through 4-8 in Chapter 4 list key and indicator species for the habitats most closely identified with the Plateau. These tables also show the threatened bird and mammal species from the impacts of inundation and below-dam riparian losses, and the potential efficacy of mitigation measures. Of these, the Grey headed lapwing, River lapwing, White-winged duck, Lesser fish-eagle, Pied falconet, and Small-clawed otters, Elephant, and Banteng are listed as globally threatened, warranting particular attention. With the exception of the White-winged duck and Elephant, these species are using other areas of the N-NT ecosystem, specifically the

NBCA. The Banteng is apparently no longer found and is not listed with the fauna of the Plateau by WCS (1996). Of particular concern are the extremely rare White-winged duck and the Elephant. These two species are globally threatened.

5.8.3.2 White-Winged Duck

It is likely that the 5-10 pair of White-winged ducks is not a genetically, nor demographically secure population, and that the population would not survive for long in any case without the Project. These resident birds occur in such widely separated populations that genetic exchange is unlikely. The nearest population to the Nakai Plateau is near the Cambodian border in the Xe Pian Protected Area on the southern Bolovens Plateau. The current population is experiencing the 'founder effects' of genetic changes in small populations. This describes the genetic drift caused by a random loss of variability, which ultimately leads to behavioural dysfunction, reduced vitality, growth, egg production, disease resistance, and other effects of inbreeding depression (Wright 1922). In some cases, small populations can become rapidly more adaptive by such mechanisms as heterosis, but the greater likelihood is immediate genetic and demographic risk, e.g. a random environmentally caused breeding failure, or the loss of an entire cohort to hunting in a small population. The degree of inbreeding depression depends on how long the birds have been so low in numbers, how long they have been isolated, and whether any similar bottlenecks have occurred.

It is quite probable that historic riparian and wetland changes coupled with the hunting pressure described earlier has led to the current status of the White-winged duck. With contemporary land use practices and potential changes (absent the dam), it is likely the population will continue to diminish and disappear.

Mitigation measures to counter some of the impacts for this species are proposed in Section 6.2.2.

5.8.3.3 Impact on the Elephant Population

The issue at NT2 is conflict arising from human encroachment (Seidensticker 1984). The current centres of distribution for the estimated 100-150 elephants (about 10 to 15 family groups) are at the points where the Nam Xot and the Nam Theun drainage enter the Plateau. Spoor and sightings are most common in this central area (to be inundated). However, there is some indication of movement across the river to the west near the Nam Malou basin, which will be flooded at FSL and dry for several months each year as the water is drawn down. From the Southwest of Ban Nam Theun they appear to move in and around the hilly west side of the downstream Nam Theun corridor (as in Figure 4-9). Seasonality of movement and resource use, or group fidelity during seasonal movements have not been established. The degree of interchange with populations to the Northwest in the limestone areas of the NBCA, is not known.

The degree of impact from inundation will depend on the traditional use of these areas by elephants, the numbers and family groups which are involved in these local movements, and the proximity of people, their stock and crops. When the timing of elephant movements is more fully known, with mitigation proposed to minimise contact or settlement in the path of these movement, and with forage reserved at the Nam Malou basin and elsewhere at the northern end of the impoundment, it is likely that some of the northern sub-population (Nam Xot/Nam Theun) will survive the flooding and influx of people. The mitigation measures are discussed in Section 6.2.5. This region of the impoundment currently has the most diverse mosaic of vegetation types. Therefore some of the area to be flooded is still high quality habitat (e.g. the Nam Niam drainage) and provides considerable forage.

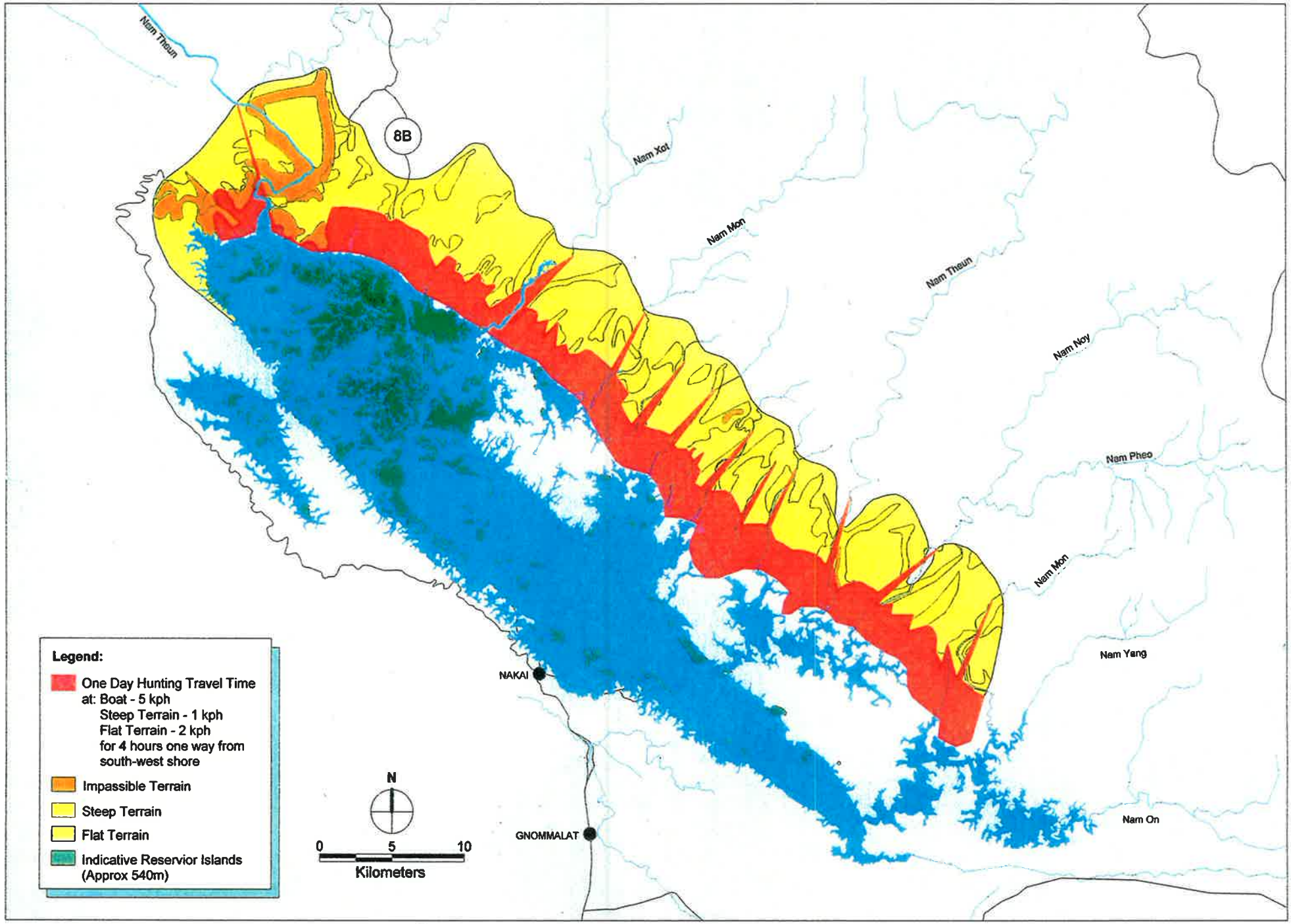


FIGURE 5-3 HUNTING TRAVEL TIME

The southern sub-population (if they actually are distinct) will be much more distant from Project features and does not experience much loss of habitat in the narrow Southeast end of the reservoir. More of the undisturbed Plateau will be available to this sub-population in the absence of commercial logging (which reportedly is generating elephant mortality from poaching for ivory by loggers).

The maze of islands in relatively shallow water in the Northeast portion of the inundation area is a possible movement corridor to seasonal areas which were once readily available and where elephant sign has been recorded. It is possible that elephants will cross on the dam. Sukumar (1992) suggests that they will travel along a dam if it is five m wide and covered with dirt. The crest of the Nam Theun dam is to be 6m wide but will serve as a road. This section of road is proposed to be closed at night (except for emergency access) in part to facilitate movement by large wildlife species.

The resettlement area includes the southern periphery of the Nam Malou basin, very near likely points of elephant egress from the island area of the reservoir. However no villages are planned within about 5 kms of the likely crossing points. Elephants which cross here are likely to return to the Northeast side of the reservoir several months later. It is known that elephant families will go back to the same seasonal areas they annually occupy. Based on the elephant sign, it is likely that some families and single bulls currently use these habitats and others to the Southeast toward Ban Nakai Nua.

The corridor geometry of the scarp and shoreline could funnel movements of foraging elephants. Elephants emerge from cover at night to enter fields in groups of seven or eight, mostly males. They return for several nights, each consuming about 75 kg/night. Such fields can provide 25 percent of an animals diet for several months (October-January) with two-thirds of the crop lost. Such use of fields is simply an extension of seasonal movements influenced by contact with desirable and increasingly scarce resources. Animals somewhat stressed by the loss of familiar habitat become 'frustrated' (Sukumar) when people attempt to protect their crops. This is when most attacks occur.

Habitat and population fragmentation is now considered one of the most serious global conservation problems. It is a subtle process which occurs over a period of years. It has become a dominant factor in the landscapes of this century due to the enormous increase in the human population and the technologies of land conversion. The tools to analyse the meaning of population fragmentation and to Project management responses are just maturing (as the relatively new field of Conservation Biology).

A minimum viable population (less than one percent inbreeding/generation) of most species of birds and mammals is about 50 breeding adults for short term security and 500 for the long-term. Because many animals do not breed, and males are often poached for tusks, this means about 120 - 150 elephants (with one male per two females) are necessary to maintain the population for the short term, (about the number estimated on the Nakai Plateau). If poaching reduces the number of males and restricts genetic input of half of the parents, the effective population will need to be much larger. Some heavily hunted elephant populations have sex ratios as high as 1 male: 20 females. For this reason it is very important to reduce or eliminate poaching and this should be addressed in the NBCA management plan.

For long-term security a metapopulation (reproductively connected sub-populations over a wide area such as the Khammouane/Kading/Nakai-Nam Theun protected area complex) would need about 1,300 animals and the habitat to occasionally connect them (one or two males every 10 years). The minimum viable area necessary to support an elephant population of 125 over

the short term at a typical tropical forest density of 0.1/sqkm (the current density on the Plateau), is about 1,300 sqkm. Although this figure varies with habitat quality, it approximates the current area of the entire Plateau. The description of the Project and habitats on the Plateau indicates losses of one-third of the Plateau to the reservoir and about 20 percent more to relocated villages and infrastructure. In the absence of crop raids as a forage supplement, of a viable mitigation program, and with any significant poaching further skewing sex ratios, a loss of about one third to one-half of the current elephant population is likely. Any elephant population below current numbers (100-150) would not be viable in the short-term.

To summarise, in the absence of mitigation and enforcement, the effects of inundation on the north-western elephant sub-population could lead to significant loss from both habitat loss and human conflict. The EAMP recommends that GOL undertake and develop mitigation strategies suggested in Section 6.2.5.

5.8.4 Threats to Forest Biodiversity Without the NT2 Project

It is important to recognise that significant threats to forests and forest biodiversity in the Nakai Plateau and N-NT NBCA are going to be present regardless of whether the NT2 Hydropower Project moves forward (Bangkok Post February 3, 1997 'Laos: Logging worsens dam's toll'). Hunting and trading in wildlife products in the area have become intense and sophisticated (Marsh 1996). Incursions into the NBCA by heavily armed hunters are well-known (WCS 1995; personal communications with local residents). An increasing number of outsiders are clearing forests to practice shifting cultivation. GOL has not had adequate personnel or resources to contain the situation. The World Conservation Union (IUCN) and Wildlife Conservation Society concur in the view that current threats to both habitats and species in the N-NT NBCA are so great as to make implementation of an effective conservation program essential if the area's wildlife and biodiversity values are to have any hope of being preserved (WCS 1995 and 1996; Marsh 1996).

Continued logging of the Plateau can be expected in the absence of the Project. Coincident with logging is the destruction of natural forest habitats, and the introduction of ever increasing numbers of people into the Plateau area, ostensibly to work, and then to settle or remain long enough to take advantage of whatever natural resources, including wildlife and NTFPs, that might be taken from the area. The no-Project alternative does nothing to alter the trend toward exploitation of the natural resources found in the Plateau area, which can be expected to continue, and in fact to spread at an accelerated rate into the NBCA from the more accessible areas of the Plateau. In the absence of the Project, there also will not be the all important financial contribution to the management of the NBCA, which is, in economic terms, a bid by NTEC that sets the value of the resource. Without the NTEC bid, no resource re-evaluation occurs. The current trend toward exploitation and non-sustainable use will continue, and the area will decline further in value to the point where both the Plateau and the NBCA will only be a place for habitation of people at marginal levels and further exploitation of an increasingly depleted store of resources.

5.8.5 Impacts to Wetlands

5.8.5.1 Areal Loss of Wetland Habitat

Total wetland area on the Nakai Plateau is estimated at more than 50 sqkm of freshwater lakes, ponds, marshes and flooded grasslands. These span an area of 100 sqkm, across the Plateau and Nam Theun NBCA. The NT2 Reservoir will cause the loss (via inundation) of approximately 55 percent (27.4 sqkm) of Nakai-NT NBCA wetlands. Total wetland area in

the Kammouane Province is estimated at 682 sqkm, including riverine habitat and floodplain wet rice paddy, and that for the Lao PDR is 9,652 sqkm (Claridge 1996).

The closest wetlands inventoried to date which are similar in type and extent to those of the Nakai Plateau are three that are found within a 60 km radius (Claridge 1996) of the NT2 Reservoir. They are the following :

- *Nam Hinboun Wetlands*, Kammouane Province, the section of the Nam Hinboun River between Ban Hinboun where Route 13 crosses the river and Ban Phahang, some 35 km upstream. Wetlands are permanent and seasonal riverine with associated freshwater lakes and ponds, seasonally flooded forests, grasslands, shrublands, and rice paddy. Estimated area is unknown, but covers 35 km of the Nam Hinboun River and its floodplain.
- *Nam Thon Wetlands*, Borikhamxay Province, in the catchment of the Nam Dua/Nam Thon river system, between Highway 13 and the Mekong River. Wetlands are permanent and seasonal freshwater lakes, ponds, and marshes. Estimated area is 28 sqkm.
- *Xe Bang Fai Wetlands*, Kammouane Province, 40 km from Thakhek towards Savanakhet between Route 13 and the Mekong River. Wetlands are freshwater lakes, rivers, ponds, marshes, and rice paddy. Area of extent is approximately 125 sqkm, and actual area about 30 sqkm.

5.8.5.2 Loss of Wildlife Habitat

Wildlife to be most impacted by the inundation of Nakai Plateau wetlands are the more than 35 species of birds known to utilise the wetlands throughout the year. Of particular concern is the globally threatened White-winged Duck (*Cairina scutulata*) (ref 5.8.3.2 above). Six to twelve pairs were sighted near slow-flowing stretches of river on the Nakai Plateau in 1995 (Claridge, 1996). The Nakai Plateau is known to be only one of two areas in the Lao PDR hosting populations of the White-winged Duck. These birds have also been found in small pools and drying wetlands of the lowlands south and west of the Bolovens Plateau. This region of freshwater lakes, ponds, marshes and seasonally flooded grassland is located in the Attapeu Province approximately 130-150 km south and slightly east of the Nakai Plateau. The region is part of the Xe Pian-Xe Khampho wetlands, the extent of which is 300 sqkm, although total wetland area is less than 20 sqkm. With respect to loss of wetlands however, the creation of a reservoir with a large drawdown (10m) compared to the average depth when full (7.1m) will result in a variety of pools, mini lakes and moist drawdown zones being formed. It will be a matter of interest to observe how this potentially diverse range of habitats will influence the prevalence of wildlife-particularly when so much of it will be either in or adjacent to a protected area.

At minimum operating level there will be 286 sqkm of exposed littoral area. The moist soils will harbour a wide array of semi-aquatic invertebrates such as molluscs and insects, as well as snakes and turtles, thus providing a forage area for predatory animals. The standing vegetation exposed at drawdown (mostly dead trees) will provide cover for some wildlife species as well. However, the degree to which this area will provide the resources lost by inundation of the original wetlands is unknown. It is recommended that both habitat requirements and alternative areas which can be utilised by vulnerable species be studied prior to inundation. Such mitigation measures are discussed in Section 6.2.2). Vulnerable species of concern are the Black Stork (*Ciconja nigra*), Blythe's Kingfisher (*Alcedo hercules*), Crested Kingfisher (*Megaceryle logubris*), Green Peafowl (*Pavo muticus*), Grey-headed Fish-eagle (*Ichthyophaga ichthyaetus*), River Lapwing (*Vanellus duvaucellii*), Small Pratincole (*Glareola lactea*), Snipe (*Gallingo sp.*), Tawny Fish-Owl (*Ketupa flavipes*), and White Winged Duck (*Cairina scutulata*). Specific mitigation measures for the White Winged Duck are recommended in Section 6.2.2).

Information gained from study of habitat requirement and alternative areas such as the one recommended for development of wetlands areas in Section 6.2.3, can then be used to preserve or enhance areas containing critical habitat or food resources that would otherwise be available to the species of concern. The information can also be used to evaluate the likelihood that migrating birds may be able to find and utilise neighbouring wetland areas on the Nam Hinboun, Nam Thon, and Xe Bang Fai all less than 60 km away.

5.9 AQUATIC HABITATS AND FISHERIES

5.9.1 Physical Alterations to Habitat (Hydrology and Flow Regime)

After the dam has been constructed and the reservoir has been filled operations can be started. With the reservoir operations water from the Nam Theun basin is diverted to the power station and discharged into the Xe Bang Fai basin. NTEC has advised that the water flow in the Nam Theun river below the dam will be a minimum of 2 m^3 during the dry season with additional spills over the dam during the wet season. NTECo proposes to divert the remainder to the Xe Bang Fai basin to generate electricity.

5.9.1.1 Nam Theun and Tributaries in the Plateau Environment (Zones 4 and 5)

The dam forms a physical barrier to upstream fish migration during all seasons and to downstream fish migration during the dry season. During the wet season downstream migrating fish may survive the steep drop of water spilled over the dam in these years that spills occur. There is no evidence that fish are migrating all the way from the Mekong river to the Plateau area. Fishermen catch much bigger size fish during the wet season than during the dry season. But it is perfectly possible that the big size fish are coming from the deeper pools and scoured holes close to the rapids along the Nam Theun and Nam Kading. Species potentially migrating from the Mekong mainstream to the Plateau area are Bagridae. There are a significant number of rapids and waterfalls of several meters high between the Plateau and the Mekong. Bagridae are not known to migrate such distances under such conditions. In addition the 15 meter high Theun-Hinboun dam, which is already under construction, will block any possible fish migration from the Mekong mainstream to the Plateau area. Therefore, only locally migrating fish will be affected by the Nam Theun 2 dam. Species as for instance *Tor* cf. *tambra*, *Tor tambroides* and *Tor lateristriatus*, which have been observed in the Nam Theun on the Plateau may actually migrate between the Lower Nam Theun and the headwaters. The distribution of locally migrating fish species such as the *Tor* species can be impacted by the dam, acting as a physical barrier. Juveniles of *Tor lateristriatus* have been observed mostly in shallow areas with sand substrate and large adults inhabit deep pools. If large adults cannot adapt to the reservoir environment the species might become extinct upstream of the dam. Any direct losses to fishermen resulting from a loss in fish production in the Nam Theun below the Damsite (Zone 4) will be mitigated through reservoir productivity (Zone 1) as stipulated in Section 6.2.6 on compensation for lost fish production. Mitigation measures are recommended for the NTECo to promote investments in aquaculture (Section 6.2.4) and reservoir fisheries (Section 6.2.4).

The draw down of the reservoir water will cause much fluctuation of the water level. Large land areas will be inundated temporarily and form part of the aquatic habitat during part of the year only. The reservoir water surface area has an average annual fluctuation between 450 and 195sqkm. The rise and fall of the water level of the reservoir will affect aquatic habitats in the lower parts of the tributaries. Aquatic habitats with high primary production and high fish biomass such as rapids and riffles in the lower parts of the tributaries will be drowned out by the reservoir. The habitats at slightly higher elevation will be drowned out during part of the year and the habitats at lower elevation will become part of the reservoir.

Existing aquatic habitats in the Nam Theun river on the Plateau area such as rapids, riffles, pools, floodplain and wetlands will disappear and will become part of the reservoir. Fish species inhabiting

these habitats will have to adapt to reservoir conditions, may find similar habitats in the headwaters, or become locally extinct. Here again it is quite likely that at present, during the wet season the rapids, riffles and pools are drowned.

The 2 m^3/sec minimum guaranteed flow to be released at the dam will be of critical importance for the conservation of aquatic habitats in the river stretch between the Nam Theun 2 dam and the headpond of the Theun Hinboun Hydropower Project. This will be provided as mitigation described in Section 6.2.6. The diversion of water from the Nam Theun to the Xe Bang Fai basin results in a considerable reduction in wet season flow. The wet season flow will consist of spills at the dam when the reservoir level reaches maximum supply level plus up to 10 m^3/sec from the local catchment. The simulated reservoir operations over the last 43 years predicts average spills ranging from 27 to 332 m^3/sec. between August and October; however, actual spills during wet seasons with relatively low rain fall are zero. Under these circumstances during the wet season, that occur once in six or seven years and during all times during the dry season the minimum 2 m^3/sec will be released at the dam. The flow in the downstream river will be augmented by flows upstream of the Nam Phao confluence ranging from 0.3 m^3/sec in April to 10 m^3/sec in the wet season. The minimum guaranteed release may help sustain conditions to reduce impacts on aquatic habitats in the Nam Theun river from the Nam Theun 2 dam to the confluence of the Nam Phao and on downstream to the headpond of the Theun-Hinboun Project.

Loss of Riparian Vegetation From Changes in Water Availability

The existing riparian vegetation is highly resistant to seasonal fluctuations of the water table. The soils are saturated with water at least part of the year. Bamboo forms the main vegetation on the riverbanks and seems to proliferate in this dynamic ecosystem. Where the riverbanks consist of rock outcrop or sandy soil not much vegetation grows on the riverbanks. With the reduction of flow downstream of the dam the water table will drop. The drop in water table may not meet the habitat requirements for *Salix* sp. However, the sparse density of *Salix* sp. does not raise concerns about the loss of contribution to aquatic habitats.

From aerial photographs taken of the mostly rocky and occasionally sandy riverbanks in the 12 km long river stretch between the dam and the confluence with the Nam Phao it can be concluded that trees growing close to the riverbed are of the same species and of the same size as trees growing on higher elevations. This indicates that the drop in water table will not significantly impact the existing riparian forest habitats.

Nam Kading, Xe Bang Fai and Relevant Tributaries

Potential impacts of reduction of flowrate by the construction of the Nam Theun 2 dam on the Nam Kading are not expected if the Theun-Hinboun Hydropower Project starts operating. The operating criteria for the Theun-Hinboun project is designed to accommodate spills and minimum riparian release of the Nam Theun 2 Project, in effect allowing these to pass downstream in the Nam Kading without interference. Therefore effects of flow reduction on the aquatic habitats in the Nam Kading or Mekong mainstream are determined by the reservoir operations of the Theun-Hinboun Hydropower Project only, except that wet season spillages will be reduced by the routing effect of the Nam Theun 2 reservoir.

Water diverted from the Nam Theun 2 reservoir into the Xe Bang Fai basin is discharged from the tail race channel into the Nam Kathang Noi. The Nam Kathang Noi will be modified to receive a discharge of 210 m^3/sec. A bypass canal to connect the Nam Kathang Noi with the Nam Kathang Ngai is provided in the design drawings. The construction of the bypass canal does not change natural occurring flowrates and water quality in the Nam Kathang, and avoids blocking off upstream and downstream fish migration between the Nam Kathang mainstream and the Nam Kathang Noi. This allows fish to migrate upstream into the regulating pond and into the Nam Kathang Noi.

The water from the tailrace channel received in the to-be-adjusted river bed of the Nam Kathang Noi will enter the regulating pond. The regulating pond will be constructed in the river bed of the Nam Kathang mainstream. At the end of the regulating pond a weir will be built to adjust flow rates to be discharged in a 35 km long channel connecting the regulating pond with the Xe Bang Fai. The channel will be built in the low-lying land of the Gnommalat plain following the height of land initially and the natural drainage. The main natural drainage used will be the Nam Phit. A bypass will be constructed along the regulating pond, between the Nam Kathang Ngay and the Nam Kathang mainstream to maintain the natural flow patterns within the Nam Kathang as in Figure 3-5 (Regulating Pond and Weirs) and Figure 3-6 (Downstream Channel). NTECo will maintain a minimum flow in the Downstream Channel during times when power is not being generated. This mitigation measure is designed to sustain fish populations throughout the year, and is discussed in Section 6.2.6.

The Nam Phit is a natural drain for most of the wet season. In the dry season it becomes dry, except for a couple of kilometers of backwaters from the Xe Bang Fai upstream of the confluence. With the discharge of 210 m^3/sec from the power station the Nam Phit will continuously contain water. The riverbed has to be widened and probably deepened to carry the increased flow at a maximum water velocity of 1 m/sec. There will be major changes in flow regime and seasonal aquatic habitats in the Nam Phit. The river bed of the Nam Phit has much vegetation and trees, which need to be removed. During the wet season most fishery methods consist of fish trapping. In the dry season some isolated pools in the riverbed function as fish trapping ponds. Small frogs, crabs and mollusks are collected for consumption in the dry season. Existing fisheries practices will undergo major changes with the continuos waterflow in the Nam Phit, especially to the confluence with the Xe Bang Fai where the backwater environment will change from medium to fast flowing aquatic habitat. Fish species such as the air breathers commonly associated with isolated pools and slow flowing lowland tributaries will be significantly impacted.

At the weir of the regulating pond the option exists to discharge water in the mainstream of the Nam Kathang. This mitigation measure will possibly replenish the Nam Kathang during the dry season in order to maintain and enhance beneficial uses as described in Section 6.2.6. The Nam Kathang presently has a very low flowrate in the dry season, resulting in an over use of the water resources and boat travel difficulties.

The Xe Bang Fai mainstream will receive 210 m^3/sec extra the year round. Downstream of the confluence with the Nam Phit, all the drains and tributaries to the Xe Bang Fai will experience high water levels and flow in the Xe Bang Fai. At the confluence of the drains and tributaries the area of backwaters will be increased. The general effect on fish production will be positive: more water, more fish production. The existing fish diversity is not expected to be greatly affected. The nominal endemic species found in the middle reach of the Xe Bang Fai have also been observed above the confluence with the Nam Phit. Downstream of the confluence the flowrate and water depth will be increased, but it is expected that the existing diversity of the fish fauna, which is similar to that of the fish fauna of the Mekong mainstream, will not change dramatically.

Loss of Existing Wetlands and Creation of Wetlands in the Reservoir

Some perennial wetlands exist due to flooding of the Plateau area in the wet season. Most of the wetlands are used by buffaloes and livestock for bathing and drinking, form a water source for paddy fields and are fished. The improvement of access by the construction of logging roads is believed to have increased the exploitation of wetlands. Existing fisheries practices during the dry season include the use of buckets to empty parts of the wetlands. Claridge (1996) mentions the value of the wetlands for wildlife, however, fish species recorded from wetlands on the Plateau do not have any conservation value. Most fish species found in the wetlands are air breathers, which are associated with sluggish or stagnant water with oxygen poor conditions and are widely distributed in

the Mekong basin. During filling of the reservoir the wetlands may contribute to the establishment of potential reservoir fish species.

The operation of the reservoir will create many islands, of which a considerable number will be temporary only. The fluctuation of the reservoir level therefore will create temporary wetlands on islands which do not have established natural drainage lines. Reservoir fish may get isolated at certain times of the year in seasonal wetlands and may be prone to natural die-off but will also provide an important temporary food source for wildlife.

In order to protect all fisheries resources within the project area the EAMP recommends a ban on fishing with explosives throughout the Basin be imposed by GOL to mitigate Project-related losses to fisheries.

5.9.2 Water Quality Alterations on the Aquatic Habitat

Loss or modification of aquatic habitats are induced by change and deterioration of water quality.

5.9.2.1 Temperature Effects

Temperature influences the density of water. The absorption of solar energy heats the water. Light is absorbed more rapidly near the surface of a water body. The warm water near the surface becomes less dense than cool, deeper water. Thus the waterbody can become stratified if wind action cannot mix the upper and lower water layers. The result of stratification is a warm surface water layer and a relatively cool bottom layer. The two layers are separated by a thermocline where the temperature cools of, within a short distance in depth.

With the water diversion from the reservoir to the Xe Bang Fai basin a quantity of 210 m^3/sec cool water will be introduced in a warm lowland river. The existing temperatures in the Xe Bang Fai range from 21 deg C to 32 deg C (Mekong Secretariat). The estimated temperature of the diverted reservoir water ranges from 18 deg C in the dry season to 30 deg C in the wet season. The difference in temperature between the diverted reservoir water and the water in the Xe Bang Fai will be reduced by the expected temperature rise of the diverted water in the regulating pond and in the 34km run to Xe Bang Fai. The retention time of the diverted water from the power station to the confluence of the Nam Phit with the Xe Bang Fai is approximately 12 hours. The average monthly air temperatures on the Gnommalat plain range from 22 deg C to 32 deg C. Aeration of the diverted water in several drops in the channel will also significantly help to reduce the water temperature difference and hence there is not expected to be any significant impact on fish migration. The expected temperature difference between the diverted water and the water in the Xe Bang Fai will be less than 2 deg C. In the wet season the discharged water is mixed with equal or greater quantities of water in the Xe Bang Fai. Therefore there will be no sudden temperature changes in the Xe Bang Fai during the wet season. In the dry season the Xe Bang Fai flow will essentially be the discharged water and largely take on its characteristics including temperature.

Fish migration in the Xe Bang Fai river could be impacted even by this temperature difference. Upstream fish migration from the Mekong river to the upper Xe Bang Fai could be altered to the Nam Phit river instead. The tributaries of the Xe Bang Fai located upstream of the Nam Phit, such as the Nam Kathang, heavily over-fished during the dry season with the existing low water flow, may have reduced replenishment of fish by migration during the rainy season. However year round releases (see mitigation in Section 6.2.6) from the regulating pond downstream to the Nam Kathang plus unaltered flows from the Nam Kathang Gnai would be sufficient to maintain the Nam Kathang fish population more or less at present levels.

The spills from the reservoir over the dam will have similar temperatures as the surface layer of the reservoir. The 2 m^3/sec to be released at the dam site can be taken from the top or near the top and will largely determine the temperature at this point of the Nam Theun.

5.9.2.2 Dissolved Oxygen

Low dissolved oxygen (DO) concentrations in water can cause fish kills or can hamper growth of fish. Continued exposure to low DO concentrations is also a precursor to bacterial and viral infections of fish. The minimum DO concentration tolerable for fish increases, with increasing carbon dioxide levels. High concentrations of carbon dioxide interfere with respiration.

DO concentrations higher than 5 mg/l are desirable for aquatic life. The reservoir is predicted to have DO concentrations from 5 - 8 mg/l over the first two years, ninety-five percent of the time. In the hypolimnion of the reservoir anoxic conditions are expected for short periods not exceeding 30 days in the first year. As in the Nam Ngum reservoir it is expected that the DO of the epiliminon will not be significantly lowered during times of turnover. Only water from the epilimnion will be released below the dam. Water diverted from the reservoir to the powerhouse will need reaeration not exceeding 30 days per year. No significant impacts of low DO concentration are expected on aquatic life in the Xe Bang Fai because reaeration is provided at several drops in the downstream channel.

5.9.2.3 Ammonia and Sulfide

Lethal effects to fish as well as pathological changes in fish organs and tissues are caused by un-ionized ammonia (NH_3). The toxic effects of un-ionized ammonia increase with low dissolved oxygen concentrations, but decrease with increasing carbon dioxide concentrations. High concentrations of ammonia are expected following phytoplankton die-offs. The concentration of un-ionized ammonia increases substantially with increasing temperature and increasing pH. Peak concentrations of 25 µg/l ammonia are predicted to occur during the wet season. These concentrations are close to the baseline values for receiving waters, and are not expected to have any impact on fish.

Bioassays of a number of fish species suggest that any detectable concentration of hydrogen sulfide should be considered detrimental to fish production. Fish egg survival and fish fry development are particularly vulnerable to hydrogen sulfide (Boyd, 1979).

Due to the continuous high oxygen levels in the epilimnion no impacts of hydrogen sulfide will be expected at the surface water layer. Stratification of the reservoir and anaerobic conditions in the hypolimnion are predicted by the water quality model to form hydrogen sulfide; however the likelihood of that happening is low due to the short periods of anoxic conditions in the hypoliminion.

5.9.2.4 Other Factors

The desirable pH range considered for good fish production is between 6.5 and 9 (Boyd, 1979). Predicted pH values for the Nam Theun 2 reservoir are within this range. Photosynthesis removes carbon dioxide from water during daylight causing a rise in pH. The pH of soft waters as the Nam Theun may reach high levels, during periods of heavy photosynthesis of phytoplankton blooms. During the night, respiratory processes release carbon dioxide and the pH declines. The increase of nutrients will lead to phytoplankton blooms in the reservoir. High nutrient levels are expected within reservoirs with insufficient removal of vegetation before impoundment. This can lead to high daily pH fluctuations, which are detrimental to fish production and can even result in outbreak of fish diseases.

Turbidity increase by suspended soil particles will seldom have direct effects on fish, although it may damage the gills at high levels. Turbidity may adversely affect fish populations by restriction of light

penetration limiting photosynthesis. Sedimentation of soil particles may affect spawning grounds and destroy communities of benthic organisms.

The rapid renewal of water within the Nam Theun 2 reservoir (6 months retention time) suggests that no significant effects of potential increase of reservoir water salinity are expected.

Agriculture activities in the resettlement areas may lead to an increase in the use of pesticides. Many pesticides are extremely toxic to fish. The EAMP recommends that agriculture activities be controlled by GOL as detailed in the mitigation measures provided in Section 6.2.4 and also in the RAP.

Dioxins have been measured in a single sample of fish liver and a total amount detected of 0.34 ng/kg during the Theun Hinboun impact assessment (NIVA 1995). Measured concentrations of dioxins were comparable with background concentrations found in fish, suggesting no existing harmful residues of dioxins in the reservoir environment.

At the end of the 1980s, the viral fish disease Epizootic Ulcerative Syndrome (EUS) caused high mortality of fish in natural waters and aquaculture ponds in the Lao PDR, Myanmar and Thailand (ADB/NACA, 1991). The disease outbreak caused considerable economic losses to fresh water fisheries. No direct cause has been found for the EUS outbreak, but deterioration of the water quality greatly increases susceptibility of fish to various diseases.

5.9.3 Impacts on Aquatic Habitats and Fisheries

With the change of the Nam Theun river in the Plateau area and with a reservoir draw down zone of ten meters, impacts on aquatic habitats and fisheries can be expected.

5.9.3.1 Nam Theun and Tributaries in the Plateau Environment (Zones 4 and 5)

With the creation of the reservoir, the confluence of the tributaries with the reservoir will change into river deltas within the reservoir. It is at the location of the river mouth where river sediments are deposited. At these places fish gather for food. With the change of location of the river mouth, due to the fluctuation of the water level of the reservoir, the location of sediment deposition will change. Thus the tributaries may need to find their way through the deposits when the reservoir is at minimum supply level. This change in the location of the river mouth results in a dynamic environment with shifting sediment deposits and changing water depth affecting the local water quality, primary production, fish diversity and fish production. As in the Nam Ngum reservoir, it could be expected that the fishermen may concentrate their activities at the mouths of the tributaries, indicating the value of these newly formed aquatic habitats for fisheries.

The greatest effect on flow will be immediately downstream of the dam. Low flows of 6 to 18 m^3/sec have been recorded and estimated After the dam has been built a minimum guaranteed release of 2 m^3/sec will be adopted which will alter the fish habitats below the dam, including the rapids that will be affected by reduced flow rates. A riparian release of 2 m^3/sec may alter the physical shape and the elevations of the rapids, but the pools will still exist. Apart from the riparian release of 2 m^3/sec, the area below the dam will receive water from spills over the dam during most of the wet seasons. Reduced flow rates in the dry season will lower the DO levels in pools downstream of the dam. Eventually fish species with low DO requirements may take over and form the major part of the fish fauna. The fish diversity will be significantly impacted. Decrease of fish production is expected only in the first few years until the fish species adapted to low DO levels take over. Based on oxygen requirement for 1 kg of fish, needing 1 liter of water per minute for optimal growth, a minimum riparian release of 2 m^3/sec will potentially be able to support a standing stock of 120 tons of fish, far more than the estimated existing 11 tons at the dry season between the dam site and the confluence with Nam Phao. Fish species which replaced the fish species of fast flowing waters, are

not expected to be flushed away by spills over the dam. Fishing should not be permitted in this stretch of the river because it will be part of the wildlife corridor, which is designed to have minimum human intrusion.

Apart from the range of fish habitats and niches a critical factor which determines the fish biomass in the Nam Theun river is believed to be the existing low concentration of nutrients. Currently, the low nutrient concentrations allow only primary production of periphyton in the rapids. Primary production of floating phytoplankton virtually does not exist. This leads to a low biomass in pools and runs of the river together with a relatively low diversity of the fish fauna compared to the diversity in the rapids. In the existing situation a decrease in flow rate in the river reach below the proposed dam site will result in a linear decrease in the amount of nutrients passing through, resulting in less primary production and less fish production.

What the exact effect of the decreased flowrate below the dam will be in terms of biodiversity, standing stock and production is difficult to quantify; however, decrease of flowrate will have special impact on the rapids, which are of a high value as fish habitats. We can expect that the minimum flowrate together with impacts of the dam on water quality of the reservoir and impacts of the dam as a physical barrier for migrating fish will decrease the fish biodiversity. In particular the air breathers and fish species commonly found in swamps and backwaters like Nong Boua and Nong Bian are expected to find their niche in pools with high fluctuating DO levels. The fish production below the dam site will decrease temporarily with the changes in composition of fish fauna. The water surface area and depth of pools are not expected to change significantly. Fish production in the long term may reach the same level or even higher due to the expected increase of primary production in the pools.

The minimum riparian release of 2 m^3/sec will not sustain the existing rapids. Fish species which need fast running waters will be affected e.g., *Bangana* sp. n. aff. *sinkleri*, *Barilius pulchellus*, *Garra* cf. *pingi*, *Onychostoma* cf. *elongata*, *Scaphiodonichtys acanthopterus*, and most species of the families Balitoridae, Sisoridae and Gobiidae (Kottelat, 1996). The EAMP recommends that NTECo implement the downstream surveys to evaluate the changes that will occur (Section 6.2.6).

Impacts of the minimum riparian flow are mainly expected on the fish diversity below the dam. Fish production will be temporarily affected by the change from a fast flowing river into a slow flowing river. Other fish species such as the air breathers are expected to take over. Not much change in the total water surface area of the pools is expected. The temporarily isolated pools will have increased primary production. Therefore fish production is not expected to decrease, if the pools do not get overheated.

The Nam Theun river stretch from the confluence with the Nam Phao to the headpond of the Theun-Hinboun Project is about 46 km long. One new fish species, *Pseudecheneis* sp. n., was caught only in the Middle Nam Theun. Insufficient information on the seasonal water quality of the tributaries is available to predict the effects of minimum riparian release downstream of the confluence with the Nam Phao but the effect of Theun-Hinboun headpond could be expected to be the governing influence in this area.

5.9.3.2 Xe Bang Fai and Relevant Tributaries (Zones 10, 11 and 12)

The Xe Bang Fai basin will receive 210 m^3/sec from the Nam Theun 2 reservoir. Apart from the physical changes in hydrology and flow regime the main impacts are expected to relate to water quality. To reduce potential impacts the retention time in the regulation pond and aeration facilities in the downstream channel have been designed to allow compliance with water quality criteria established for the operations phase of the project. These criteria allow water discharged into the Nam Phit to support aquatic life, and allow use of the water from the drainage channel for fisheries and aquaculture purposes.

5.9.3.3 Below Confluence with Mekong (Zone 15)

The cumulative effects of the Nam Theun 2 and the Theun-Hinboun Hydropower Projects will result in changes of the flowrates of the Nam Theun/Nam Kading, the Nam Hinboun and the Xe Bang Fai river. The changes in flow rate of the rivers will have impacts on the possible migration of fish from the Mekong mainstream up the Nam Kading/Nam Theun. Apart from the possible changes in water quality no impacts on fish migration relating to the increased waterflow are expected in the Nam Hinboun and the Xe Bang Fai.

The size and shape of the plumes of the Nam Kading/Nam Theun, Nam Hinboun and the Xe Bang Fai in the Mekong mainstream will change. The river plumes containing suspended particulate matter, nutrients and phytoplankton are believed to be of importance as feeding grounds for fish. The plume of the Nam Kading in the Mekong will be significantly decreased by water diversion in the Nam Theun. The plumes of the Nam Hinboun and the Xe Bang Fai will be significantly increased.

Exploratory fish surveys in adjacent river basins are currently under way to determine the endemicity of species fo fish identified during earlier surveys in the Nam Theun/Nam Kading and Xe Bang Fai. This information is necessary to understand impacts on fish communities in the Nam Theun/Nam Kading and Xe Bang Fai. This mitigation measure is outline in Section 6.2.2. Local fish standing stock in the Mekong will be altered and fisheries activities in the Mekong mainstream may change accordingly.

5.9.3.4 Nam Theun 2 Reservoir (Zone 1)

The Nam Theun and large parts of the tributaries, with their seasonal high flow and seasonal water depth fluctuations will change into a large waterbody with almost no flow. Habitats such as riffles, pools and rapids which before the Project were temporarily drowned out during the wet season will be permanently inundated. The depth of the reservoir and associated light penetration will restore primary production mainly to phytoplankton rather than periphyton, which presently characterizes the rivers.

As in the Nam Ngum reservoir significant changes will occur in the phytoplankton composition the first few years after completion of the dam. Ten years after impoundment the phytoplankton in the Nam Ngum reservoir was dominated by Desmidaceae, Dinophyta and Chrysophyta (Mekong Secretariat, 1984).

The change in flow regime together with the increase of nutrients will change and increase primary production and will cause different secondary production. Primary production in the form of phytoplankton will give zooplankton populations as secondary producers the opportunity to develop. The dominant populations of macro invertebrates will change. Fish will need to adapt to the new feed sources and opportunist fish species will take advantage of the food bounty. Other fish species will become less frequent or disappear.

With the enormous increase of water volume and water surface area there will be nearly no competition between the fish species for food and space. Without any competition the effort to be made to find food will decrease considerably, causing more effective use of food for growth. This may lead to growth rates of certain fish species seldom seen in natural lakes. During the first few years of impoundment opportunist fish species will form the major part of the fish population. These species are not highly dependent on a specific food source and will not be selective in the choice of their spawning grounds.

After a period of years more specialised fish species dependent on a specific food source and the selection of specific spawning grounds will have found their niches within the fluctuating water volume of the reservoir. Through the more effective utilisation of specific food sources and specific spawning grounds the more specialised species will drive their wedge within the ecosystem of the

reservoir, resulting in a decline of the opportunist species. With the maturation of the reservoir the competition between species and the competition for food resources between individuals within individual fish species will increase. Predatory fish species will influence the population dynamics.

After initial high fish production, fish production stabilises and fish diversity increases within a period of 10 years after impoundment of the reservoir. After this period of time the new aquatic ecosystem of the reservoir will have gained maturity with the stabilisation of nutrient concentrations, fish production and fish diversity.

With the diversion of 210 m^3/sec of reservoir water through the power station fish may be sucked into the tunnel, this is expected to have influence on reservoir fish populations and furthermore, will cause nauseous odours at the turbines. The intake structure will be fitted with screens to minimise this impact.

Filling of Reservoir

During construction of the dam water from the Nam Theun is diverted, bypassing the riverbed at the damsite. The construction of the dam will be staged during the dry seasons. During the first dry season the dam will be partially completed only. In subsequent wet season the reservoir will fill to the level of the unfinished dam and the remaining water will spill. At this stage of initial filling of the reservoir the minimum guaranteed flow of 2 m^3/sec will be maintained through the diversion tunnel in the Nam Theun riverbed to minimise the effects on aquatic life in the Nam Theun below the dam. Also during the time that spills occur, the riparian flow through the tunnel will be maintained to accommodate upstream fish migration. Fish species not observed during the surveys held in the dry season may migrate into the reservoir area. These migrating species may form potentially important reservoir fish.

During the second dry season the minimum guaranteed release of 2 m^3/sec should be maintained, however this time the release should not be taken from the bottom layer of the reservoir. It is at this time that changes in water quality of the reservoir can become detrimental for aquatic life downstream of the dam. By releasing water from the proposed multiple port outlet and through the aeration valve (see Sec 3.4.3), impacts on the downstream fish habitats will be minimised. The multiple port outlet will include screens to avoid debris and fish entering the outlet and clogging up the aeration valve.

Reservoir Aquatic Plants

As in the Nam Ngum reservoir the seasonal fluctuations in water level will prevent extensive growth of emergent aquatic macrophytes. The draw down of the reservoir forces emergent macrophytes to survive in conditions below 9 meters of water column. Insufficient light penetration in these conditions will impair growth of macrophytes. Macrophytes do not occur below 2.5 meters when the Secchi disk transparency is 2 meters (Boyd, 1979). In addition, exposure and desiccation in the drawdown zone will limit emergent growth.

Claridge (1996) mentions the observation of *Ceratophyllum demersum* and *Vallisneria spiralis* in shallow, sheltered locations in the Nam Theun river at the Nakai Plateau. Both can form a refuge habitat for fish and form a food source for herbivorous fish, but will most likely not survive in the draw down zone.

Occasional dense growth of other aquatic vegetation such as *Azolla*, *Pistia*, *Eichhornia* and *Salvinia* have been observed in the Nam Ngum reservoir. The submerged aquatic plant *Hydrilla verticallata* grows abundantly in shallow waters three to five meters from the shore and to a depth of four meters (Mekong Secretariat, 1982). Submerged vegetation are usually absent from waters with moderate to heavy plankton blooms. Therefore high nutrient levels in the reservoir may prevent growth of *Ceratophyllum* and *Hydrilla*, but may stimulate growth of floating vegetation as *Eichhornia.*

Floating water plants such as water hyacinth (*Eichhornia crassipes*) can show very rapid vegetative growth, the adverse effects of which are high oxygen demand through decomposition, interference with capture fisheries and navigation, clogging of water intakes and spillways, increased evapotranspiration water losses and also providence of ideal habitats for the snail intermediate host of the water-borne disease *Schistosomiasis* (Mekong Secretariat, 1982). Mekong Secretariat (1997) states that some outbreaks of floating aquatic macrophytes invariably occur during the first year or two of impoundment due to the trophic upsurge phenomenon. Drawdown is clearly a highly effective method for controlling the proliferation of floating macrophytes. All reservoirs with substantial drawdown are clear of *Eichhornia*, *Salvina* and other floating species.

It has been suggested as a mitigation measure that NTECo build a weir in the Nam Malou to create a sub reservoir containing a permanent water level, which might have positive impacts on fisheries (Section 6.2.4). Due to risk of proliferation of aquatic plants, especially during the first years after impoundment it will not be advisable to isolate parts of the reservoir by weirs or dikes. On maturity of the reservoir it might be considered to permanently inundate part of the artificial floodplain to form special habitats for desirable fish species in the reservoir.

Drawdown Zone Vegetation

In the Nam Ngum reservoir grasses have appeared on the exposed shoreline at low water levels in locations where the land has gentle slope. Most of the steep slopes, consisting of rock outcrop are virtually bare and do not support vegetation.

The draw down zone in the reservoir will function as a floodplain area for fish. The draw down zone will be inundated in the wet season and fall dry during the dry season, simulating more or less the natural fluctuations of flood plain areas. The shallow areas, prone to wind and wave action, will have high DO levels and will mix bottom soil and water, resulting in nutrient contribution. The enlarged littoral zone of the reservoir will form a nursery grounds for fish.

Potential Reservoir Fisheries

Annex K provides a complete list of fish species recorded in the Nam Theun, and indicates those which may be able to thrive in the reservoir. There are about 23 fish species which will be able to adapt to reservoir conditions to establish populations. There will be potential for reservoir capture fisheries, without the need for releasing exotic or new fish species. An analysis of potential yield for the reservoir capture fishery is also found in Annex K. Various means for estimating the yield are used, including comparison with other regional reservoirs.

The lowest recorded MSY in regional reservoirs of 17 kg/ha at maximum supply level has been adopted as a safe estimate for the maximum sustainable yield of the Nam Theun 2 reservoir. This corresponds with a projected total annual fish catch in the Nam Theun 2 reservoir of 765 tons.

Risks and Environmental Acceptability of Introducing Exotic Fish Species

Welcomme (1993) describes the possible impacts of transportation and release of introduced fish species and transferred fish species outside and within their present range. The following risks have been identified, which lead to the conclusion, not introduce any exotic species in the reservoir.

Degradation of host environment

An example can be the common carp (*Cyprinus carpio*), which has been observed in the Nam Theun at a downstream location by Roberts (1996). The common carp, through its habit of rooting up the bottom will muddy the waters. This may shade out macrophytes, choke benthic invertebrates, and through the more rapid recycling of phosphates contribute to accelerated eutrophication. As a result the composition and abundance of the existing fish fauna can be altered.

Disruption of host community

The existing fish fauna can be affected by the competition between the introduced and the existing fish species, by direct predation and by stunting. The introduced species may out compete existing species resulting in a reduction or disappearance of populations. The introduced species may eliminate local species by predation. Stunted populations of the introduced species may suffocate existing species.

Genetic degradation of host stock

By interbreeding of newly introduced fish stocks with the existing fish stocks the genetic fitness is more likely to be reduced than to be enhanced. The genetic characteristics of hatchery reared fish are less adaptive than those of the wild stock.

Introduction of disease and parasites

Outbreak of bacterial, fungal and viral diseases in fish hatcheries is a common phenomenon. The use of chemicals such as malachite green, formaldehyde and the use of antibiotics and chemotherapeutics in hatcheries is wide spread. The introduction of hatchery reared fish is believed to be linked with high risks for disease outbreaks in natural waters.

Socio-economic effects

The socio-economic implications of introduction of species can vary widely from complete change in fisheries methods and fisheries yields to the replacement of fish species with different market value. Subsistence fisheries may change in industrial fisheries and vice versa.

The environmental risks associated with introduction and transfer of fish species in the project area are expected to occur with the diversion of water from the Nam Theun basin to the Xe Bang Fai basin and from the consideration of potential aquaculture activities in the reservoir.

Water diversion from Nam Theun basin to Xe Bang Fai basin

It is unlikely for the fish species and fish eggs to survive the pressure changes associated with fall through the head race channel and into the tunnel and then passage through the turbines. The remains of the fish, possibly infected with disease, however, are discharged in the Xe Bang Fai basin.

Aquaculture development in the reservoir

The fish species commonly cultured in the Lao PDR consist mostly of 'exotic' species as common carp, two Chinese carps, two Indian carps and Nile tilapia. The only indigenous species cultured with success is the silver barb. No aquaculture activities in the Plateau area are believed to exist before the Project. With the introduction of aquaculture activities in the reservoir considerable environmental risk will be taken. Fish typically escape from aquaculture facilities. The EAMP recommends that GOL should not permit aquaculture activities on the Nakai Plateau prior to or after inundation unless using species known to be indigenous to Plateau water bodies.

The NBCA area will also serve as a conservation area for the potential endemic species found in the headwaters of the Nakai Plateau. It is important to avoid any detrimental effects on the potential endemic species by the introduction of fish in the reservoir or by starting aquaculture.

5.9.4 Primary Links to Other Sectors of Assessment

5.9.4.1 Forestry

The EAMP recommends that GOL define the boundaries of the N-NT NBCA in order to control access by fishermen into the tributaries of the NBCA. All the headwaters of the NBCA will be of importance as conservation areas for aquatic life, including the potential endemic fish species. Inhabitants of the NBCA should have limited fisheries rights in the upper sections of tributary arms of the reservoir and in the headwaters. The potential endemic fish species probably do not adapt to reservoir conditions. The NBCA preferably should include the inundation areas of the tributaries at

full supply level of the reservoir. Likewise it is considered desirable to control all fishing and boating activities on the reservoir to minimise potential unregulated access to the N-NT NBCA. The EAMP proposes that GOL set the boundary of the NBCA at least at full supply level of the reservoir and to include the reservoir and drawdown zone at all times.

5.9.4.2 Wildlife

Due to the minimum riparian release of water from the reservoir without sediment load the existing sandbars downstream of the dam will be altered in location and extent in the long term. The sandbars are of importance as a habitat for the River lapwing and wading birds, such as plovers.

The riparian release will influence the fish biodiversity as it approaches minimum or no-flow conditions. The targeted flow of 2 m^3/s will have a moderate to insignificant effect on overall fish productivity below the Dam, but its effect on biodiversity is overshadowed by the presence of the Dams (T-H and NT2) themselves. Fish standing stocks are expected to be impacted only temporarily, primarily by a change in fish species. A continuously released riparian flow at the dam will therefore not significantly impact aquatic life in terms of quantity as a food source for wildlife.

5.10 IMPACTS ON LAND

5.10.1 Agricultural Land

5.10.1.1 Nakai Plateau

Reservoir inundation eliminates 58 ha of cultivated paddies and approximately 280 ha of shifting cultivation. Impoundment at maximum water surface permanently covers 53 sqkm of wetlands, scrub terrain, agricultural lands, and village and road areas. Some 26 percent of the 53 sqkm is so called grazing (scrub) land. Another 57 percent are wetlands that partially serve as grazing areas during the dry season. The remaining area, 17 percent, incorporates villages, roads, and agricultural (rice) production land. This agricultural area loss is permanent. Agricultural production, on the other hand, does not need to be a permanent loss. With good planning, production from the resettlement area should match, and even surpass, production totals from the Plateau area prior to inundation. Mitigation measures on improved production to support sustainable livelihoods to people in the project area are recommended in Section 6.2.4.

Indirect impacts of agricultural land losses on the Plateau, and the increase of settlements on the southern rim, deal more with terrestrial habitats and wildlife issues rather than agricultural ones. This emphasis is due to the fact that new village locations are in, or near, forests. Enhancements and mitigation of these indirect impacts vary with site and issue and are dealt with in the RAP once it is known how many people will be settled in each area.

5.10.1.2 Gnommalat Plain

On the Gnommalat plain (Zones 8 and 9) a loss of agricultural land occurs with the first 10 km of Downstream Channel construction. The estimated amount of productive land loss is approximately 65ha of cultivated paddies. A width of 65m (as discussed in Ch 3) which includes the channel and the channel access road width, establishes the area lost. Direct loss of agricultural land Using an estimate of 1ha per household, the construction modifies land holdings for 65 households. Direct loss of agricultural land reduces rice production by 150 tons p.a., assuming annual production of 1.5 tons per ha. Other land may be converted to paddy, or use of existing land may be intensified through irrigation to make up this deficit. Construction of the channel also creates access difficulties. Map surveys indicate the need for new road bridges at four locations, and foot-tractor bridges at twenty locations along the entire 35km length of new Downstream Channel. The EAMP recommends that NTECo arrange to

have the TKC ask the people to verify the map survey and indicate where they would like footbridges. all present footbridge plans include sufficient width for small farm tractors. Details on these constructions is provided in Chapter 3.

Indirect impacts on agricultural lands from the Downstream Channel are minor. Rice production (yield) will not be substantially affected. Mitigation can easily cover what yield is lost from the loss of the 65ha for construction of the Downstream Channel. The EAMP recommends that NTECo invest in better regional irrigation facilities, as discussed in Section 6.2.4. The homes of villagers will not be relocated, and the channel is routed around settlements. Groundwater rises about 1 to 2 m in the vicinity of the channel. Local dry-season ponds will have more water than before and some local depressions will become wetlands. As an offset mitigation measure to enhance irrigation works, rural electricity will be provided as detailed in the RAP report and is discussed in Section 6.2.4.

5.10.1.3 Xe Bang Fai Reaches (Zones 10, 11 and 12)

Presently, an occasional flood damages or destroys crops along the Xe Bang Fai, as shown in Figure 5-4 (Flood Plains of Xe Bang Fai). Such floods can affect any portion of the 1,900 ha of rain-fed rice fields in the upper reach of the Xe Bang Fai defined as the 48-km length just upstream of the Nam Phit confluence to the narrows below Ban Thahat. The floods can also affect the 500 ha in the middle reach defined as the 37-km stretch between Ban Thahat and the bridge on Highway 13. With the addition of turbine release to natural flooding pattern, greater agricultural losses may occur. Hydrologic studies indicate that flooding will be deeper, longer and more frequent (see Section 5.4). For the Mahaxai area, the increase in depth of flooding for the 5-year flood is 73 cm. Using the same case, the duration of flooding is increased by about 36 hours as a result of the turbined flow above the current rise and fall totals of 50 hrs. Flood frequency also increases. On the floodplain, back from the river, it is difficult without more detailed analysis to assess what the precise changes in depth and duration of flooding will be as this depends on local conditions related to drainage and incident rainfall.

This combination of higher, longer, and more frequent flooding due to constant turbine flows will decrease annual rice production if the present cropping pattern were to continue. Accurate estimate of this can be made from conducting pre-project flood surveys for baseline information and then, after the first year of flood impact monitoring to estimate impacts. The rice crop cannot take an inundation of longer than four days before yield decreases (Chapter 4). For the 10-year flood without the Project, a total of 16,000ha is flooded (including villages, roads , rice fields and open land), and with this flood approximately 1,800 ha worth of rice producing area is lost (estimated from DOI Report). With this same natural flood in combination with a constant turbine release, based on the same field survey an additional 300 ha of rice cultivation may be affected. With such frequent impacts the EAMP recommends that the present cropping schedules be changed to dry and shoulder season irrigation. This proposal is being developed fully as part of the Resettlement Action Plan (RAP) for NT2.

Constant turbine releases also prevent dry-season river bank gardens at their present levels, and cause additional riverbank erosion. The dry-season water level in the upper and middle reaches of the Xe Bang Fai will increase in the neighbourhood of 3 to 4 m, and possibly as much as 4.7 m during the dry season. Higher water levels take out low bank gardens and erodible banks. Both impacts (flooded gardens and eroding banks) are easily remedied. Gardens can be moved up higher on the bank. Compensation measures are provided in the RAP Report.

At the Highway 13 bridge, the turbined water will increase the depth, duration, area, and frequency of flooding, as it will at Mahaxai, estimated to be less than 30 cm for depth, and approximately 30 hours for duration.

At the confluence with the Mekong, however, there will be a reduction in annual peak flood level in the Mekong. The amount of decrease has been estimated by SMEC to be 17 cm at Thakhek upstream of the confluence of the Xe Bang Fai, and 14 cm at Mukdahan downstream from the confluence. The people living on the delta along the Mekong will benefit from less flooding due to the constant turbine releases. Those people near the bridge will endure more flooding. NTEC's calculations suggest that, overall, the number of homes and area flooded will not be significantly changed by the Project's constant turbine releases.

Delta farmers within the Xe Bang Fai floodplain upstream of its confluence with the Mekong will benefit from a program of wet-season fishing and dry-season rice crop irrigation. Fish production will be sustained and there will be an increase in agricultural production without the stresses and losses due to flooding. Indirect impacts with regard to agricultural lands for all three reaches of the Xe Bang Fai are similar to those resulting from the loss of agricultural areas on the Plateau. Dry or shoulder season irrigation can provide more enhancement opportunities, than negative ones.

5.10.1.4 Other Impact Zones

Road and transmission line construction impact agricultural land. New roads open forest areas to settlers, who convert the forest to agricultural land uses. Road development removes agricultural area from production in the Gnommalat plain, and along the approach of Route 8B back to its existing alignment. The transmission lines cross some 23km of agricultural lands. The details on related impacts are presented in the Sub-EA on Transmission Lines (Annex M). Each section presents the details on recommended mitigation for an identified impact due to the road and transmission line construction. Agricultural land impacts are not expected in the other Impact Zones.

5.10.2 Forest Land

Besides losses in the inundation zone, other direct impacts of the Project on forests land will involve the resettlement of about 900 families from the inundation zone, construction of the dam, work camps, roads, switching station, and downsteam channel, quarry, disposal of spoil, and construction of the transmission line to Thailand. The areal extent of these forestry impacts is minor compared to inundation by the reservoir. Most of these sites are under agricultural use or otherwise already deforested. An exception is the escarpment road, construction of which is planned between Nakai Village and the damsite.

Indirect landuse impacts will also result from the power plant due to increased population pressure, and with better access to the thus far remote areas including the NBCA, which will after the Project be better connected to the rest of the country, and will lead to substantial level of immigration. These impacts are discussed in detail in Section 5.8.

5.10.3 Archaeology, Cemeteries and Other Significant Features

5.10.3.1 Purpose of the Assessment

The purpose of the assessment is to identify all cultural properties that are likely to be affected by the Project, to evaluate their archaeological or cultural significance, and to devise appropriate management measures. Appropriate measures are those that are responsive to both national and local wishes and needs. Thus, though the age qualification stipulated in the GOL's decrees is appropriate for items of national significance, the value placed on newer items by local communities must also be considered. Measures must also conform to national laws and regulations, as well as protect items of value from illegal removal before or during construction.

Field work was carried out for earlier environmental assessment (Team, 1995). Discussions with NTEC Project staff and review of Bank documents indicate that Team's previous assessments are acceptable. A team of archaeologists and social scientists are currently updating field identification, as well as consulting with local communities about acceptable management measures, in conjunction with preparation of the Resettlement Action Plan (RAP). The RAP will include measures for managing archaeological, historical and cultural features.

Both the 1990 and 1995 investigations identified possible sites for features by consulting local people, some of whom assisted the teams on their explorations. Local knowledge was supported by reviews of relevant literature, examination of satellite photos and maps. The two teams visited the same 25 Plateau sites located in or near the inundation area. The 1994-95 investigation added one site near Ban Thong Man (Gnommalat area). Areas visited include the Plateau sites of Ban Nam Nian, the northern and southern parts of Ban Nakai, Ban Don, Ban Nikhom 3, Ban Bouama and the ancient pagoda at Ban Nakai; the channel to Xe Bang Fai sites of Ban That Thod, Ban Phon Latkhoui, the former Ban Gnommalat, Ban thong Mang-Tha, the abandoned pagoda at Kouan Kou (Sibounheuang pagoda), Pha Kiu cave, Ban Pha Thoung , the area at the mouth of Nam Phit and Ban Na Kiu.

5.10.3.2 Historical Setting

Both the previous assessments and several other studies indicate that important archaeological or historical items are unlikely to be found in the Project area because evidence suggests it has not been inhabited by culturally or technically sophisticated people (Ovesen, 1993). There appear to be no records of pre-historic inhabitants. In fact, as the CARE (1996) report states, "the story of Nakai . . . is shrouded in primitive mystery." Details of maps drafted as late as the 19th century indicate how little the area's geography was understood. The few manuscripts detailing the history of settlements in the past century or so reportedly were lost when villages were evacuated during the war in the mid-1960s (Ovesen, 1993). In addition, most of the inhabitants of the area are animists whose sacred places are natural features or nominally Buddhist overlaid on many animistic beliefs and practices.

French and Japanese investigations of the 1940s and 1970s respectively indicate that the middle slope areas (Lao Theung) were occupied by humans about 500 years ago, while the lowland areas (Lao Loum) were first occupied only about 200 years ago (EAMP, 1995). Existing evidence suggests that early occupation was impermanent as the area's remoteness prevented permanent habitation while making it an attractive place for people seeking refuge. Prince Anou, for example, is supposed to have used the area as a refuge (circa 1805-27) when fleeing the Thai army. Mention is made of "pre-historic items" such as caves and shelters in the limestone areas of Mahaxai and Gnommalat lowlands. The evidence of these as shelters for people, as well as its historical importance, is unclear. In any event, they will not be impacted by the Project.

In more recent times, Prince Phetsarath, viceroy and prime minister immediately following Lao's independence and later leader of resistance against the French, sought refuge from them in the Nakai community. He built a hunting lodge and a temple, where he installed several Buddha images, and started a cattle raising business. There are also reports of old Buddhist temples in some Plateau villages. These temples were apparently destroyed during the war and not rebuilt later.

5.10.3.3 Project Impacts

The earlier assessments found few sites of great archaeological or historical significance. A few items are probably significant, but little remains today. These include the abandoned

Buddhist temple located in an overgrown area between Ban Nakai Tai and Ban Nakai Neua and about 25 meters from Highway No. 8 and the foundations of a hunting lodge built in the 1940s by a former viceroy and leader of resistance to French control.

Most of the artefacts from the temple appear to have been removed, with only two sandstone images and a corner stone. Local sources contend that the temple was built in the 16th century, but it is unlikely that the area's inhabitants would have adopted Buddhism this early. A recent survey estimate the temple's age as about 100 years. The hunting lodge of Prince Phetsarah is located near Ban Nakai Tai. The lodge itself was destroyed by a fire and only the foundation remains. Some archaeologists speculate that the foundation may contain artefacts of historical value.

A few other items were identified by the earlier surveys, and some of these are shown in Figure 5-5 (Location of Archaeological Sites).

Ban Don	Wooden pagoda
Ban That Thot	Stupa with Buddha images
Ban Keng Gnao	Bronze Buddha image
Pha Kiu	Cave(s)
Kouan Ku	Sibounheuang pagoda (stupa, chapel, praying hall)
Tham pura	Cave, stone Buddha, pottery jug
Ban Phonsavang	Small shrine, 2 Buddha images, traces of temple
Various villages	Cemeteries

5.10.3.4 Management Measures

The EAMP recommends that NTECo implement two kinds of management measures (i) for items that will be affected by construction of various Project features and (ii) for items that are in the reservoir inundation area. A proposed environmental management plan prepared by the TKC states construction affected objects and sites will be marked and "the need for preservation made clear to all persons working on the Project". Active preservation measures, fencing-off such sites, and relocation will be undertaken. If disruption is unavoidable or new discoveries are made during construction, the Ministry of Culture and Information will be consulted and appropriate direction and permission acquired. In order to prevent items from being stolen, they should be catalogued (described on paper and photographed) and physically protected during the construction as detailed in Annex J.

For structures and objects in the inundation area, relocation of items of national significance should be undertake under the guidance of the Ministry (and local offices) of Culture and Information. It may also be necessary to undertake some excavation at sites potentially holding artefacts.

For cemeteries and other items/structures of local importance, NTEC should consult relevant communities for development of culturally acceptable relocation and reconstruction. This work will be done as a part of the resettlement of villages and is addressed by the RAP.

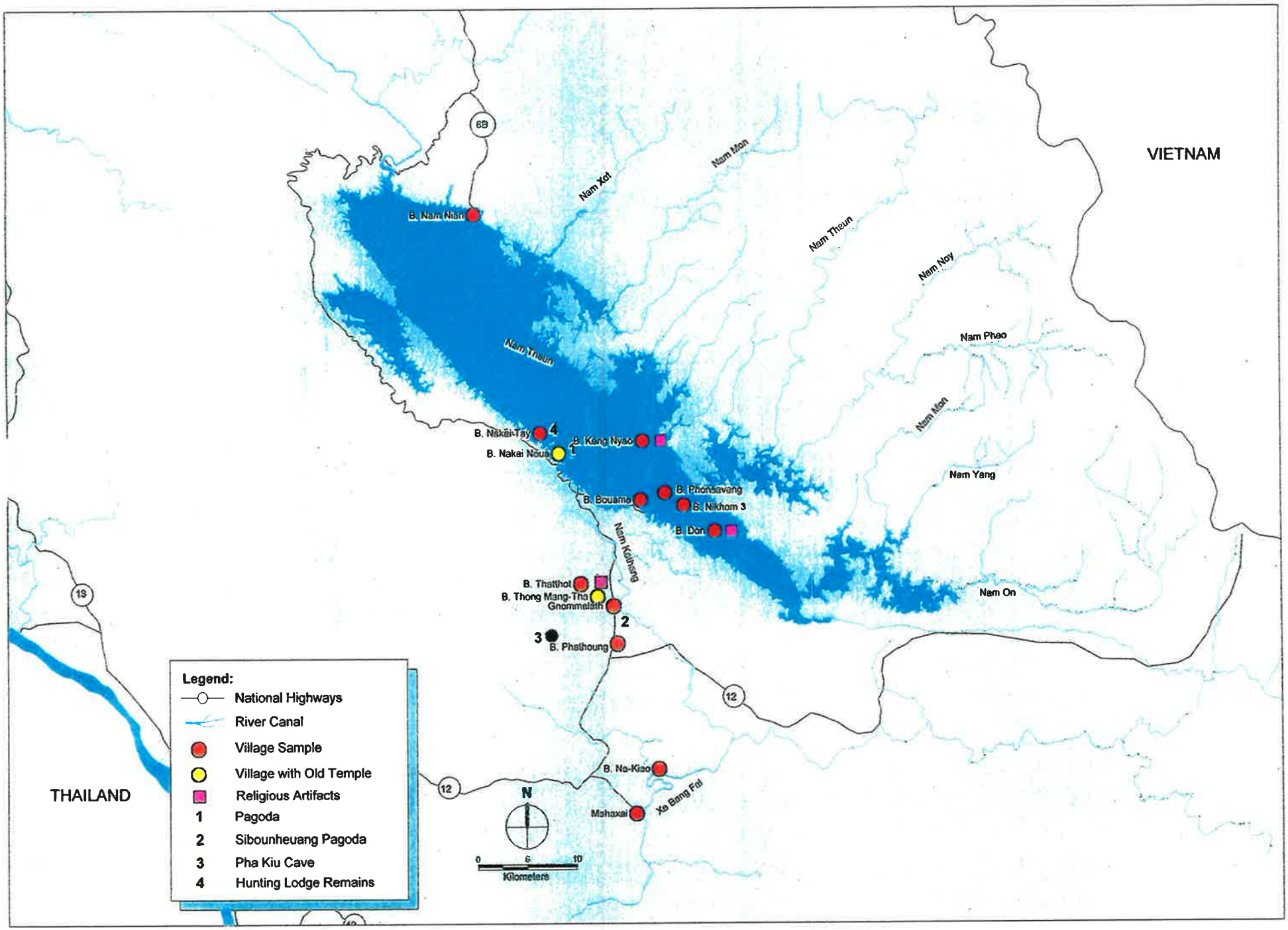


FIGURE 5-5 LOCATION OF ARCHAEOLOGICAL SITES

Source: TEAM 1995

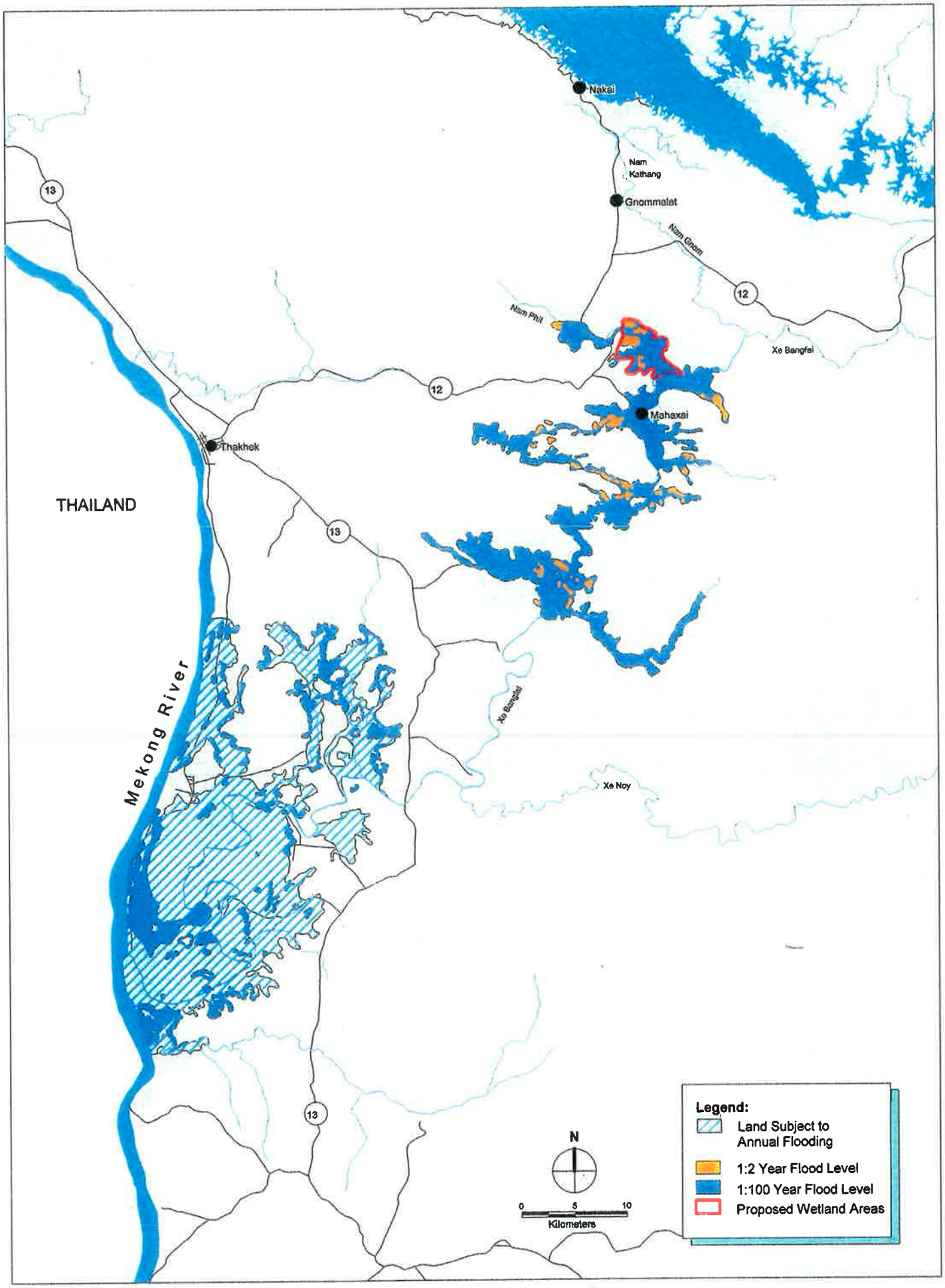


FIGURE 5-4 FLOODPLAINS OF THE XE BANG FAI

Source: PDG, 1995

5.11 PROJECT IMPACTS ON PUBLIC HEALTH

The reservoir, during construction and when completed, is not expected to have an adverse lasting impact on public health within the area of its influence. The downstream area along the irrigation channel, and in the smaller irrigation channels, may play a role in the creation of conditions suitable for continued mosquito breeding, when non-irrigated areas are without breeding, but this is all that will occur and, providing adequate public health measures are introduced, no adverse effects should be expected. Other public health problems expected to be experienced are related to the influx of large groups of construction workers rather than to the impact of the reservoir and the downstream channels, and are dealt with further in this section.

5.11.1 Water Related Diseases

The water related diseases over which concerns have been raised are malaria, schistosomiasis and opisthorchiasis and apart from that outlined in 5.11 above it is considered that impacts will be minor, provided the correct control measures detailed in Section 6.2.3 are in place and functioning.

5.11.1.1 Malaria

Suggestions have been made (Macdonald 1996) that malaria will become a serious problem following an increase in malaria vector density through the availability of increased breeding sites for *A.minimus, A.maculatus* and *A.dirus* at the reservoir and in the area of the downstream irrigation channels. It is accepted that the any irrigation channels, built as part of the Resettlement activities from water available from the downstream channel may constitute a source of continued mosquito breeding for *A.maculatus* and *A. minimus*, however, the proposal that *A.dirus* will increase in numbers following cattle rearing in the area of the reservoir and that their flooded hoof-imprints will provide ideal breeding for *A. dirus* cannot be accepted at this time. At present this mosquito has not been recorded from the area and its behaviour and survival at the altitude of the reservoir during the cold season is not known but considered to be at low levels.

Nam Ngum Experience

During construction of Nam Ngum dam more than 25% of the workforce suffered from malaria at any one time). At that time, DDT (Dichloro-diphenyl-trichlorethane) household residual spraying was regularly carried out as well as the mosquito proofing of all buildings where possible and appropriate. Malaria remained a problem and there was much concern on what the malaria situation would be after the dam was completed. However, following completion of the dam, and its subsequent filling, the mosquito vector population declined and the incidence of malaria dropped to levels where only a few cases of malaria are now diagnosed each year. Reasons for this centre on the elimination of suitable breeding places of the two principal vectors A.minimus and A.maculatus as the dam reached its final level.. This situation has continued to the present. While such an event may not occur in the present Project the previous experience with these disease vectors is important and may well indicate trends which will be seen elsewhere.

5.11.1.2 Schistosomiasis

Schistosomiasis is absent from the project area and is not expected to be a problem with completion of the reservoir or any irrigation channels. Its nearest focus is Khong island, Khong District in the southern reaches of the Mekong in Champasak province. Following the finding of small numbers of the vector snail at Mahaxai it has been suggested that schistosomiasis could become established. It is considered highly unlikely that *Schistosoma mekongi* would be able to establish itself, from its nearest base in Khong. The disease at Khong island has been under considerable control programme pressure since 1989 and

prevalence in the population of about 10,000 persons is now less than one per cent, the majority of those infected being aged between 5-14 years of age.

5.11.1.3 Opisthorchiasis

This disease can only be transmitted through eating raw fish and so fish dishes provided in the mess halls which are cooked, is considered not to be a potential problem. Raw fish dishes are popular in some of the resident communities and it is possible that members of the workforce will expose themselves to conditions where the disease can be transmitted. However, it will be part of the programme to inform all communities of appropriate control methods.

5.11.1.4 Other Parasitic and Vector-borne diseases

Other parasitic and vector borne diseases will remain unaffected by both the reservoir and the newly irrigated areas.

5.11.2 Human Immunodeficiency Virus and Other STDs

HIV is the most important potential health problem which both immigrant workers and the existing communities face and which the Project must be well prepared for. Other sexually transmitted diseases (STD's) are present in the population but are more easily identified and treated.

Transmission of HIV is either by unprotected sexual contact, contaminated blood or body fluids or through the use of shared hypodermic needles among infected drug addicts. Every effort will be made to publicise these facts to both the workforce and to the resident communities.

Although it will be possible at the time of the preliminary medical examination, when recruiting staff, to carry out a simple blood test for this purpose. In addition, this test, like all the other laboratory based tests being carried out for HIV, identifies the patient's antigenic response to HIV which normally only appears about three months after contracting the infection. This means that there may be many false negatives and suspected cases may have to be further tested three months later. That, in turn. will not give a result on any subsequent exposure which may have taken place.

5.11.3 Construction Camp Sanitation and Health Issues

The uninterrupted good health of the workforce is of paramount concern to NTEC and NTECo will be an important criterion to be met when campsites are initially being selected. These issues will be addressed by NTECo via the TKC as mitigation as noted in the TKC Environmental Management Plan and are also discussed in Section 6.2.3. Good siting for the camp with the availability of natural drainage will be another of the criteria to Anti-malaria measures following current accepted practice will be instituted at campsites and facilities established for the early diagnosis and treatment of patients with the disease..

Accommodation facilities at the campsites will include :

- adequate daytime and night-time lighting
- ventilation of buildings to normally accepted standards
- mosquito and fly proofing of mess halls and residential accommodations as well as workplace buildings
- sanitation and washing facilities adequate for the resident workforce
- protected safe water available in sufficient quantity and quality

- suitable liquid and solid waste disposal systems at each campsite

A polyvalent medical unit will be established in the base-camp for the diagnosis and treatment of communicable diseases, simple medical complaints and the handling of medical emergencies and accidents. It will be staffed by:

- one Medical Officer (with experience in minor surgery and the preparation of medical emergencies for evacuation)
- one trained nurse (of senior level)
- two medical auxiliaries
- one laboratory technician
- one driver
- one ambulance, 4 wheel drive

Project staff and their families will receive treatment at the unit. Some direct assistance from this unit will be available to nearby communities and if spare resources become intermittently available. Helicopter transport will be on stand-by for the quick evacuation of serious accidents and medical emergencies. The laboratory technician, in collaboration with the disease control officer, will monitor water quality as part of his normal duties.

Suitable workers will be selected from the workforce and receive additional training in occupational health, safety and first aid, and will form teams of two or three personnel at each work site. They will do this as an additional part of their normal work and will be under the supervision of the person responsible for occupational health and of the medical officer.

For the control of communicable diseases and other public health issues the following staff will be employed:

- one Sanitarian/ Diseases Control Officer
- one Mechanic
- three Semi-skilled labourers
- one Driver
- one Vehicle

The Sanitarian will work full time on the:

- control of vector borne and other diseases
- ensure the continued safe disposal of all solid waste and sewage
- institute fly and other insect pest control at camp sites and in the project area
- provide appropriate information and education to the workforce on prevention of diseases, including, malaria, opisthorchiasis, diarrhoea and HIV/AIDS
- will investigate disease outbreaks
- ensure correct maintenance of water and sewage treatment plants with the assistance of two labourers, appropriate transport and one driver.

5.12 OTHER POTENTIAL CONSTRUCTION IMPACTS

The TKC has developed a Construction Environment Management Plan which details minimum TKC actions in these areas. There mitigations are detailed below and are discussed in Section 6.2.3 and Annex J.

5.12.1 Air Quality Impacts

Most of the air pollution will originate from the fugitive dust resulting from construction activities. In addition to the land clearing and excavation activities for reservoir construction, construction of water conveyance systems, tunnels, and distribution systems, will be potential source of air emissions from point sources.

Most of these are easily controllable and the impacts will be temporary and minor. As detailed in Section 3.4.2.3 water spraying will be the primary protection measure against fugitive dust. All disturbed areas will be stabilised using recommended erosion control measures, and all construction vehicular movement will be carefully regulated to prevent any fugitive dust.

Adequate ventilation systems will be provided for tunnel and other underground construction works. All forms of burning of construction waste and garbage will be conducted according to relevant internationally acceptable guidelines and regulations to minimise any obnoxious or toxic fumes emission.

5.12.2 Noise Impacts

Noise impacts during construction will be temporary and minor primarily from construction equipment and vehicles. All noise levels from construction equipment will be maintained between 50dBA and 85 dBA, meeting the OSHA and MSHA requirements for operator sound exposure limits. Only noise levels from equipment like the Rockbolting jumbo and Jumbo drills for tunnelling and caverns would range around 100dBA. Workers in tunnels will be provided with adequate hearing protection. With these controls the impacts are not expected to generate any significant affect.

All construction equipment will be regularly maintained against wear and tear to keep the noise levels to acceptable levels as stipulated by the relevant standards and guidelines.

Impacts from noise during construction are not expected to cause any nuisance value to the inhabitants of the area as most of the construction sites are very remote from areas of human settlement. In construction areas close to villages and settlements, the construction hours will be restricted and engine noise control devices on construction equipment will be adequately maintained. All construction workers will be provided with adequate hearing protection.

5.12.3 Spoil Disposal

As detailed in Section 3.4.2.5 and Figure 3-7, spoil disposal sites have been designated at, (i) if possible, below minimum water level in the reservoir near the dam and intake works, (ii) on top of the escarpment for some of the tunnel works, (iii) at the escarpment base for the rest of the underground works, and (iv) in depressions and other areas along the alignment of the downstream channel.

All the spoiled material will be collected by scrapers and transported by trucks and dust mitigation measures will be taken by application of suitable wetting agents. All the material will be stockpiled and erosion prevention measures will be taken. The stockpiles will be constructed with smooth slopes and free draining patterns. The height of the stockpile will be limited to 3 meters, and topsoil stockpiles will be deep ripped to provide for moisture retention and regrowth. Drainage and erosion from the stockpiles will be controlled by locating them in

areas away from drainage lines, the erosion of the base of the dump will be prevented by providing a diversion bank uphill to prevent any runoff from reaching the pile, and at the same time constructing a silt fence to contain any runoff resulting from the pile.

5.13 Safety Issues and Occupational Hazards

Mitigation measures to maximise safety and minimise the risk of occupational hazards will be developed as part of the "Workplace Health and Safety Manual".

5.13.1 Introduction

Historically the main safety hazards in a hydroelectric power project have been associated with power plant construction involving land clearing activities through blasting and use of explosives. In addition there is potential for injuries to workers on the site from use of heavy equipment and any hazardous material and incidents related to traffic movements or accidents.

A proper occupational health and safety plan as part of the "Workplace Health and Safety Manual", acceptable for both GOL and the World Bank will be implemented by NTEC. This will include data on noise and air pollutant exposure controls, the various hazardous equipment handling procedures; types, numbers and locations of fire control systems and the fire response procedures, spillage prevention and clean-up; employee health and training; provision of medical treatment; safety training; and the plant safety management structure.

5.13.2 Tunnelling and Blasting

Project design will take into account the earthquake hazard in the region, and provision will be made in the tunnel design to enable prompt repair of tunnel failures. Tunnel construction methods will include adequate attention to worker health and safety. All excavation will proceed in a reasonable manner such that the amount of overbreak, and hence the rock quantities to be removed, are reduced to a minimum, at least along the tunnel length, away from the portal area. All fissured segments in the tunnel route will be avoided in construction to the extent possible. Reinforcement measures, such as rock bolting with wire mesh, will be provided as appropriate to prevent the rock mass from loosening and deteriorating.

Adequate measures will be taken to prevent leakage along the joints by way of grouting behind the segments. In order to reduce any risk associated with water leakage from the tunnel, the inside of the tunnel lining will be coated with a waterproofing product. Provisions could also be made for use of rubber gaskets between the tunnel segments. The tunnel may be excavated by conventional drill and blast methods.

When excavation will take place below the water table, appropriate provisions will be taken to avoid encounter with sudden water inflow at the heading. Probing will be performed ahead of the face in a systematic manner in order to be able to use appropriate measures such as grout curtains, in time.

All blasting activities will be properly scheduled and sufficient advance notice will be given to the workers and the operators in the area to safeguard them from the fallout of the activity. Blasting will be carried out with internationally approved methods and procedures and all necessary precautions will be taken in the process.

Adequate monitoring by the Turnkey Contractor as well as the EMO will ensure strict compliance with safe tunnelling and blasting procedures at all times, and will implement suitable remedial measures in the event of any exigency.

5.13.3 Use of Heavy Equipment and Explosives

All construction workers will be trained in the use of heavy earth moving equipment and other machinery in the construction of the Project. This training will be conducted as a part of their induction program, and their performance will be closely monitored by TKC's designated supervisors.

Guidelines will be laid out in the, "Workplace Health and Safety Manual", for safe use of explosives. All plant personnel and workers will be sufficiently trained in the safe use of all explosives. This will include measures for safe use of gaseous and other inflammable material, cleanliness and workplace management in the explosives store and warehouse, wearing of safety helmets and other protective gear. All explosives used in the plant will be inventoried and access to the explosives store will be strictly regulated and permitted for only authorised personnel.

5.13.4 Fire Protection

Adequate fire protection facilities will be provided. The fire fighting system will consist of site fire ring header with hydrants and hose houses, hose stations, fixed water suppression systems, independent fire detection systems, and hand held fire extinguishers. Fire water will be supplied from two fire/service water storage tanks.

5.13.5 Occupational Health Measures

Adequate measures shall be taken by NT2 Project team and the TKC, to safeguard the health of the workers. These shall include provision of satisfactory sanitary facilities, well equipped with supplies. A detailed pre-employment and periodic medical examination shall be conducted for all the employees.

5.13.6 Occupational Safety and Training

A safety training program will be instituted and all workers at the time of employment shall undergo that program as a part of their induction schedule.

The personnel will be trained in the identification of risk, and potential hazardous situations, with precautions and procedures for safe storage, handling and use of all potentially risky equipment relevant to each employee's task and work. As part of the safety training the workers will be trained in detailed procedures and in an emergency evacuation plan which will be developed for all potentially hazardous activities including any activities involving blasting, construction of underground works, tunnelling etc. Personnel shall be trained in environmental, health and safety matters, including accident prevention, and equipment handling practices and their maintenance and upkeep. Detailed procedures and plan of action shall be laid out to combat emergency situations, including the location and proper use of the emergency equipment, procedures for raising alarm and notifying emergency response teams, and proper response actions for each foreseeable emergency situation. An elaborate communication system shall be provided on the plant that can be utilised to intimate the plant safety department of any eventuality.

5.13.7 Reporting

Safety audits will be conducted on a monthly basis and spot inspections will be carried out by the Workplace Health and Safety Officer to monitor operations and compliance with all relevant regulations. Statistics will be maintained by the Safety Department, and monthly reports will be submitted to the EMO and the TKC environment office. The Safety Dept., will also monitor the performance of all the sub-contractors for compliance with safety regulations.

5.14 SOCIAL DIMENSION

The EAMP focuses primarily on physical and biophysical factors of the NT2 Project's environment. Impact on the area's people is being managed by several other efforts, including a Resettlement Action Plan (RAP), a Social and Environmental Project (NTSEP), and the proposed protected area plan (NBCA). Appendix D contains the RAP outline. This section of the EAMP highlights significant issues related to the social dimension of the Project, including resettlement planning, other directly and indirectly affected people, public participation, and monitoring. Mitigation measures regarding social issues are provided in Section 6.2.4. Public education concerning the Project will be provided as discussed in Section 6.2.2. Further details are provided in the RAP.

5.14.1 Resettlement

The RAP and NT2 Resettlement Policy follows World Bank guidelines on social impact management and directives on resettlement and indigenous peoples (ODs 4.20 and 4.30). The World Bank Mission in February 1997 expressed confidence in the approach NT2 is taking to develop a plan that will meet Bank requirements. Several teams of outside experts are contributing to development of the RAP to assure that it is both economically sound and culturally appropriate. In addition, the Bank will contribute its own expertise and a Panel of Experts will continuously evaluate progress during planning and implementation stages. The major issues are dealt with briefly in the following sections. The reader is referred to the RAP report for detailed advice on these issues.

5.14.1.1 Directly Affected People

The group of people identified to be directly affected from the project was the population residing in the reservoir inundation zone. Attention has also been given to other people in Project affected areas who will lose land, structures, or other items necessary to their livelihood.

5.14.1.2 Institutional Arrangements

GOL and District Working Groups will be responsible for RAP implementation. They will be imparted with appropriate human impact management skills and skills necessary to implement the recommendations of the RAP. The Resettlement Management Unit will undertake training needs assessment. In addition, workshops and study tours are proposed to be undertaken to impart the necessary skills.

5.14.1.3 Basis of the Livelihood Model

The preliminary model is driven largely by income goals and capacity of the land to reach these goals. The model is based on the premise that to allow relocatees to adapt to the major changes in their lifestyle that follow resettlement it is essential that the resettlement programs achieve a substantial improved economic benefit for them.

The model offers a number of livelihood "packages" composed of vegetable and fruit cultivation, a combination of fodder production and livestock raising, forest lot exploitation, fishing and off-farm employment. Each family also would cultivate a small amount of rice, though most rice for consumption purposes would be purchased. Selection of livelihood package will be followed by acquisition of necessary skills and decision making initiatives over a period of time. This will also allow women to undertake more diverse forms of work and thereby contribute to family income. take on a more active role in the day to day affairs of the decision making. With the passage of time, this process will also lead people to adopt suitable technical skills.

Income may also be derived from various outside sources of employment such as : (i) available employment, (ii) available employment during periods when relocatees are not engaged in other livelihood activities, and (iii) based on relocatees' ability to develop rapid skills needed to compete successfully for scarce jobs and perform well once working. Preference will be given to relocatees for project-related work.

5.14.2 Other Directly Affected People

A number of people outside the inundation area may fit the definition of Directly Affected People (DAP). This will include people who will be affected by loss of land, crops, or incomes or whose established social systems will be altered in some way. These are likely to happen to people mostly in Zone 8 (adjoining the downstream channel) and Zones 10 and 11 (adjoining the upper and middle Xe Bang Fai). The preliminary alignment of a 65m wide channel in Zone 8 will require appropriation of about 65ha of agricultural land. In Zones 10 and 11, there will be loss of agricultural land from increased flooding in wet season. During the dry season, augmented flow will eliminate about 38ha (out of 150 ha) of vegetable gardens, though the additional water could be used to irrigate gardens on higher ground. The RAP designates compensation as the preferred measure for managing adverse effects on people outside the inundation zone. The draft Policy states that compensation will be "fair" or of "actual value at the time". All World Bank requirements in regard to "replacement value" will be implemented.

5.14.3 Indirectly Affected People

Indirect effects are the most difficult to identify, partly because the full impact of a Project only becomes apparent over time. It is particularly difficult to predict indirect effects in countries with emergent economic and development policies. One indirect impact that has consistently followed large scale development projects, is the cumulative effect resulting from inadequate management of immigration.

A Project like NT2 offers a host of opportunities, such as employment, large numbers of workers needing services, new and improved roads facilitating access to cultivable land and forest resources, water for irrigation, increases in fish production, or simply the expectation that the area may be targeted for all kinds of development activities.

NT2's construction camps will be inhabited by about 2,000 workers and family members (more details on construction camp impacts are discussed in Section 5.18). This will lead to several informal service providers, hence adequate planning will be undertaken to manage this flux of people to limit the impacts and at the same time enhance the positive effects. The EAMP recommends that all these spontaneous developments stemming from the influx of informal population be regulated by GOL based on its experience with the Theun Hinboun project The TKC have advised of their intention to construct sites for such spontaneous resettlers to include roadways, water supply and solid waste disposal areas to be administrated by an appropriate GOL agency. This will prevent rapid, unplanned and uncontrolled influx of a large number of people and thereby reduce adverse effects including competition for food and income sources and associated problems such as health, demand for infrastructure services.

5.14.4 Public Participation

Consultation and collaboration is crucial to identify and appreciate the nature and scale of a project's effects and to devise culturally appropriate measures for managing adverse effects. Constructive involvement of people, especially those who will be directly affected by a project, began early and will continue throughout construction. The NT2 Project has conducted two kinds of preliminary public participation. These include, (i) consultations with people in the inundation area, and (ii) dissemination of information at the international, national and local levels. Appendix A contains additional details on public participation process for the Project.

Further details on public participation are contained in the RAP report.

5.15 QUARRY SITES

Limestone aggregate and some sandstone will be required as road base for the realignment of Route 8B from Nakai to the damsite, as well as for construction of the dam, stilling basin, saddle dams, power house, intake structure, tunnels, and Downstream Channel. Two borrow sites, located at Phou Phako (Zone 6) and Pha Tung (Zone 9), have been selected. In addition, some sandstone may also be quarried in the damsite area (Zone 1) for crushing into fine aggregates and possibly for rip rap protections. The quarry at Pha Tung is already in operation, and the majority of the crushed material required for the construction of works in the powerhouse and Downstream Channel-Gnommalat Plain regions could be made available from this borrow site.

Development of the quarry site at Phou Phako, a limestone outcrop covering 2.6 sqkm located 20 km northeast of the NT2 damsite will involve the construction of 3 km of access roads by the upgrading of 1.5km of an existing track with new construction of the balance of 1.5 km (requiring 0.08 ha of agricultural land to be cleared) , and the excavation of approximately 250,000 m^3 of limestone aggregate (representing 0.01% of the total outcrop volume).

Large tracts of pure karst exist without vegetation, and it is this habitat type which will be exploited by development of Phou Phako quarry. Pockets of Mixed Deciduous forest exist in valleys and other depressions, but these are of limited extent on Phou Phako and will not be impacted since the quarry will be in a pure karst area devoid of vegetation.

Wildlife species are likely to be important at Phou Phako in limited areas. One such area is a large canyon-like depression on the south side of the mountain where sensitive birds and mammals may occur. However, the quarry will be located on the opposite side of the outcrop to this area and the species therein will not be impacted.

Phou Phako is likely to be important for species such as bats that utilise the limestone caves. The karst formations are known to host a diverse array of lichen species as well. The impact on karst environments may be significant, and the area of impact will be minimised as much as possible. An archaeological site exists on the western side of the Phou Phako outcrop, which is reported by local villagers in Ban Phonhoung to be sacred to the Lao Lum people in the area. Siting of the quarry on the north-west side of Phou Phako, as well as archaeological surveys prior to construction , as budgeted for in the TKC budget will eliminate the risk of damage to such sites of cultural significance.

The effects of erosion on aquatic habitats will need special consideration. Sensitive areas are to the east and southeast portions of Phou Phako which are situated less than 500 m from the Nam Kata River, in addition the access road which crosses the H. Houn stream, and the three potential sandstone quarry sites which are located adjacent to rivers. Measures for erosion and dust control will be employed following best management measures described in construction management plan of the Turnkey Contractor and also in Section 3.4.2.1. Construction worker health and safety will incur costs and planning for proper equipment, supplies and training. Proper training in extraction methods will be enforced in order to prevent unsafe rock landslides.

Spontaneous development impacts from road improvements and the influx of construction workers in the area will be anticipated in the planning. Facilitation of human intrusion into the karst area of Phou Phako will result in degradation of unique karst habitats, increased hunting and possibly some NTFP collection. Prevention or mitigation of unwanted changes will require

a long-term development effort, and is more fully outlined in the Annex L under the sub-EAs on Quarries.

The sub-EA is accompanied by recommended mitigation strategies designed to minimise impact. Institutional requirements for implementation of the recommended strategies are also provided in the sub-EA. Mitigation strategies are to be undertaken by the contractor or the relevant government Ministries during the design, construction and operation of the access road and quarry.

5.16 TRANSMISSION LINES

The transmission lines (Zone 13) will run from the powerhouse at the foot of the Phou Ak escarpment to the Mekong River, and will pass through the districts of Mahaxai, Gnommalat, and Savannakhet. The transmission line will traverse a distance of approximately 144 km and will consist of two sets of conductors installed 60-100 meters apart. The towers supporting the conductors will be 45-55 meters high, and will be spaced on average every 300-400 meters along the alignment of the transmission line. From the powerhouse, the transmission line will run east of Route 8, cross the Nam Kathang twice near Gnommalath, then cross Route 12. It will then follow Route 13 at the village Ban Khotong for about 20 km, after which point it leads off towards the Mekong River approximately 55 km away, as shown on Figure 3-1.

The terrain through which the transmission line will pass is relatively hilly for the first 40 km from the hydropower station. The remainder of the route to the Mekong River crosses relatively flat terrain. Detailed descriptions of the sections through which the transmission line crosses are provided in the sub-EA on Transmission Line in Annex M. The lines will pass through Dry Evergreen (5.2 km), Mixed Deciduous (18.5 km), Dry Dipterocarp (61.5 km), Temporarily Unstocked (35.8 km) forests, and agricultural land (22.9 km).

Environmental impacts for the transmission lines will be predominantly direct impacts which occur during construction. These will arise from the clearing along the easements for the lines and access roads, and earthworks for tower construction. Impacts during the operational phase will largely be limited to the issues of electromagnetic radiation, visual impact and access/maintenance programs. The voltage present on the transmission lines is normally stable and varies very little. The typical voltage is considered to be 3 percent above the nominal voltage of 230,000 volts. Occasionally, under emergency conditions it could be required to operate the lines up to 7 percent above the typical voltage. The maximum electric field under average load conditions for the lines are approximately 3.1 kV/m for Parallel Phase circuits and 2.05 kV/m for Reverse Phase under the lines, decreasing to approximately 0.15 and 0.05 kV/m for Parallel and Reverse Phases, respectively, at the edge of the proposed easements, 30 m from the center between the lines. A separation of 100 m between the two lines will put enough distance between them so that the effects of the electric fields generated by each will not be additive at ground level. The maximum magnetic field conditions for the lines are approximately 210 milligauss (mG) for Parallel Phase circuits and 200 mG for Reverse Phase under the lines, decreasing to approximately 40 mG and 10 mG for Parallel and Reverse Phases, respectively, at the edge of the proposed easements, 30 m from the center between the lines. As with the electric fields, a separation of 100 m between the two lines will put enough distance between them so that the effects of the magnetic fields generated by each will not be additive at ground level.

Strengths of the electric and magnetic fields for the proposed transmission lines at the edge of the easements are below the most stringent recommended limits set by the Australian National Health and Medical Research Council by a factor of 100. Most studies on the health impacts of electric and magnetic fields have recommended a policy of prudence. This policy will be maintained in the construction and maintenance of the lines, particularly in preventing the

development of houses, overnight shelters or places of business within the 60 m easements of each line and in between the two lines (which will be 60-100 m apart).

Potential impacts are discussed in further detail in the sub- EA on Transmission Lines in Annex M. They are accompanied by recommended mitigation strategies designed to minimise the impact. Institutional requirements are also listed for implementation of the recommended strategies. Mitigation strategies are designed to be incorporated by the contractor or the relevant government Ministries during the Design, Construction or Operational phases of the transmission lines works.

5.17 ROADWAYS

Roadways construction will involve the following works:

- The improvement of Highway 12 from Thakhek to Gnnommalat and Route 8B from Gnommalat to Nakai;
- The establishment of various access roads on the Gnommalat Plain which make up a network of tracks linking Route 8B with the power station and ventilation gallery, regulation pond and downstream channel;
- A network of access roads on the Plateau to important operational areas of the project (O&M building, saddle dams, intake, surge shaft); and
- The replacement of Route 8B currently in the inundation zone to create an all weather heavy vehicle link between Nakai and the Nam Theun 2 damsite and back to join Route 8B south of Lak Sao.

The environmental characteristics of the area through which the road will pass and which will be impacted upon by the road working activities have been detailed in Chapter 4. Briefly, the road will traverse virtually undisturbed forest, primarily Dry Evergreen forest (91 km), and to a less extent Mixed Deciduous forest (9 km). Other hàbitat types crossed by the road alignment are Temporarily Unstocked forests (4.5 km) and agricultural areas (3.5 km).

The access roads on the Plateau (service roads to Operator's Village, Upper Water Intake, and rim bunds D1-D4) are all on flat to gently undulating terrain covered by Broadleaf/Coniferous Forest, with the strong dominance of pines tending the community towards coniferous forest in places. The access roads leading from Route 8B (as it descends from the Plateau) to the top and bottom of the surge shaft, both traverse areas of Broadleaf/Coniferous forest.

Environmental impacts include both direct impacts at the road construction site and in the immediate surroundings, and indirect impacts in the adjoining area. Indirect impacts include induced economic, social or environmental effects, whether planned or spontaneous, which are consequences of increased accessibility and lower transportation costs.

Total direct forest vegetation loss for new road construction will be approximately 201 ha. This is a significant impact, particularly for the Dry Evergreen Forest (164.5 ha), a habitat type housing many vulnerable animal species, and several valuable tree species. Vegetation losses will also occur for Mixed Deciduous forests (16.6 ha), Temporarily Unstocked forests (9.77 ha), and agricultural areas (5.8 ha).

As discussed in the environmental baseline section of the sub-EA in Annex N, the relocated Route 8B will pass through large areas of primarily intact Dry Evergreen Forest. These habitats are highly valued by national conservation authorities in the Lao PDR. These forests also contain many "luxury wood" and first class wood" species, and therefore proper salvage forestry should be utilised for removing such trees during easement clearing.

A major direct environmental impact associated with roads is erosion. The relocation of Road. 8B will be along the southwest ridge of the Nakai Plateau. This is a high gradient area, and mitigation measures will be required to minimise impacts particularly on steep slopes, unstable soils, where runoff and drainage will be high, and near waterways. High runoff from the catchment will require adequate drainage structures and culverts. Drainage will be provided by bridges, natural drainage canals, and culverts. Inadequate drainage would cause water to pool, and there is a potential that these then could form areas where fish can be trapped. Lack of adequate drainage and stagnant pools may be breeding grounds for aquatic invertebrates known to be intermediate hosts of waterborne diseases. The TKC should ensure drainage structures are designed and constructed to appropriate standards which will avoid these negative impacts.

Road route location and design will be based on cut and fill parameter, much of the excavation material can be used as fill and roadbase in road construction elsewhere along the relocated Route 8B. Other soil and spoil removed during construction should be stockpiled in areas to be inundated by the reservoir. Disposal bins, toilet and wash facilities should be provided on site, with appropriate treatment prior to disposal. Disposal should be in areas free from the potential of drinking water contamination. Disposal in or near should current aquatic environments and reservoir inundation areas will be avoided. Dust control should be implemented by the application of water to the work area.

Influx of new workers will add to the number of people in the area. Poaching, fishing, and gathering of forest products adjacent to the new road are likely to occur. Hunting and fishing activities by the work forces should be restricted, and should include enforcement measures. Construction worker health and safety will incur costs for proper equipment, supplies and training.

There are many indirect impacts to be considered from the improved year round access to the Project area from new and upgraded roads. Increased access will facilitate people both moving in to settle (spontaneous development) and utilising the road for passage from one area to another. Preventing or mitigating unwanted changes will require a long-term development effort. Human intrusion through this rich forest could result in increased roadside villages, illegal logging, intensive hunting and NTFP collection, and forest fires. Controls on new settlers along the relocated Route 8B will be an integral part of the NT2 Project Resettlement Action Plan in its southern sector. The EAMP recommends that GOL also institute such plans in the NNT-NBCA area in the area traversed by Route 8B..

Potential impacts due to construction of roadways are further discussed in the sub-EA on Roadways in Annex N. This is accompanied by recommended NTECo mitigation strategies designed to minimise the impact as described in the sub-EA. Institutional requirements are also provided for implementation of the recommended strategies. Mitigation strategies are designed to be incorporated by the contractor or the relevant government Ministries during the Design, Construction or Post-construction phases of the road construction.

5.18 CONSTRUCTION CAMPS

A total of five construction camps will be temporarily constructed to house the 2000 workers needed during construction of the Project works. In this section the referenced TKC commitments are abstracted from the Construction Environmental Management Plan. The following camps will be put in place:

- Power station work camp, to house 1,100 workers (Zone 7). The camp is situated between the Nam Kathang and Nam Kathang Noy rivers in early to mid-secondary succession Mixed Deciduous and Dry Dipterocarp forest.

- Dam site work camp (Zone 1), to house 400 workers, a small proportion of which will remain at the site to operate the dam during the operations phase. This work camp is situated in predominantly Dry Evergreen forest.
- Nakai work camp (Zone3), to house 300 workers. The camp will be placed outside Nakai District village near the intake structure. The location has yet to be determined, but will be situated in an unstocked forest or cleared area already under heavy impact from the town of Nakai District.
- Phou Phako work camp (Zone 6), to house 50 workers. Approximately 0.5 km of roads will be needed to access this work camp. The location has yet to be determined, but the area surrounding the karst formation to be excavated is characterised by rice paddy and agricultural lands.
- Pha Tung work camp (Zone 9), to house 150 workers. The site and the access roads have already been cleared. The surrounding area is dominated by rice paddy and mixed crop agriculture.

In addition to the work camps, an estimated 1 km of access roads to these sites will be required (one half km each for access to the Nakai and Phu Phako work camps). Access roads to the other three sites (power station, dam site, and Pha Tung quarry) have already been constructed.

The areal extent of the impacts from the construction camps at the power station, Nakai, Dam site, Phu Phako and Pha Tung and the associated access roads is minor compared to inundation by the reservoir. Nonetheless, all camps will be selectively located so as to avoid clearing as many major trees and vegetation as possible from the area.

The principal threat to forests is from potential indirect impacts. Based on experience from the Theun-Hinboun Hydropower Project, an additional 4,000 people could enter the area near the powerhouse work camp as merchants, temporary and informal workers. This large settlement concentration with attendant needs for food, housing and fuel could impact significantly on nearby forests, many of which are currently in good condition. These increasing demands will likely exacerbate current unsustainable levels of resource extraction, including hunting and fishing. Measure to control such population increases within the project area are designed and The EAMP supports their implementation as a joint effort between NTEC and the GOL spontaneous resettlement control sub-committee.

Special attention to sediment control measures will be taken during construction and operation of the work camps. This will be of particular importance at the power station work camp given its location within 500 m of two rivers, the Nam Kathang and the Nam Kathang Noy. The camps will be located far enough from the riverbeds to minimise disturbance to the riverine environment and protect aquatic habitats.

Generation of refuse from the work camps may encourage improper disposal of fill material and garbage in the area. Adequate disposal, toilet, and wash facilities will be provided at several locations throughout each work camp, and waste will be burned or buried.

Dust control will be implemented by the application of water to the work area. Noise generating activity will be restricted to certain periods of the day. Construction camps will be sited far enough away from construction so that noise is not disruptive. Construction worker health and safety will incur costs for proper equipment, supplies and training. The consolidated bid proposal provided by the TKC will include adequate amounts for provision of safety and health measures at the project sites.

Influx of workers and associated families and merchants into the Project area can facilitate the disease transmission such as malaria and sexually transmitted diseases. Worker education and

training programs focusing on awareness and risk of exposure will be implemented. A comprehensive occupational health and safety program as discussed in Section 5.13 will form part of all Contractors' Terms of Engagement and will be supervised by the TKC's designated on-site representatives.

Potential impacts are further discussed in the sub-EA on Work Camps in Annex O. They are accompanied by recommended mitigation strategies designed to minimise the impact. Institutional requirements are also listed for implementation of the recommended strategies. Mitigation strategies are designed to be incorporated by the contractor or the relevant government Ministries during the Design, Construction or Post-construction phases of the road construction.

5.19 RESETTLEMENT SITES

Approximately 4,500 persons who currently live within the inundation area will be relocated. The proposed resettlement area (Zone 3) of 220 sqkm. is situated on the southwest side of the proposed reservoir as in Figure 3-11. _The impacts of the resettled peoples and their livelihood activities is dealt with in the RAP, a companion document to this report. The Final Draft will include extracts from the RAP executive summary on these issues.

5.20 CUMULATIVE IMPACT ASSESSMENT

Cumulative impacts are possible on three different scales, each with its specific type of impact:

- The Basin-Wide Scale encompassing the Nam Kading-Theun River system and those basins receiving trans-basin diversions, the Hinboun and Xe Bang Fai, in which physical flow alterations are substantial, watershed management practices exert their cumulative impacts, biodiversity issues are common throughout the Basin; and social issues accumulate in village and town centres as a result of the NT2 and the Theun Hinboun Projects.
- The National Scale in which sectoral issues associated with water resources, habitat protection, biodiversity and the national development interests are at stake.
- The Regional Scale focusing on the Mekong River in which hydrological changes accumulate with potential effects on water quality and quantity, biodiversity and biological resource yields, and household economy, primarily in the Tonle Sap Basin, and also in the Mekong Estuary.

Experience shows that cumulative impacts are best addressed through regional planning. The EA points out where these impacts occur and points the direction toward more appropriate planning domains.

5.20.1 The Basin-Wide Scale

The area encompasses nearly all of Central Laos joined by the watershed of the Nam Kading-Theun System and the Nam Hinboun and Xe Bang Fai watersheds. A small area along the Vietnamese border drains east into Vietnam, but should be included in the Basin area under future planning scenarios. The area has some of the highest biodiversity in Laos, and some of the most intact primary forests. Nevertheless in the north portion of the drainage along the Nam Meun, extensive tracts of degraded forests are found. This area will provide most of the riparian flow in the lower part of the Basin after both planned hydropower projects are completed. Areas closer to the interior of the Basin, along Highway 8, and in the lower Xe Bang Fai watershed also experience land management concerns that are best addressed at the Basin-Wide level, including flooding, degraded habitats, and inefficient land utilisation practice.

Development of human resources is closely linked with environmental management. Individual projects, such as NT2, cannot be expected to manage the cumulative effects of an area altered by many circumstances including other projects. Consequently, longer term human issues will be best accomplished within a basin-wide context. The problems associated with projects not integrated within a larger development framework are well documented. Aside from duplication of efforts and inefficient resource use, the cumulative effects of unplanned development can produce serious social and economic problems.

5.20.1.1 Water Flow and Riparian Release

The minimum flow riparian release from NT 2 is not a factor in the amount of water that will be released through the Theun-Hinboun spillway for maintaining riparian needs. The MDX Power Public Company Ltd. (MDX), the Theun-Hinboun BOT company, has agreed to release 5 cumec minimum as dry season flow, and it is stated as such in the 'Environmental Mitigation Agreement' that MDX as the designated operator of the Theun-Hinboun joint venture company has signed with GOL. In the event the 5 cumec is not acceptable from the standpoint of maintaining beneficial uses below the Dam, and if justified on that basis, MDX will consider increasing the amount. (R. Kay, Exec VP MDX, personal communication; 24 Feb. 1997).

Simulated operations for Theun-Hinboun power generation have been performed by MDX, both with and without the project, in order to understand the effect of NT2 on downstream conditions below the Theun-Hinboun Dam, and the result of these simulations is that NT2 has no significant effect on the quantity of dry season riparian release through the spillway at the Theun-Hinboun Dam.(R. Kay, personal communication) There will be significant reduction in wet season flow downstream of the Theun-Hinboun Dam as a result of NT2.

Recent work by SMEC (1997) showed there was no difference in Theun-Hinboun power generation due to change from the 3-turbine to 4-turbine options at NT 2.

5.20.1.2 Watershed Management

The nature of watershed management affects the quantity, release and quality of water in the Basin. The diversion of much of the average annual flow into lower basins points toward the importance of overall management needs, and specifically in the remaining tributaries below the Theun Hinboun Project, such as in the Nam Meun. The NT2 Project does not accelerate watershed degradation in the Basin, and indeed provides funding for ensured sustained protection for its own upstream watershed. The urgency for enhanced watershed management exists without the NT2 Project, although it is capable of resolution in view of the added value assigned to the water resource as a result of its increased intensity of utilisation. Mitigation measures for watershed management will be provided by GOL (as discussed in Section 6.2.7).

5.20.1.3 Biodiversity

Protected areas extend throughout the Basin beyond the limits of the NT2 Project watershed. Biodiversity values in this area are perhaps the best in Laos and probably exceed those found almost anywhere in Southeast Asia. The Project should limit the fragmentation of these habitats and animal populations through the expected improved management of the N-NT and Khammouane NBCAs (see Section 6.2.5). Fragmentation occurs in the Basin independent of the Project as a result of increases of human population and ongoing development. The population of the basin is expected to double in about 25 years without in-migration. A wildlife corridor is proposed to link the N-NT and Khammouane Limestone Protected Areas. Some of the species which will benefit are globally threatened, including elephant, tiger, and wild dog.

5.20.1.4 Social Issues

Some of the cumulative social effects of development without a fully developed planning framework can be predicted, while others can emerge as a result of an inability to recognise issues before they become serious. A larger development framework gives an opportunity to continuously monitor conditions, act as a "caution signal" to identify problems and intervene quickly at the planning and budget allocation level. This approach also supports cumulative capacity building for both government agencies and local communities.

Some predictable effects of rapid and unplanned development while not easy to pre-quantify, are related to the influx of people, project workers and other people who hope to take advantage of real or imagined development benefits, into areas incapable of supporting indiscriminate exploitation. An expanded population in this sparsely populated area need not have negative consequences. A process guided by sound social and economic planning, co-ordinated by a skilled Government entity, can protect the area's human, terrestrial and aquatic environment while, at the same time, bring social and economic benefits. NTEC recognises such issues on the basin-wide scale and is accommodating these in its project development plans through the implementation of RAP and TKC environmental management plans (Sections 6.2.4 and 6.2.3) and its continued support for the NNT-NBCA management plan (Section 6.2.5). These will be accompanied by professional development and language training programs for government staff involved in management.

5.20.2 National Scale

5.20.2.1 Water Resources

Within the Mekong river stretch between the confluence of the Nam Kading/Nam Theun and the Xe Bang Fai already three reservoirs are in operation on tributaries on the Thai side of the Mekong river. These are the Nam Un, the Nam Phung and the Noung Han reservoirs, which drain to the same Mekong river stretch as the Nam Theun, Nam Hinboun and the Xe Bang Fai. Predictions of change in the water level of the Mekong river by the hydropower projects in the Nam Theun are based on the unchanged operational criteria for the Thai reservoirs. This demonstrates the need for regional impact assessments. Regional impact studies take into account the cumulative impacts of all reservoirs on the tributaries in this sector of the Mekong, including the proposed Nam Kading and for the Xe Bang Fai. It should be noted that the hydropower potential of the Nam Theun/Nam Kading basin is proportionately higher than the area it occupies in the lower Mekong basin.

5.20.2.2 Habitat Protection

Environmental controversy related to hydropower dams results from their often negative impacts on aquatic ecology and fisheries. The controversy is aggravated by the lack of baseline data and existing knowledge regarding ecological processes for assessment of the environmental value and the role of capture fisheries. Hydropower dams block or alter the migration of certain fish species whether or not fishways are installed. Minimisation of flow rates downstream of dams, associated with diversion of water to neighbouring river basins may further result in the loss of access to spawning grounds of migrating fish species in downstream sectors. Hydropower dams do affect the area, frequency and duration of flooding. Less flooding and less flood plains, result in declining fisheries. However reservoirs such as Nam Ngum do contribute considerably to the national annual fishing yield. A regional impact assessment focussed on Lao PDR should prioritise the lower Mekong tributary basins for hydropower development as well as for conservation of aquatic habitats. It is understood that both the ADB and the Mekong River Commission are initiating studies along these lines over the next 2-3 years.

5.20.2.3 Biodiversity

The Project will have a positive impact by providing training of, and employment for, a number of biologists and wildlife conservation and enforcement officers. The Project will also provide a catalyst for the first national effort in community level environmental education. This Project will provide a testing ground for integrating forest and watershed management with wildlife and wildlands management.

A negative impact occurs in the aggravation of development and continual deterioration of natural habitat. The NT2 Project is not expected to exert such an impact beyond the threshold of acceptability. Further analysis within the context of national conservation planning needs to go further to evaluate the nature of these impacts.

5.20.3 Regional Scale

The Mekong sub-region is considered by some to be linked together in hydrologic, ecological and economic domains. Within any of these domains, the NT 2 Project is small by comparison with what has already occurred and what is planned for the future. In economic terms, there would be few who would argue that an economically stronger Lao PDR would be able to participate more effectively in the development of the region. The Lao PDR Government is pursuing a policy of developing hydroposer for sale to its neighbours, particularly Thailand and Vietnam. It is doing this at a time when the cost of generating electricity from gas fired combined cycle turbines is at an all time low and appears set to stay that way. It is becoming clear that many of the 60 or more dam sites in Lao PDR, many of which were originally identified by the interim Mekong Committee during the decade of the 70s,will not be economic to develop, at least in terms of conventional economics. Both targetted markets are developing access to gas at a faster rate than to hydro plants.

The Asian Development Bank (ADB) is planning further environmental studies in the Greater Mekong Sub-region (GMS), one of which in particular will address cumulative impacts from development projects. It is not surprising, therefore, that identifying which dams will be built on tributaries in Lao, for instance, occupy a number of specialists full time.

The effects on the Mekong of further reservoir development include altering flow regimes in both the wet and dry seasons. Floods are dampened and dry season flows increase as more runoff is retained in storage. Sedimentation patterns, fish migration and riparian livelihoods are changed.. One important effect that has gained the attention of numerous researchers involves alteration of the flooding regime in the Tonle Sap and potential effects on the Mekong Delta. Many of these concerns are linked. The same causes, e.g. dampening of floods and increasing dry season flows, results in changes in water stage along the channel of the Mekong and the volume of water exchange in the Tonle Sap.

5.20.3.1 Mekong River Hydrological Changes

In assessing the regional impact in terms of hydrological terms, a number of factors need to be taken into account.

NT2 will not play a role in cumulative impacts upstream of the confluence of the Nam Kading with the Mekong. The dams on the Nam Ngum and these planned in China will.

Downstream of the Nam Kading the above dams will have cumulative impacts with NT2 and after the Xe Kang with the dams on the Bolivans plateau area. In addition various industrial and mining developments along the Mekong will have an influence an cumulative flows and water quality.

Obtaining useful data about all these projects is impossible for individual consultants and even governments. It is therefore appropriate that Hydrology Section describes changes along the Mekong reach from the confluence of the Nam Kading to Mukdahan. There is a four percent reduction in dry season flow at in the Mekong at the confluence of the Nam Kading as a result of the NT2 project. At Mukdahan it can be shown that dry season flows slightly increase. Flood peaks are dampened. SMEC (1996) estimated the two year flood peak at Thakhek would be reduced 17 cm and also reduced at Mukdahan by about 14 cm.

Further downstream these effects are progressively dampened by additional catchment flows. That is, flood peaks will be moderated at Thakhek but less at Mukdahan and dry season flows will be increased but barely noticeably.

Effects on the Tonle Sap can be estimated by comparing the hydrologic contribution of the Nam Theun with total Mekong flow and considering the amount of Mekong flow contributing to the inflow of the Tonle Sap. An analysis of this nature was performed by ORSTOM (1993) and is used as the basis for the estimate contained herein.

Mekong Committee data indicate the Nam Kading contributes 5.2 percent of average annual inflow to the Mekong River from a catchment representing 1.8 percent of the total Mekong River catchment area. The NT2 dam intercepts less than one third the flow in the Nam Kading or less than 1.7% of the average annual Mekong flow. The mean annual discharge of the Mekong at Vientiane and Pakse[4] are 4,550 and 10,100 cumec, respectively. (ORSTOM 1993 p. C-11). The mean annual flow at the confluence with the Tonle Sap is estimated to be about 12,000 cumec. The last 40 years show a trend toward lower annual discharges at Pakse, which might be attributed to factors in the catchment. Reduced flow periods are observed from the record during 1955 - 61 and then during 1985 - 89; however the data are inconsistent and spotty.

Maximum water level in the Tonle Sap, or Great lake, usually varies between 9 and 10 masl, but sometimes the maximum is no more than 8 masl, and can reach nearly 11 m. In general, correlation of bathymetric, water level and flow data for the Tonle Sap River and the Great Lake is poor.

The maximum water level in the Tonle Sap occurs between June and September when the average flow at Phnom Penh is 26,200 cumec.

For the same period the current average flow of the Nam Theun at the dam site is about 520 cumec. Of this about 210 cumec is released into the Mekong via the Xe Bang Fai and the remainder stored (unless the reservoir is full and then it will be spilt thereby restoring Mekong flows to their natural level). At worst there is a reduction in average flows of 310 cumec or 1.2% of the flow at Phnom Penh.

Because of the poor data regarding Tonle Sap inundation and flows at Phnom Penh it is not possible to predict the impact on the height of water of the lake, but clearly it would be very small and probably less than 5 cms in 10 metres. This is consistent with ORSTOM who considered existing dams have affected the inflow and maximum water level in the Tonle Sap, but water levels in the Lake also have a strong natural variability that makes actual effects difficult to detect.

[4] Values from Pakse are used because the location provides the longest period of record near to the Tonle Sap. The drainage area for the Mekong at Phnom Penh is 20 percent larger than that at Pakse; however the regimes are similar and there is good correlation between discharge at these two points.

The impact could be greater if NT2 intercepted above average peak flows but, of itself, NT2 is unlikely to have a significant impact. The developers of NT2 have indicated they will co-operate fully with the ADB study described above aimed at quantifying cumulative impacts. It is therefore not possible to quantify the cumulative impacts an hydrology but work is proceeding that will provide a more useful picture prior to a decision been made on NT2. The remainder of this section presents the probable impact of NT2, so that at least its role in cumulative impacts can be more widely known.

5.20.3.2 Other Effects

Major physical and ecological changes can occur in deltas and estuaries as a result of changes in sedimentation and salt water intrusion. The small contribution of the Nam Theun to overall sediment yield in the Mekong indicates the NT2 project will not affect deposition patterns in the Delta.

Salt water intrusion is at its worst during low flow periods. NT2 augments low flows in the Mekong, hence it helps to prevent salt water intrusion. During the wet season, when the flood stage of the Mekong is reduced as a result of the project, salt water intrusion at the mouth of the Mekong is not a problem.

The water quality of the Mekong River compares favourably to other rivers concerning nutrients, organic matter as well as oxygen conditions. With the creation of dams and reservoirs in the tributaries of the Mekong river reduced suspended matter and turbidity may improve the Mekong as a good source for water supply. The construction costs of pump stations in water supply projects will decrease with the expected diminished fluctuations of the water level in the Mekong mainstream.

Navigation will generally be improved in the Mekong river by the increase of dry season flow and diminished water level fluctuations resulting from the construction of hydropower dams.

In summary, NT 2 will contribute an incremental effect to hydrological change in the middle and lower reaches of the Mekong that is expected to be minor in contrast to installed capacity of dams already constructed in Thailand or under construction or proposed elsewhere that will impact flow regimes in the mainstream Mekong. While NT's contribution can be reasonably quantified there is a need for a centralised body such as ADB to document the contribution from other projects so that cumulative impacts can be properly estimated.

5.21 INTACT RIVERS ASSESSMENT

Intact Rivers policy concerns the focusing of development in one or more watersheds and provision of alternative dispersed watersheds with intact and free-flowing rivers. Many of the rivers in Lao PDR are not suitable for hydropower even under the most optimistic engineering and financial assumptions. Furthermore, while the GOL has entered into numerous understandings regarding the development of hydropower schemes on many of the rivers in Lao PDR, it is becoming recognised that many of the projects will not prove to be economic. Increasingly the GOL has concentrated its attention on the three river systems with the highest rainfall, i.e. the Nam Ngum system, the Nam Theun system and the Xe Khang (Bolivans plateau) system. Each of these systems already has a dam operating or almost finished on it. The list of projects put forward to EGAT up the year 2006 only includes projects from these three river systems. These developments reflect an intact river policy of a generic type.

The approach is also providing time for a more integrated development of intact rivers policy.. Information required to develop such a policy is being amassed, in step with actual developments in the Nam Theun and elsewhere in Laos. Information on the status of HPO and is being developed via the Alternatives Studies Analysis and other work such as the ADB-

financed Power Planning Study and EU-financed IPP studies. Another ADB study (being undertaken by the Hydropower Office, MIH), focuses on the Xe Khong, Xe San (along Vietnam, Cambodia and Lao borders) and Nam Theun Basin.

5.21.1 Nam Theun Basin

The Water Use Study by Norplan (1996) evaluates cumulative impacts on the Nam Theun Basin, a topic that is central to the intact rivers argument. It presents a brief comparison of values from various natural resource options and compares the value to power production revenue. Revenues, valued at $500M annually, dwarf benefits from irrigation ($60M), forestry losses ($44M) and fisheries, currently valued at $6M. The report calls for integrated planning and identifies the need for institutional strengthening at the Basin wide level. Without such a planning agenda in place, the future for the Nam Theun River is unclear. GOL holds in their hands an opportunity for Basin planning which could set an example for the rest of Asia. The facilities planned along the Nam Theun are shown in Figure 5-6 (Nam Theun/Nam Kading Drainage Basin).

5.21.2 The National Perspective

Most study of national power planning is occurring at HPO and its technical support groups. The first of these studies is the ADB power planning study that commenced in January 1997. It is currently investigating small (< 50 -70 MW) developments aimed at the domestic market, for government implementation by EdL. These projects will probably be financed by multi-lateral and bilateral agencies. The study aim is to identify and rank at the preliminary stage sites according to technical, financial and environmental feasibility.

A further study carried out under European Union funded Independent Power Producer (IPP) studies is making preliminary evaluations of social, environmental and economic elements at the feasibility/pre-feasibility level. The study is looking at all previously identified sites, except those for which MOUs have already been signed. A further study is focused on the Xe Khong, Xe San and Nam Theun Basins. This study includes both social and fisheries assessments.

The HPO studies will recommend the most desirable sites yet even the ones considered not optimum may not be totally discarded, as with most projects their viability, or likelihood of implementation, is dependent on foreign interest. As a consequence, much of the available literature identifying proposed hydropower developments for Laos contains extensive lists of projects including some of relatively low prospective achievements. The list is likely to grow as alternatives to these are proposed. Further work is necessary at the national planning level to integrate resource management with hydropower.

5.22 INTACT RIVERS COMPLIANCE

Intact rivers are most likely to result where power production is not feasible due to rainfall and slope limitations. Isohyet distribution in Lao indicates highest rainfall activity over the Nam Ngum area and the Bolovens Plateau in the South. Rainfall intensity is still high (but slightly lower than the Bolovens) over the Nakai Plateau and North of Luang Prabang. One factor in undertaking these developments will be the standardisation of approach concerning environment that may limit the cost effectiveness of some projects. At the same time these standards will provide some assurance that hydropower development and natural resource management can coexist.

5.23 MULTIPLE USE ASSESSMENT

This Multiple Use Assessment (MUA) is a review of Project Benefits for multiple uses, including water supply, irrigation, fisheries, recreation and other uses. The target aims to maximise benefits from reservoirs.

The MUA provides an overview of NT2 involvement with assisting in area development along with GOL and local agencies. It contains a review of tourism and recreation potential without setting actual targets, addresses land use, agriculture and animal husbandry in Zone 3, mostly addressed through the RAP; considers pumped irrigation and electrification as key contributions of the RAP in the DS Area (Zones 8 and 10), looks at fisheries and aquaculture potential under consideration along the DS Channel in the Nam Phit floodplain; and addresses use of tailwater for water supply drawn from the DS Channel and below, in the Nam Kathang and Xe Bang Fai.

5.23.1 Tourism

In 1995 tourism ranked as the country's fourth highest revenue generator at US$ 24.7 million, behind wood products (US$ 88.3 million), garments (US$ 76.7 million), and electricity (US$ 25.1 million). Considering the limited collation of tourism statistics during this period, the value of the tourism market is likely understated. These statistics nevertheless reflect a substantial growth trend which should continue to make a significant contribution to the Lao economy.

Lao Tourism

Tourism in Lao PDR is dominated by regional tourism, with international visitors representing only seven percent of the market. Of the 403,000 visitors to Lao PDR in 1996 (NTAL, 1997), 78% were regional, and the majority of these (86%) entered on border passes rather than passports. Border passes are available for a fee to residents of districts adjacent to Lao border crossings, and allow the recipient into the country usually for a day, but sometimes for overnight stays.

Tourist attractions are dispersed throughout the country, and the average international tourist in 1995 stayed 4.25 days. In general Lao PDR is not an established tourism destination, and lacks many of the facilities necessary to accommodate the tourism markets flourishing in neighbouring countries.

Currently, The National Tourism Authority of Lao PDR and Lao tour companies promote the attraction of specific temples and religious sites close to the Mekong River, and also the beauty of the Khammouane Limestone NBCA and limestone landscapes along the Xe Bang Fai. Additionally, the potential for rafting and canoeing on the Nam Kading, Nam Theun and Xe Bang Fai are also noted in Lao travel guides such as the Lonely Planet (1996). Tourist facilities in Bolikhamsay and Khammouane are limited, however increasing trade between Thailand, Lao PDR and Vietnam, and particularly increased usage of the transport routes north and south of the project area will likely stimulate the development of supporting industries. Improved access created by the NT2 Project, such as road improvements to Route 12 east of Thakhek and a new alignment for Route 8B will also likely attract a proportion of the day-tripping Thai tourists to the reservoir, NBCA and the Khammouane Limestone area, and international tourists who may increasingly travel by road to the tourist attractions of Champassak as road improvements to Highway 13 are completed.

The NBCA Management Plan is considering features both internal and external to the reservoir that will influence future tourism.

Laos may be able to provide a niche for eco-tourism to both international and regional tourism markets. Currently, UNDP and NTAL are designing a model eco-tourism development in Luang Namtha in northern Lao that may provide the precedent for sensitive tourism developments in areas such as the NNT-NBCA. Additionally, as in other significant biodiversity conservation areas such as the Annapurna Conservation Area in Nepal and Puerto Rico, the attraction of international scientific research could provide a significant injection into the local economy, while also increasing understanding of national natural resources.

5.23.2 Irrigation

Currently irrigation systems exist in two locations within Project impact zones. A 2,400 ha gravity system exists on the plain in Gnommalat District. Approximately 1500 ha also exist, under the command of seven separate pumped irrigation systems, in the Xe Bang Fai flood plain. Most of these pumped systems serve cultivated land, south of the river, in Xaybuly District, Savannakhet Province. None of these existing irrigation systems functions as well as planned. They are under utilised and not well managed. The gravity system in Gnommalat District only provided water to 740 ha during the 1996 irrigation season. Command (hydraulic) head is insufficient from the weir at Ban Thathod to reach all fields included in the irrigation network. Pumped systems in the delta serve much less than the 1500 ha under their command. The Irrigation Department reports in 1996 that only 130 ha in this area were irrigated. Field visits performed in February 1997, found about 500 to 700 ha being irrigated. The present state of irrigation systems does not allow the agricultural potential in these area to be fully realised.

The NT2 Project creates potential for irrigation (agricultural) development through the provision of an assured water resource for use on the Gnommalat plain and in the Nam Phit and Xe Bang Fai river systems (see Section 6.2.4). Under the current arrangement the Project, once completed, releases an estimated 200 m^3/s increment to the flow of these river systems. It can also release part of the total to the Nam Kathang. The additional water resource offers potential both as a supplemental wet season and, more significantly, a source of assured dry season irrigation water.

Constant discharges also reduce the height (pumping head) for pumps during the dry season. Assurance of water in the dry season, and the reduction the cost of dry-season irrigation, increases the potential of irrigation in all three reaches of the Xe Bang Fai. The upper reach of the Xe Bang Fai, has good irrigation potential and is the easiest to develop since a power source exists already in the region. Due to limited irrigation area, and access difficulties, the middle reach has the least potential and is the most difficult to develop. Very good potential exists to expand irrigated area in the lower reach, below Highway No.13, once the existing systems are functional.

Potential for gravity irrigation system development exists in the Gnommalat plain on both the left and right banks of the Nam Kathang, as in Figure 4-14 (Agriculture Development Area). Estimates place 4,000 ha of cleared land as available for irrigation development on the right bank area and another 3,000 ha on the left bank. Further evaluations would be needed to confirm assumptions, but map work and field visits broadly indicates some 2000 ha along the Nam Kathang and 1000 ha along the upper and middle reach of the Xe Bang Fai, also have irrigation potential. Past studies performed on irrigation potential in the lower reach of the Xe Bang Fai, placed the extent of irrigation area potential at 4000 to 5000 ha, including the existing area served now. Together the areas for potential irrigation development amount to around 12,000 ha. Realisation of irrigation potential along the river reaches, requires construction of new pumping systems. Pumping schemes require a power source, which presently does not exist in many of these potential locations.

The cost for gravity system development is likely to reach US$2000 to $3000 per ha when main and secondary canal construction is included. This cost does not include head works construction costs. Head works are necessary to divert water for the irrigation systems from the Downstream Channel. Costs for pumping systems, once electrical power supply is available, are higher due to the need to purchase and install pumps. Estimates for pumped system development run around US$4,000 per ha.

The opportunity to develop irrigation in these areas coincides with the current national policy for irrigation development in Lao PDR. The Government wants to improve production stability through an expansion of cultivated area under irrigation. Emphasis is on the development of small to medium scale schemes rather than large irrigation projects. By the year 2000 the policy objective of the Ministry of Agriculture and Forestry, is to increase irrigated area to 25,000 ha from the present estimated total of 11,000 ha, (Lao-IRRI, 1995). Developing just the Downstream Channel areas of potential could provide 6,000 to 7,000 ha, of the 14,000 ha objective. Increasing irrigated areas within the Xe Bang Fai flood plain could add to the total.

Successful utilisation of the potential constant water source depends on ability to develop these irrigation systems. Local irrigation development is not the responsibility of the NT2 Project. Success rests with the Government programs and its irrigation department. The NT2 Project can help. NT2 support in this area is described in the RAP. The success of these depends on: (i) better design work, (ii) communication between the users and the designers before design work starts, (iii) trained irrigation system operators, (iv) institutional support for the built schemes, (v) adaptation of new technology to local conditions, (vi) proper maintenance of completed systems, and (vii) funds to design, construct, and operate good systems. Funds for the study, and eventual development of irrigation systems should come from local funds provided by Lao Government. Revenue made available to the Government from the NT2 Project is only one source of Government funds. Finally, success depends on the commitment of the Irrigation Department to implement, monitor, and improve on development strategy.

5.23.3 Fishery Potential

Both capture fisheries and aquaculture activities are expected to increase with the creation of the reservoir and the water diversion to the Xe Bang Fai basin.

5.23.3.1 Potential for Capture Fisheries

According to Care (1996) the existing annual fishing yield of the Nam Theun at the Plateau and the annual fishing yield of the headwaters of the Plateau totals 104 tons. The potential annual maximum sustainable fishing yield of the reservoir alone is projected to be 765 tons, and is discussed as a RAP mitigation measure in Section 6.2.4).

The Nam Ngum reservoir with a similar water surface area as the Nam Theun 2 is supporting 3,800 fishermen (Mekong Secretariat, 1997). If 3,800 fishermen should be given the right of subsistence fishing in the Nam Theun 2 reservoir each fisherman would not be allowed to catch more than approximately 0.5 kg per day to avoid probable over fishing.

Instead of subsistence fisheries, commercial fisheries can be supported in the reservoir, allowing less fishermen with a higher daily catch.

A fisheries management plan, which makes the choice between subsistence or commercial fisheries should be considered in the RAP as further discussed in Section 6.2.4.

5.23.3.2 Potential for Aquaculture

With the availability of water during all seasons and the improvement of access, the potential for development of aquaculture is higher than before the Project, and is discussed as mitigation in Section 6.2.4. However, development of Cage culture in the reservoir will have to be undertaken with due regard to , (i) supplemental feeding, (ii) suitable fish species to be cultured, and (iii) adequate dissolved oxygen concentrations of the surrounding waters. More details are provided below.

Floating cage culture is based on the principle that the surrounding waters provide the necessary water exchange within the cages to sustain favourable growing conditions of fish. Increase of nutrient concentrations by fertilisation to enhance primary production in cage culture is not viable. Fertilisation is effective in pond culture only since water is contained within the pond, whereas fish production in cages utilises the ambient primary production levels in the surrounding waters. Thus supplemental feeding is essential for successful cage culture.

Critical factors for successful cage culture with be the availability, and food conversion rate. Fish feed sources, which can provide reliability of supply and low food conversion rate do not exist near the reservoir.

In addition no reliable supply of indigenous fish species for cage culture in the reservoir exist. Therefore, because of the high pollution load caused by the high conversion ratio of available feed supply, cage culture is not advised to be developed in the reservoir because of high pollution loads caused by the high conversion ratio of available fish feed.

Extensive aquaculture as integrated livestock-fish culture in ponds and rice-fish culture in paddy fields do not need high investment costs, do not discharge water from the ponds and rice fields and do not need additional feeding with animal protein, hence extensive aquaculture has better potential for development in the Gnommalat plain, especially with the increased water availability as diverted from the reservoir.

IRRI (1995) has supported rice-fish culture at the Gnommalat plain in the past, but due to flooding and lack of water after stocking these experiments failed. Rice-fish culture will be more successful in irrigated rice fields since it requires regular water supply and protection from flooding. In rice fields the annual production of fish can reach up to 150 kg/ha, if trenches with a width of 2 - 5 meter and a water depth of approximately 60 cm are constructed along the bunds. A positive impact of stocking fish in rice paddies is the reduction of risks of rice pests, through the consumption of insects by the fish.

Aquaculture development in the Gnommalat plain in the form of rice-fish culture or extensive pond culture can be stimulated with the construction of a hatchery. The hatchery could produce traditionally cultured exotic species, but in the near time serve as a research centre to develop culture of indigenous species. The hatchery could serve as the centre of extension services to the fish farmers and supply fry and fingerlings for rice-fish culture and pond culture at the Gnommalat plain.

5.23.3.3 Markets

I. Impact on Availability of Fish in the Marketplace

Using a figure of 10,000 as an estimate of the future population around the NT2 reservoir area, local fish consumption based on minimum required nutritional needs is calculated to be 217 tons per annum (based on the estimated minimum nutritional need of 21.7 kg/capita/day, Mekong Secretariat 1992). If the annual fishing yield of the reservoir is 765 tons, 548 tons of fish per year would be available for marketing outside the reservoir area to towns such as Lak Sao, Mahaxai, Thakhek or Vientiane or even to Thailand. This will be equal to 1,500 kg of fish per day. It is not expected that

marketing of fish from the reservoir will cause any over supply in the market place. Salt water fish is imported from Thailand into the Lao PDR (selling of dried salt water fish has been observed even in Ban Nakai) and fish prices in the Lao PDR are in the same range as meat prices, indicating that demand for fish is higher than supply.

II. Potential for Enhancement of Markets as a Means of Income Generation

Care (1996) estimated the average price of 1 kg of fish paid to the fishermen as 850 Kip per kg. Prices per kg of fish sold in the Vientiane market range between 1,600 - 5,000 Kip (Vientiane Times, 1997). With the development of access for fishermen to the reservoir, the establishment of central landing places along the south shore of the reservoir, together with small fish processing and ice making facilities a distribution network can be set up to supply fish within the local area as well as to outside markets. At the moment middleman are already operating by buying fish from the Plateau area and selling in Laksao. According to one middleman the buying price of fish at the village close to the Damsite was 500 Kip and his selling price in Lak Sao market was 1,000 Kip.

Given adequate fishing facilities, processing, access for the fishermen to the reservoir and transport for marketing the catch 1,500kg of reservoir fish can fetch on a daily basis a minimum revenue of 1,500,000 Kip can be generated from selling fish outside the reservoir area. The value of reservoir fish consumed at the reservoir area could then be at least 297,000 Kip per day.

5.23.3.4 Reservoir Fishery Role in Resettlement

Fisheries can form a substantial income for the people in the resettlement areas, if the fisheries right is obtained. Income by fisheries activities can be generated in kind by subsistence fisheries, in cash by commercial fisheries or in a combination of both. Processing, distribution and marketing centres of fish can be developed within the resettlement areas as a means of livelihood. These centers can be run by the resettlers themselves to guarantee the fish price per kg for the fishermen of the reservoir. Existing fisheries practices such as fishing with explosives and fishing with agro-chemicals need to be banned. A comprehensive reservoir fisheries management plan involving the participation of resettlers is also required. The same plan has to include programs for the monitoring of fish population, their use and control program for preventing over-fishing in the reservoir. These have been addressed by the RAP and are also discussed in Section 6.2.4.

5.23.4 Biodiversity

The design and development of corridors based upon studies of movements of birds and mammals is being undertaken under the Project. Some of the species which will benefit from these mitigation measures (discussed in Section 6.2.4) are globally threatened, including elephant, tiger, and wild dog. Another positive impact for the basin and region is the creation of a large area of seasonal wetlands. Wetlands are the most modified ecotype of the region as well as of the basin, as they are the first to be converted to agriculture, generally rice. With wetland conversion, the Schomberg and Elds deer have disappeared, hog deer are low in numbers, and many forms of wading birds, waterfowl and other wetland associates have been greatly diminished. The Project may restore wetlands as an extra mitigation measure as presented in Section 6.2.3

The development and management of potential wetland sites is possible near the village of Mahaxai. In this case, the Project can create wetlands for much of the fauna of the Plateau which was lost or depleted many years ago. A site has been identified which will provide about 18 ha of wetlands if the internal hydrology is stabilized, water can be seasonally manipulated, and the wetland is designed in advance for wildlife and waterfowl (e.g. nest islands and boxes, timing of water coverage, and plantings). Based on study data, such mitigation is designed to support small but genetically secure populations of both bird and animal species currently

resident on the Nakai Plateau. The development of such a wetlands area is subject to TKC discussions with the local population who may wish to see this area developed for fish farming.

5.23.5 Water Supply

Water diverted from the Nam Theun 2 reservoir is discharged from the tail race channel into the Nam Kathang Noi. The Nam Kathang Noi will be modified to receive a discharge of 210 m^3/sec.

At the weir of the regulating pond the option exists for NTECo to discharge water in the mainstream of the Nam Kathang. This mitigation measure is discussed in Section 6.2.6. This option will replenish the Nam Kathang during the dry season. The Nam Kathang has a very low flowrate in the dry season, resulting in an over use of the water resources.

5.24 GLOBAL ENVIRONMENTAL ISSUES

The major global environmental concerns are the proposed Project's potential for global warming and the threat to biodiversity.

5.24.1 Global Warming

There are two important factors relating to the contribution of greenhouse gases to the atmosphere by the Nam Theun Hydro Project. The first factor is the amount of greenhouse gas loading of the atmosphere that will occur by the conversion of the 450 sqkm of Nakai Plateau to lake. The second factor is a comparison of this amount of greenhouse gas with that produced by fossil-fuelled electrical energy generation of an amount equal to that generated by Nam Theun 2. Any other alternatives for generating electricity are considered in Analysis of Alternatives Study.

The proposed Nam Theun reservoir surface area is 450 sqkm, presently covered with a mosaic of various forest types, wetlands, and some agricultural fields. Fifty-one percent of the area is not presently forested, being made up of savannah, grasslands, abandoned paddy land, old shifting cultivation with secondary regrowth, severely logged areas, and other non-timber bearing lands. Only 17 percent of the reservoir lands are Mixed Deciduous and Coniferous or Coniferous Forest. The remainder is Mixed Deciduous Forest (Prosser 1997).

Following inundation, this store of organic carbon will be decomposed by a diverse array of bacteria. The decomposition of carbon will result in the production of carbon dioxide (CO_2) and methane (CH_4), the two greenhouse gases most responsible for the anthropogenic-forced increase in global warming. Much of the production of greenhouses gases will take place in the first years following inundation, and may take decades or even more to complete where the waters are entirely anoxic. In the end, the original carbon stock will be dissipated as follows :

- Diffused as gases to the atmosphere through the reservoir surface.
- Transferred as gases to the atmosphere from reservoir waters in the conveyance channel and rivers downstream from the power plant and spillway.
- Converted into new life in the reservoir water or released water.
- Remain stored in submerged and fallen trees.

5.24.1.1 Global Warming Potential

Each greenhouse gas produces a different degree of warming effect for a given amount (expressed in moles), and the life-times of the different greenhouse gas molecules are different. A molecule of methane is much more effective in forcing warming than carbon dioxide, but the average life-time of a carbon dioxide molecule in the ongoing atmospheric processes is much longer. In the anthropogenic-induced warming of the world's climate, carbon dioxide gas

contributes approximately 65 percent and methane 16 percent. In terms of a unit of mass of anthropogenic-produced gas, methane is much more effective in the warming process. To account for these differences, methane is converted to its equivalent mass of carbon dioxide, and all results are reported as tonnes of CO_2. This unit of conversion is called the Global Warming Potential (GWP) of the gas. Thus, carbon dioxide has a GWP of unity and methane a GWP value much greater than one, depending on the time period being considered.

The ratio of the annual GWh generated to forested area flooded is a good overview of the relation between hydropower development and greenhouse gases. Comparison of some forested hydropower projects' potential for greenhouse gas production, (McCully, 1996) can be gauged by comparing the electricity output in comparison to flooded area.

Project	Reservoir Area, km^2	Generation GWh/year	Generation per Unit Flooded, GWh/year/km^2
Balbina, Brazil	3,147	970	0.3
Tucurui, Brazil	2,247	18,030	8.0
Churchill/Nelson Canada	1,400	16,000	11.4
Grand Rapids Canada	1,200	1,700	1.4
Nam Theun 2	450	5,400	12.0

Compared to other hydro projects, the energy production from Nam Theun 2 is favorably placed in terms of forest area inundated.

The estimate of greenhouse gas production at Nam Theun (Delmas and Galy-Lacaux) is based on a carbon stock of 70 t(C) representing all below ground carbon which can be converted by biological processes. The yearly production of gases was based on measurements taken from two reservoirs, Petit Saut in French Guyana (first 24 months of operation), and Buyo, Ivory Coast (17th year of operation). Both are in the forested tropics. The results for 20 years of operations are given in the table below.

The Delmas and Galy-Lacaux estimate of carbon release to the atmosphere from forest biomass at Nam Theun is as follows :

Process	Methane million t	Carbon Dioxide million t	Total Released million t (C)
Flux through lake surface	0.12	6.5	1.86
Exported downstream, then fluxed to atmosphere	0.45	4.0	1.43
Total	0.57	10.5	3.29

After starting with 5 million tons of carbon biomass, 3.3 million tons (C) has been converted to atmospheric carbon. That is a reduction of two-thirds in 20 years. However, there is more than one-third left in the reservoir. It was estimated that an atmosphere-to-reservoir flux of 0.4 million tons (C) in the form of carbon dioxide gas occurred in the same period, leaving the reservoir with 2.1 million tons (C). This carbon is in the form of original biomass not yet decomposed, aquatic life in the water column, and decaying dead organisms on the lake floor.

According to the arguments of Delmas and Galy-Lacaux, the methane and carbon dioxide released to the atmosphere in 20 years converts to between 24 to 40 million tons of CO_2 in terms of Global Warming Potential (GWP). In contrast, a fossil-fueled electric generating plant producing the same GWh generates from 85 to 110 million tons (CO_2) in 20 years depending

on the type of fuel, fuel oil producing the lowest number and natural gas the highest. Coal is in between.

Half of the GWP for the Nam Theun reservoir will be realized in the first 5 years of inundation. After 20 years, the production of greenhouse gases from the original biomass will be very small.

The morphology and operating conditions for the Nam Theun reservoir are quite different than for those for which Delmas and Galy-Lacaux studied. At Nam Theun, the amount of reservoir in anoxic condition is small at almost all times in comparison to the total. In the other parts, conditions are aquatic and aerobic for part of the year and dry terrestrial for another part.

The latest estimate for the vegetative stock for the area as a whole at the time of flooding is 57 tons biomass per ha (t/ha) for above ground vegetation (Prosser 1997). If the carbon content remains as before, this converts to 23 t(C)/ha, a very sizable reduction from the previous value of 40 t(C)/ha. Also, tests on below-ground samples have produced an estimate of 34 t(C)/ha in the top 10 cm for this component. 70t(C) is the below ground carbon that can be converted by biological processes.

On Global Warming

The National Research Council of the USA has issued a plan to study the global amount and distribution of aerosols since they mitigate the forcing effect of anthropogenic greenhouse gases (carbon dioxide, methane, nitrous oxide, and halocarbons), ozone, and fossil-fuel soot. The state of knowledge now leaves a broad range between the lowest and highest estimates of the forcing effect for aerosols, the atmospheric suspensions of microscopic and sub-microscopic particles. "If aerosol forcing is at the high end of the uncertainty range, aerosols could be negating virtually all of the present greenhouse forcing." At the other end of the estimates, the amount of aerosols are hardly an influence on global warming. (After Schwartz and Angreae 1996, p.1121).

In total the study used 110 t(C)/ha compared with the current estimates of 57 t(C)/ha. The CWR report in fact considers only 5cm of underground biomass to be reactive which would reduce the figures even further.

With these new values for biomass carbon, the production of greenhouse gases will be less than that given above. The Nam Theun 2 Project will look even more favorable than the fossil-fuel equivalent over the long term when greenhouses gases are considered.

Clearing more of the reservoir area of biomass is a consideration to improve water quality, but clearing is only effective in reducing the greenhouse gas contribution if the vegetation is removed for sawlogs, wood to make chipboard, or some other use to keep the carbon out of the atmosphere.

5.24.1.2 Contribution of Thermal Power Plants to Additional Greenhouse Effect

A comparison can be made between NT2 GHG emissions and comparable thermal power plant (Delmas and Galy-Lacaux, 1996) GHGs generation. The following Tables summarise the greenhouse gas emissions from thermal power plants (coal, fuel oil and gas fired). Greenhouse gases include in addition to CO_2, methane and nitrous oxide, being significant for natural gas and fuel oil.

Greenhouse Gas Emission Factors (Environment Canada, 1992)

Fuel/Gas	CO_2	CH_4	N_2O
Fuel Oil	2.73 T/kL	0.15 kg/kL	0.26 kg/kL
Coal	2.39 T/T	0.02 g/kg	1.1 g/kg
Natural Gas	1.88 T/ML	25 kg/ML	0.02 kg/ML

Greenhouse Gas Emissions from a 700 MW thermal power plant over twenty years.

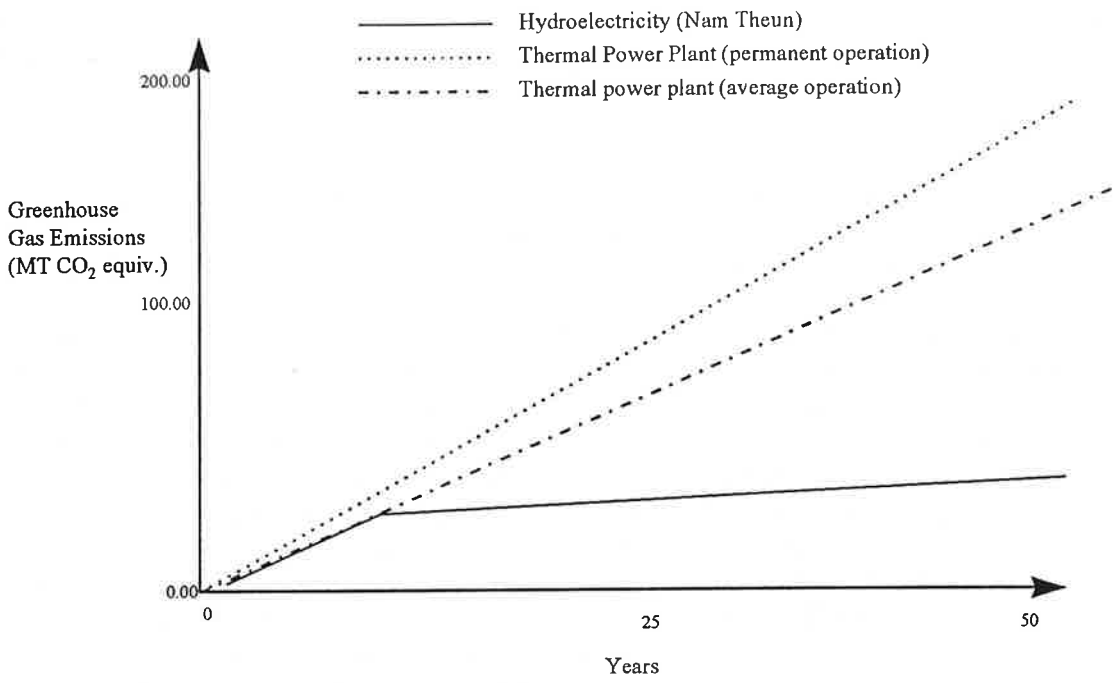
Fuel	Fuel consumption/hr.	Fuel consumption 20 yrs.	CO_2 emission 20 yrs., MT	CH_4 emission 20 yrs.	N_2O emission 20 yrs.
Fuel Oil	170T/H	29.8 MT	87	4.8KT	8.28KT
Coal	250T/h	43.8 MT	105	0.9KT	48KT
Natural Gas	150 ML/h	26.3 PL	48	638KT	0.5KT

Contribution of a 700 MW thermal power plant to greenhouse effect (in million tons of CO_2 equivalent) calculated over a 20 year period.

Emissions over 20 yrs. in CO2 eqv. -	CO2, MT	CH4, CO2 eqv. MT	N2O, CO2, eqv. MT	Total, CO2 eqv. MT
Avg. GWP per unit mass over 20 yrs.	1	77	235	-
Fuel Oil	87	0.4	1.9	89
Coal	105	0.07	11.3	116
Natural Gas	48	49	0.1	97

Thus, it can be seen that the total greenhouse gas emissions (in CO_2 equivalent), over a period of twenty years varies from 89 MT for fuel oil, to 116 MT for coal and to 97 MT for natural gas. These emissions remain approximately constant and thus the accumulated emissions increase linearly with time. However these calculations are for full-time operation for 8,760 hrs per year. To produce 5,400 GWh (anticipated hydro production), the thermal plant needs to operate only 7,700 hours per year. The values of greenhouse gas emissions are then 78 MT for fuel oil, 85 MT for gas, and 102 MT for coal It can be seen that in all the three cases, the GWP is much higher than the calculated GWP for NT2, i.e., 24 to 40 MT of CO_2 even at the higher Carbon loads used in the study..

This reservoir emissions represent less than half of the emissions of a thermal power plant of comparable power. However, these industrial installations are expected to last for more than 20 years. Over longer periods of time (50 to 100 years) NT2 is highly preferrable to fossil fuel in terms of additional greenhouse effect. This is illustrated schematically in the figure below where the greenhouse gas emissions are extrapolated to 50 years both for NT2 reservoir (681MW) and equivalent thermal power plant (700 MW). Details are provided in Robert Delmas and Corrine Galy-Lacaux study on, "Green House Emissions and Energy - Hydroelectric Vs Thermal Production : Applications to Nam Theun 2 Project -1996".



Source : Delmas and Gary-Lacaux, 1996

5.24.2 Biodiversity

Given the high percentage of natural cover, and diversity of wildlife habitats and species, the proposed Nakai Nam Theun (NNT) conservation area, or the NBCA is considered one of the most important biodiversity sites in Lao PDR, being the largest of eighteen such conservation areas recently set aside under Lao PDR's new National Forestry Law 1997. The NBCA is nationally and internationally recognised as one of the most important biodiversity sites in South-East Asia with numerous rare and endangered species being present in the area. Most of the NNT-NBCA is remote and yet to be surveyed. It is contiguous with the Vu Quang Conservation Area in Vietnam and discussions are underway with UNESCO's World Heritage committee and it is expected that NNT and the adjacent Vu Quang may be listed as a transboundary World Heritage Site (Goodland, 1996).

A major part (over 85 percent) of the NT2 catchment lies within the NBCA and thus preservation of the ecological integrity of the NBCA becomes an integral part of overall NT2 Project effort. The NBCA's forests comprise most of the Project catchment and are the source of a steady supply of water with minimum suspended sediment. Effective watershed management and biodiversity conservation are mutually supportive objectives. Maintaining the watershed's hydrological integrity depends on conserving the forests which provide habitat for a significant portion of the area's biological diversity.

Biodiversity assets in the Project impact area comprise the natural flora and fauna as well as traditional crop varieties, though much of flora and fauna have already been impacted as a result of intensive logging, hunting, shifting cultivation, lowland agriculture and non-timber forest product collection.

Habitat losses will occur following reservoir inundation, including riparian and wetland types, which is home to many key species of birds such as River lapwing and White-winged duck and mammals such as Asian elephant. Some of the ecosystems affiliations to be submerged are rare in Lao PDR and elsewhere in the region. This includes the old growth of *Pinus merkusii* forests, perhaps the last in South-East Asia. Although it has already been severely impacted by salvage logging, significant areas remain above the inundation which will be conserved in the

NNT-NBCA.. While habitat and aquatic species loss will occur due to creation of the reservoir, a mitigation plan must be designed such that there will be a net positive gain in conservation terms. Loss of reservoir area ecosystems will be compensated by NTECo's contribution to funding the effective management of NNT-NBCA.

The Project Development Group (NTEC) will assist in both funding and logistical support for the NBCA conservation program, and other international banks, donors, technical assistance agencies and specialists plan to assist the NNT conservation and social management effort.

The World Bank's (WB) involvement in the Project as loan guarantor has helped guide a comprehensive effort aimed at ensuring that the Project's environmental and closely related social impacts are carefully assessed. The NT2 Project Resettlement Action Plan (RAP) for relocating approximately 1,000 families from the inundation zone to areas between the western reservoir margins and the Plateau's escarpment is based on providing livelihood activities which are compatible with sustainable development and protecting biodiversity in NNT-NBCA. An integrated conservation, management and development program for the NNT-NBCA in which 4,800 families currently reside, and an associated WB supported Social and Environment Project (NTSEP) will protect biodiversity in the NBCA. The SEP also includes development programs to ameliorate Project-related impacts in downstream areas affected by water diverted from the NT2 reservoir. The goal of these environmental and social programs will be to ensure conservation of the NNT-NBCA, and its surrounding areas and improved livelihoods through income generation and environmentally sustainable resource use for all people to be affected by the Project.

5.25 Summary and Conclusions

The present chapter covers a variety of project impacts and their environmental effects on the resource values and the people associated with them. Changes in baseline values are considered both with and without the project. Impacts on geology, climate, hydrology, rivers and wetlands, forests, wildlife and fisheries, land use, public health, and the social dimension were studied. Of these, four main issues, on water quality, river water diversion, resettlement, and biodiversity emerge as most critical. These have both positive effects as well as, in cases requiring some form of mitigation as proposed in Chapter 6.

Water quality downstream of the dam, in the Downstream Channel-Gnommalat Plain and in the reservoir will change over time with biomass decay, with water quality improving after the first two years of reservoir operation. In the first two years of operation the reservoir is likely to be moderately productive. Dissolved oxygen will be depleted in the hypolimnion, although at quite high levels at the surface, and nutrient concentrations will be high enough to cause increases in algal productivity and fish production. Dissolved oxygen will increase with time and nutrients will remain low.

The diversion of river water from one river basin (the Nam Theun) to another (the Nam Kading and Xe Bang Fai) will have major impacts on the river basin morphology, fisheries, and land and water use patterns in these two systems. In the Nam Theun river, natural flows downstream of the dam will be reduced by 85percent on an annual basis. Aggradation will deepen the river channel, and the bed composition will be composed of larger, highly compacted substrate. Fishes will be concentrated in pools, and those requiring high flows may be eliminated, thus reducing fish diversity. Movement of regionally migrating species will be restricted by the dam.

In the Xe Bang Fai, the addition of 210 m^3/s will increase the annual flow by 92percent. As the groundwater table is elevated, water levels in wells will increase, wetlands will form in low areas, and water will be available for irrigation. The agricultural potential of the area will thus

increase. Both the duration and frequency of flooding will increase, which will affect residents of the floodplains.

The annual flow of the Mekong River will remain unchanged at the mouth of the Xe Bang Fai. The amount of decrease 187 km upstream at the mouth of the Nam Kading will nearly equally the amount diverted and will not be a significant effect. Monthly average low and high flows will be slightly less extreme below the confluence of the Xe Bang Fai with the Mekong River due to the holding capacity of the reservoir.

The resettlement of 4,500 people currently residing in the inundation area will require a substantial amount of new infrastructure, training and economic assistance. Given that the wildlife and forest natural resources are being depleted by the people living on the Nakai Plateau, the resettlement program which provides a viable livelihood alternative through agroforestry, will foster a sustainable land use system to be adopted by these people. In addition, the relatively low nutrition, public health and incomes of people on the Nakai Plateau will be greatly improved by the development of new infrastructure associated with the resettlement program.

Present threats to forest biodiversity will continue to exist with or without construction of the dam and inundation of part of the Nakai Plateau. Wildlife hunting and trading is intense and increasing. Forest clearing for shifting cultivation is accelerating due to population increases on the Plateau, both from natural population increase and immigration. Continued logging can be expected.

Efforts to manage these threats to biodiversity will be facilitated by a financial contribution to the NBCA management trust. Further, many wildlife populations and forest habitats that would be lost to the reservoir are found in the NBCA, and more value will be gained in efforts to conserve habitats in the NBCA. The recognition of biodiversity values in the NBCA, and improved capabilities for effective management of this area, will set an example for enhanced conservation measures from which the GOL can benefit in other provinces and NBCAs.

Impacts from specific project construction works are also considered. The relocation of approximately 100 km of Route 8B through primarily undisturbed dry evergreen forest will require clearing valuable trees species, and may increase access and exploitation of forest products and wildlife on the southwest side of the reservoir. Construction of 144 km of dual 230-kV transmission lines from the powerhouse in a southwesterly direction to Savannakhet on the Mekong River will impact a minimal amount of unstocked forest and agricultural land. Construction of work camps to accommodate 2,000 workers will require housing, health and safety, and domestic water needs for these people. In addition, planning for impacts on the environment by the in-migration of the associated 4,000-8,000 families and merchants expected to accompany the workers will also create impacts. Quarries will be used for the excavation of limestone and sandstone fill. The impacts of 4,500 relocatees on the Nakai Plateau adopting a sustainable agroforestry livelihood will add some impacts that can be managed with adequate regulation as part of the RAP.

CHAPTER 6

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ATTACHMENTS

6. ENVIRONMENTAL MANAGEMENT PLAN

6.1 INTRODUCTION

The Environmental Management Plan (EMP) comprises 52 Environmental Protection Measures (EPMs) and the establishment and maintenance of the institutional framework required to facilitate, implement, and monitor successful completion of the Plan.

The environmental study areas relevant to this section of the report are the same as described in Chapter 3 of the EAMP. The ESA Zone Map, shown in Figure 6-1, is used to refer to locations where specific EPMs are considered applicable.

The objective of the EMP is to provide a framework for (i) undertaking EPMs related to direct project impacts, and (ii) monitoring of those EPMs throughout the life of the project, focusing primarily on the construction phase. The EMP also provides a basis for evaluating the actual project performance in carrying out the EPMs, including environmental monitoring, with description of the performance criteria that are needed to show that adequate attention has been given to each EPM and its associated monitoring requirement.

The EMP includes mitigation and monitoring for physical and biological effects from the project. It covers EPMs recommended to be undertaken by the GOL and NTECo. The recommended EPMs generally can be classified as mitigation measures, monitoring and studies. Record keeping and standardisation functions are also identified. Record keeping is required of all participants in relation to their activities. Standardisation attempts to document best practice for use in developing criteria for future projects.

The EMP does not include EPMs relating to relating to socio-economic issues or EPMs in the NBCA. The EPMs related to impacts in these areas are to be detailed in the RAP and the WCS/IUCN study respectively.

The Final Report of the EAMP will include summaries of the EPMs contained in these studies, relating to biodiversity, physical and environmental impacts. This will be undertaken to ensure that the EPMs correspond to all identified impacts.

6.2 ENVIRONMENTAL PROTECTION MEASURES

The EPMs are planned activities to ensure prudent environmental management. The EPMs recommended by the Consultant are listed in Sections 6.2.1 to 6.2.7, grouped by the body responsible for EPM execution.

Table 6-1 relates the EPMs to the impacts identified in chapter 5. This table is presented so that the reader can locate the EPM description in the text, and view other attributes of the EPM. This table indicates which sections of the report lead to and necessitate the undertaking of each EPM, based on baseline values prevailing in the project area and the assessment of impacts on specific environmental values.

A total of 52 EPMs are recommended for implementation under the EMP, as shown in Table 6-2. This table cross-references the EPMs by type, or discipline, of activity, the location within the project area (or nominates that the EPM is institutional in nature), the project phase in which the EPM will occurs, the responsible party, the estimated cost, and the schedule for the activity.

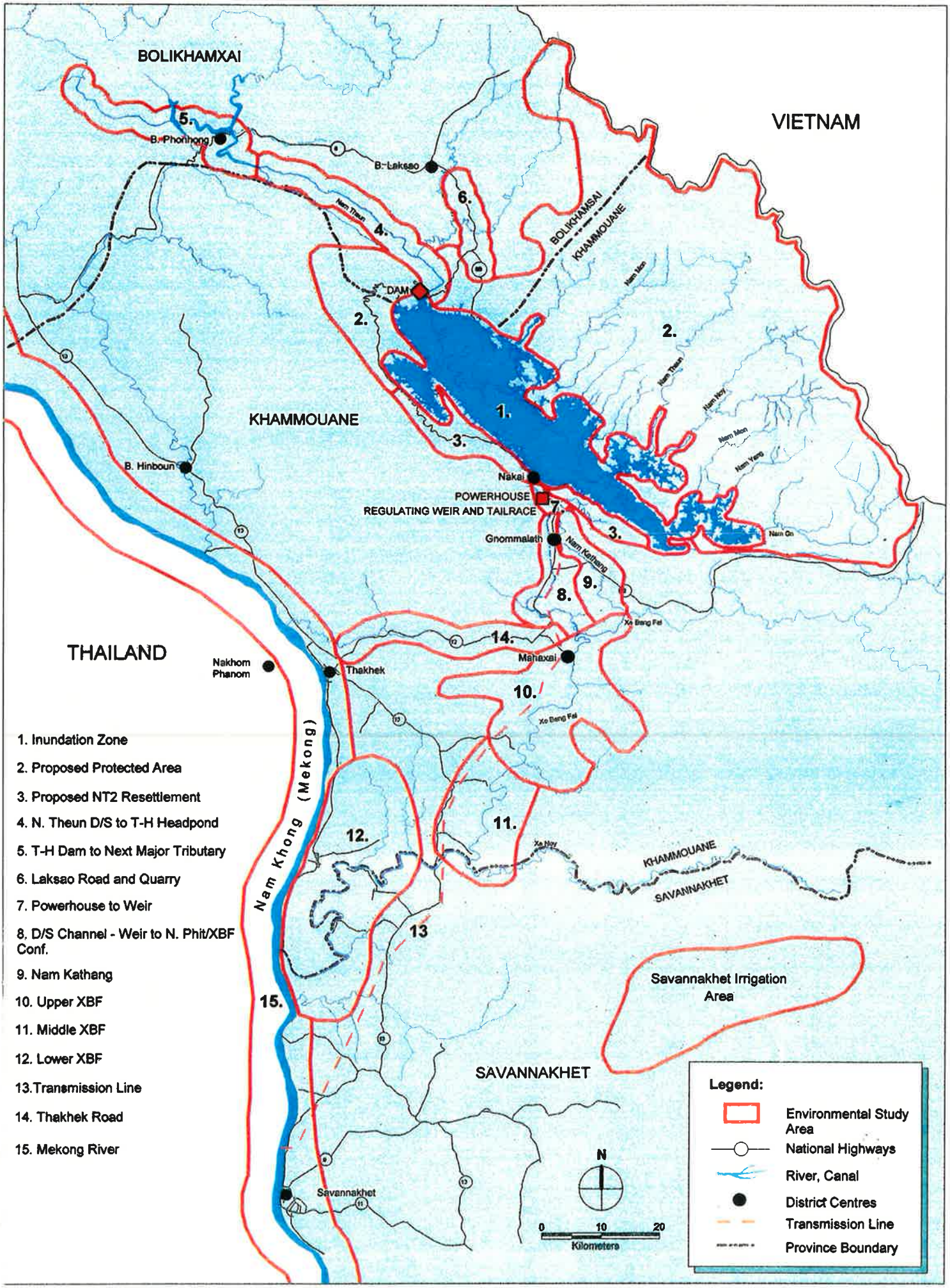


FIGURE 6-1 ENVIRONMENTAL STUDY AREA ZONE MAP

The Master List of EPMs is accompanied by the Implementation Schedules and Period Cost Estimates found in Tables 6-3 through 6-8. These are intended to illustrate timing for undertaking specific EPMs, and to serve as tools for discussion among the World Bank, GOL and NTECo. The means for adjusting contributions and incorporating mitigation measures into contractual documents is the responsibility of the negotiating parties. The Final Report of the EAMP for NT2 will contain updated information on EPMs, costs, and inclusions among different categories, which will represent a further stage in the resolution of these issues.

6.2.1 NTECo Financed EPMs to be Undertaken by STENO

EPM 1 - Formation of the EMU
Formation of the Environmental Management Unit (EMU) is a GOL responsibility, which will be supported by NTECo for coverage of meetings, venues and minor technical assistance on an as-needed basis.

The budget estimate is $50,000.

EPM 2 - Performance of duties by EMU
Capacity building at the local level is part of the overall scope of the Technical Assistance (TA) for the EMU. The TA approach at the local level might focus on visual and educational materials, as well as utilisation of the village meeting concept, to explain and resolve issues. Additional support for performance of duties by EMU is also recommended, to be supported by NTECo. This is a separate budget to cover local costs for venues, educational materials and language training. This will be revised and reconciled with NTSEP when that budget has been finalized.

The budget estimate is $150,000.

EPM 3 - Strengthening EMU with Technical Assistance
The technical assistance (TA) for capacity building will provide technical support, equipment and financial resources for strengthening the members of the EMU, STENO, HPO/MIH, EdL and Provincial and District level staff. The actual focus should be defined at the time the project develops. The overall support is envisaged as about 12 MM intermittent expatriate core support with additional contract specialist inputs, coupled with approximately 100 MM Lao support from agency staff and consultants. Many of the Lao staff will come directly from the member agencies of the EMU. Equipment budget will provide vehicles, communications and monitoring equipment. A substantial share of the TA budget is for direct monitoring of EPMs. These costs would otherwise be included in individual EPM budgets. A further degree of capacity building is expected to develop from the relationship between the EMU and the NTECo EMO, which will be as supportive as possible of those aims within the context of the proper preservation of the roles of the two bodies. Direct involvement in international standard QA procedures should also be of assistance to the EMU in learning to administer this relatively new form of performance assurance. NTECo believes that such QA procedures could be of great general benefit to GOL in the monitoring of other infrastructure projects in that there is a better balance between the need for short term specialist technical skills and longer term governmental policy implementation skills.

The budget estimate is $741,000 to be expended during the construction phase of the project.

Table 6-1 : Potential Environmental Impact and Recommended EPM Linkage

POTENTIAL IMPACTS		RECOMMENDED ENVIRONMENTAL PROTECTION MEASURES		
Ref. (Ch5)	Description	Ref. (Ch 6)	Description	Responsible Party
5.2	Impacts on Geology and Landforms	N/A	No significant impacts have been identified	N/A
5.3	Impacts on Climate	N/A	No significant impacts have been identified	N/A
5.4	Impacts on Hydrology	N/A	Recommended measures are referenced in the relevant sections discussed below	N/A
	Reduced flow downstream of the dam	EPM 40	Guranteed minimum water release	Operations
	Attenuation of flood peaks	-	Beneficial impact - reduction in floods	N/A
	Gnommalat Plain - increased flow in Nam Kathang in dry season	-	Beneficial impact - provison of water to local population in dry season	
	Gnommalat Plain - higher groundwater table in the area surrounding the downstream channel	-	Beneficial impact - greater availability of groundwater for beneficial uses	N/A
	Xe Bang Fai - doubling of flow in Xe Bang Fai river	N/A	Addressed in Resettlement Program (construction of access bridges)	Resttlement Program
	Increased duration of flooding	EPM 25, 26	Irrigation and electricity provision	Resttlement Program
	Increased frequency of flooding	EPM 25, 26	Irrigation and electricity provision	Resttlement Program
5.5	Impacts on Water Quality			
5.5.1	Increased nutrients and associated water quality changes	EPM 9	Clear reservoir biomass	NTEC/BPKP
		EPM 10	Optimise salvage logging	NTEC/BPKP
		EPM 11	Optimise firewood gathering	NTEC
5.5.1	Sedimentation and resultant changes in water quality from vegetation removal in the upper catchment	EPM 35	Prohibit shifting cultivation in resettlement areas	RAP
		EPM 45	Implement watershed management plan	GOL
		EPM 45	Implement watershed management plan	GOL
		EPM 49	Prohibit logging above FSL	GOL
5.5.2	Proliferation of water weeds	EPM 38	Downstream Surveys	Operations
5.6	Impacts of Water Quality Changes			
5.6.1	Need for compliance with water quality criteria	EPM 36	Compliance with water quality standards	Operations
		EPM 42	Monitor discharges	Operations
5.6.2	Sedimentation and resultant changes in water quality from vegetation removal in the upper catchment	EPM 35	Prohibit shifting cultivation in resettlement areas	Resttlement Program
		EPM 45	Implement watershed management plan	GOL
		EPM 45	Implement watershed management plan	GOL
5.7	Impacts from sedimentation and erosion			
5.7.2.1	Change in benthic substrate and deposition patterns	EPM 6	Implement management plan in adjacent river basins	NTEC
5.7.2.2	Erosion in downstream channel	EPM 18	Employ rip rap structures where needed	TKC
		EPM 42	Monitor discharges	Operations
5.7.2.3	Erosion of banks of Xe Bang Fai	EPM 18	Employ rip rap structures where needed	TKC
		EPM 42	Monitor discharges	Operations
5.7.3	Erosion due to construction	EPM 18	Employ construction related mitigation measures	TKC
5.8	Impacts on Forests, Forest Biodiversity and Wildlife			
5.8.1	Forest loss due to inundation	EPM 10	Optimise salvage logging	NTEC/BPKP
		EPM 11	Optimise firewood gathering	NTEC
		EPM 35	Prohibit shifting cultivation	RAP
		EPM 49	Prohibit logging above FSL	GOL
		EPM 48	Implement conservation management of Pinus merkusii	GOL
5.8.2.1	Spontaneous development	EPM 50	Register resettlement families	GOL
5.8.2.3	Drying of riparian forest soils from reduced flow downstream of dam	EPM 39	Implement an adaptive management strategy plan	Operations
		EPM 40	Guaranteed minimum water release	Operations
	Adverse effect on wildlife due to decreased flow	EPM 7	Modify river morphology below dam	NTEC
		EPM 14	Provide additional wildlife studies via system dynamics analysis	NTEC
		EPM 15	Educate public from information gained in studies	NTEC
		EPM 28	Fisheries management	Resettlement Program
		EPM 45	Control hunting via a management plan	GOL
5.8.3.2	Loss of White Winged Duck	EPM 12	White Winged Duck mitigation	NTEC
5.8.3.3	Loss of elephants	EPM 13	Gather baseline information on wildlife guilds	NTEC
5.8.5	Wetland loss	EPM 12	White Winged Duck mitigation	NTEC

Table 6-1 : Potential Environmental Impact and Recommended EPM Linkage

POTENTIAL IMPACTS		RECOMMENDED ENVIRONMENTAL PROTECTION MEASURES		
Ref. (Ch5)	Description	Ref. (Ch 6)	Description	Responsible Party
		EPM 13	Gather baseline information on wildlife guilds	NTEC
		EPM 24	Implement wetlands rehabilitation	TKC
5.9	Impacts on Aquatic Habitats and Fisheries			
	Loss in fish production and diversity below dam	EPM 8	Conduct fish surveys in adjacent basins	NTEC
		EPM 27	Invest in aquaculture activities	Resettlement Program
		EPM 28-32	Implement reservoir fisheries programs	Resettlement Program
		EPM 40	Guarantaee minimum water release	Operations
		EPM 41	Compensation for lost fish production	Operations
		EPM 43	Maintain minimum flow in Downstream Channel	Operations
		EPM 44	Divert water into Nam Kathang	Operations
		EPM 47	Ban fishing with explosives	GOL
		EPM 46	Restrict use of pesticides	GOL
5.10	Impacts on Land			
	Loss in agricultural land due to inundation	EPM 25	Invest in irrigation facilities	RAP
		EPM 26	Provide rural electricity	RAP
5.11	Impacts on Public health			
	Increased risk of aquatic diseases	EPM 18	Implement construction related mitigation measures	TKC
5.12	Impacts from Construction Activities			
	Impacts from construction activities	EPM 18	Implement construction related mitigation measures	TKC
5.13	Safety Issues and Occupational Hazards			
	Increased risk of occupational hazards	EPM 18	Implement construction related mitigation measures	TKC
5.14	Impacts on the Social Dimension			
	Increased risk to social well being	EPM 15	Conduct public education on environmental issues	NTEC
5.2	Cumulative Impact Assessment			
	Watershed protection	EPM 45	Implement watershed management plan	GOL
		EPM 45	Implement watershed management plan	GOL
	Biodiversity conservation	EPM 5	Provide funding for NBCA management	NTEC
5.20.1.4	Meeting social concerns	EPM 24	Implement wetlands rehabilitation	TKC
		EPM 1	Establishing the EMU	STENO
		EPM 5	Provide management for the NBCA	NTEC
5.23	Multiple Use Assessment			
5.23.2	Irrigation	EPM 25	Invest in irrigation facilities	Resettlement Program
5.23.3	Enhanced fishery potential	EPM 28-32	Implement reservoir fisheries programs	Resettlement Program
		EPM 27	Invest in aquaculture activities	Resettlement Program
5.23.4	Enhanced biodiversity	EPM 24	Implement wetlands rehabilitation	TKC
		EPM 5	Provide management for the NBCA	NTEC
5.23.5	Enhanced use of water supply	EPM 43	Maintain minimum flow in Downstream Channel	Operations

Table 6-2
Master List of Environmental Protection Measures

	Type	Location	Time Frame: Periods equal six months beginning on 1 November 1998. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
EPM 1. Formation of the EMU	ALL	INST	
EPM 2. Performance of duties by EMU	ALL	INST	
EPM 3. Strengthening EMU with technical assistance	ALL	INST	
EPM 4. Provision of an expert panel for oversight of work	ALL	INST	
EPM 5. Funding of NBCA Authority ($1M per year)	CONSER	ZONE 2	
EPM 6. River basin management in adjacent basins	AQU/FIS	ZONE 4	
EPM 7. Modify river morphology below dam	WLDLF	ZONE 4	
EPM 8. Exploratory fish surveys in adjacent basins	AQU/FIS	NO ZONE	
EPM 9. Reservoir biomass clearing	AQU	ZONE 1	
EPM 10. Optimize salvage logging	FOR	ZONE 1	
EPM 11. Firewood from inundation area	FOR	ZONE 1	
EPM 12. White Winged Duck mitigation	WILDLF	ZONE 1	
EPM 13. Baseline monitoring for wildlife to establish guilds	WILDLF	ZONE 1, 2, 3, & 4	
EPM 14. System dynamics analysis	WILDLF	ZONE 1, 2, 3, & 4	
EPM 15. Public Education Concerning Environmental Issues	WILDLF	TRAINING	
EPM 16. Regional Health Programme and Construction Phase Health Programme	ALL	ALL ZONES	
EPM 17. Downstream Discharge via Nam Phit instead of Nam Kathang	SOC	ZONE 10	
EPM 18. Construction related mitigation measures (see auxiliary list in Annex J)	ALL	ALL ZONES	
EPM 19. Guaranteed minimum water release during filling of the reservoir	AQU	ZONE 4	
EPM 20. Installation of multiple off-take from surface to 2m below MOL	AQU	ZONE 4	
EPM 21. Installation of screen on off-take to prevent clogging of cone valve and prevent fish entrainment	AQU	ZONE 4	
EPM 22. Construct off-take to provide for variation in instantaneous release	AQU	ZONE 4	
EPM 23. Installation of a cone valve for aeration of outflow	AQU	ZONE 4	
EPM 24. Development of wetland at confluence of DS and XBF	CONSER	ZONE 10	
EPM 25. Provision of regional irrigation facilities in Xe Bang Fai	SOC	ZONE 3, 8, 10, & 11	
EPM 26. Provision of rural electricity	SOC	ZONE 3, 8, 10, & 11	
EPM 27. Investments in aquaculture	SOC	ZONE 3, 8, 10, & 11	
EPM 28. Fisheries management plan for reservoir (including fish screens at offtake)	FIS	ZONE 1	
EPM 29. Fish marketing infrastructure for reservoir	FIS	ZONE 1	
EPM 30. Prohibit cage culture in reservoir	FIS	ZONE 1	
EPM 31. Restrict introduction of new species to reservoir	FIS	ZONE 1	
EPM 32. Stocking of endemic species	FIS	ZONE 1	
EPM 33. Plantation forestry on logged and degraded lands	FOR	ZONE 3	
EPM 34. Sustainable forest management in resettlement areas	FOR	ZONE 3	
EPM 35. Prohibit shifting cultivation in resettlement areas	FOR	ZONE 3	
EPM 36. Compliance with water quality standards	AQU	ZONE 1, 4, 8, 10, & 11	
EPM 37. Monitoring water quality	AQU	ZONE 1, 4, 8, 10, & 11	
EPM 38. Downstream surveys	WILDLF	ZONE 4	
EPM 39. Operations adaptive management	WILDLF	ALL ZONES	
EPM 40. Guaranteed minimum water release	AQU	ZONE 4	
EPM 41. Compensation for lost fish production	AQU/FIS	ZONE 4	
EPM 42. Monitoring discharges	AQU	ZONE 1, 4, 8, 10, & 11	
EPM 43. Maintain canal water level when powerhouse not operating	FIS	ZONE 8	
EPM 44. Diversion of water into Nam Kathang	FIS	ZONE 8	
EPM 45. Implementation of watershed management plan	LAND	ZONE 2	
EPM 46. Restrict use of pesticides in watershed	FIS	ZONE 2	
EPM 47. Ban fishing with explosives throughout the Basin	FIS	ZONE 1, 2, 4, 8, & 11	
EPM 48. Conservation of Pinus Merkusii	FOR	ZONE 3	
EPM 49. Prohibit logging above FSL	FOR	ZONE 1, 2, & 3	
EPM 50. Register resettlement families	SOC	ZONE 1	
EPM 51. Register guns in resettlement area	CONSER	ZONE 3	
EPM 52. Register boats on reservoir	CONSER	ZONE 1	
			COD

NA = not applicable, not available, or provided in companion document, such as RAP or NBCA management plan.
Note : COD = Commercial Operation Date

Table 6-3
Schedule and Implementation for STENO Activities

	Type	Location	Cost	Time Frame: Periods equal six months beginning on 1 November 1998
				1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
EPM 1. Formation of the EMU	ALL	INST	50,000	
EPM 2. Performance of duties by EMU	ALL	INST	150,000	
EPM 3. Strengthening EMU with technical assistance	ALL	INST	741,000	
EPM 4. Provision of an expert panel for oversight of work	ALL	INST	300,000	
			1,241,000	1,166,000 75,000 1,241,000

End of Construction and Beginning of Operations Period

Table 6-4
Schedule and Implementation for NTECo Core Activities

	Type	Location	Cost	Time Frame: Periods equal six months beginning on 1 November 1998																																		
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
EPM 5. Funding of NBCA Authority ($ 1M per year)	CONSER	ZONE 2	15,000,000																																		
EPM 6. River basin management in adjacent basins	AQU/FIS	ZONE 4	506,000																																		
EPM 7. Modify river morphology below dam	WLDLF	ZONE 4	50,000																																		
EPM 8. Exploratory fish surveys in adjacent basins	AQU/FIS	NO ZONE	50,000																																		
EPM 9. Reservoir biomass clearing	AQU	ZONE 1	NA																																		
EPM 10. Optimize salvage logging	FOR	ZONE 1	NA																																		
EPM 11. Firewood from inundation area	FOR	ZONE 1	50,000																																		
EPM 12. White Winged Duck mitigation	WILDLF	ZONE 1	100,000																																		
EPM 13. Baseline monitoring for wildlife to establish guilds	WILDLF	ZONE 1, 2, 3, & 4	150,000																																		
EPM 14. System dynamics analysis	WILDLF	ZONE 1, 2, 3, & 4	150,000																																		
EPM 15. Public Education Concerning Environmental Issu	WILDLF	TRAINING	100,000																																		
EPM 16. Regional Health Program	ALL	ALL ZONES	594,000																																		
			16,750									6,750	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	10,800,000	16,750

End of Construction and Beginning of Operations

Table 6-5
Schedule and Implementation for NTECo/TKC Activities

			Time Frame: Periods equal six months beginning on 1 November 1998
	Type	*Location*	*1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30*
EPM16. Construction Phase Health Program	ALL	ALL ZONES	
EPM 17. Downstream Discharge via Nam Phit instead of Nam Kathang	SOC	ZONE 10	
EPM 18. Construction related mitigation measures (see auxiliary list in Annex J)	ALL	ALL ZONES	
EPM 19. Guaranteed minimum water release during filling of the reservoir	AQU	ZONE 4	
EPM 20. Installation of multiple off-take from surface to 2m below MOL	AQU	ZONE 4	
EPM 21. Installation of screen on off-take to prevent clogging of cone valve	AQU	ZONE 4	
EPM 22. Construct off-take to provide for variation in instantaneous release	AQU	ZONE 4	
EPM 23. Installation of a cone valve for aeration of outflow	AQU	ZONE 4	
EPM 24. Development of wetland at confluence of DS and XBF	CONSER	ZONE 10	

Table 6-6
Schedule and Implementation for NTECo/Resettlement Program Activities

			Time Frame: Periods equal six months beginning on 1 November 1998
	Type	*Location*	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
EPM 25. Investment in regional irrigation facilities	SOC	ZONE 3, 8, 10, & 11	
EPM 26. Provision of rural electricity	SOC	ZONE 3, 8, 10, & 11	
EPM 27. Investments in aquaculture	SOC	ZONE 3, 8, 10, & 11	
EPM 28. Fisheries management plan for reservoir	FIS	ZONE 1	
EPM 29. Fish marketing infrastructure for reservoir	FIS	ZONE 1	
EPM 30. Prohibit cage culture in reservoir	FIS	ZONE 1	
EPM 31. Restrict introduction of new species to reservoir	FIS	ZONE 1	
EPM 32. Stocking of endemic species	FIS	ZONE 1	
EPM 33. Plantation forestry on logged and degraded lands	FOR	ZONE 3	
EPM 34. Sustainable forest management in resettlement areas	FOR	ZONE 3	
EPM 35. Prohibit shifting cultivation in resettlement areas	FOR	ZONE 3	

Table 6-7
Schedule and Implementation for NTECo/Operations Activities

			Time Frame: Periods equal six months beginning on 1 November 1998																												
	Type	*Location*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
EPM 36. Compliance with water quality standards	AQU	ZONE 1, 4, 8, 10, & 11																													
EPM 37. Monitoring water quality	AQU	ZONE 1, 4, 8, 10, & 11																													
EPM 38. Downstream surveys	WILDLF	ZONE 4																													
EPM 39. Operations adaptive management	WILDLF	ALL ZONES																													
EPM 40. Guaranteed minimum water release	AQU	ZONE 4																													
EPM 41. Compensation for lost fish production	AQU/FIS	ZONE 4																													
EPM 42. Monitoring discharges	AQU	ZONE 1, 4, 8, 10, & 11																													
EPM 43. Maintain canal water level when powerhouse not operatin	FIS	ZONE 8																													
EPM 44. Diversion of water into Nam Kathang	FIS	ZONE 8																													

Table 6-8
Schedule and Implementation for GOL Activities

			Time Frame: Periods equal six months beginning on 1 November 1998																											
	Type	*Location*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*
EPM 45. Implementation of watershed management plan	LAND	ZONE 2																														
EPM 46. Restrict use of pesticides in watershed	FIS	ZONE 2																														
EPM 47. Ban fishing with explosives throughout the Basi	FIS	ZONE 1, 2, 4, 8, & 11																														
EPM 48. Conservation of Pinus Merkusii	FOR	ZONE 3																														
EPM 49. Prohibit logging above FSL	FOR	ZONE 1, 2, & 3																														
EPM 50. Register resettlement families	SOC	ZONE 1																														
EPM 51. Register guns in resettlement area	CONSER	ZONE 3																														
EPM 52. Register boats on reservoir	CONSER	ZONE 1																														

EPM 4 - Provision of an expert panel for oversight of work
The POE provides technical support for the EMU as well. The TA consultant and the POE, in conjunction with the EMU, should initially evaluate the work plan, and begin implementation, mainly using consultant inputs. Within six months the EMU should be familiar with the work, and after three years, the TA will end and POE will assume a consultative role with respect to the EMU. The EMP provides a budget provided by NTECo for the POE over a six year time frame, including both expatriate and Lao participation via National, Provincial and District Agencies. It is based on annual visits of two weeks by each of the POE members.

The budget estimate is $300,000 over six years.

6.2.2 EPMs to be undertaken by NTECo as Core Activities

EPM 5 - Management Funding for NBCA Authority
NTECo has committed to provide $ one million per annum for a period of 30 years to support management of the NBCA as part of its strategy for the Project Area. The relatively pristine habitats found in the NBCA will be protected to prevent further degradation. This offsets environmental effects induced by the project by a large factor, in addition to mitigation of the impact it. Without the Project the protection funding would be unlikely.

The budget estimate is $ 30 million, of which $ 5 million is during construction phase.

EPM 6 - River basin management in adjacent basins
In order to offset the loss of riverine habitat throughout the upper Nam Theun Basin, and to minimise loss of aquatic habitat below the proposed Damsite, river basin management planning is proposed for tributary a sub-basin of the Nam Theun. The EMP recommends a study for the Nam Phao (Zone 4) tributary. The terms of reference for the work should avoid duplication of activities with the ongoing watershed management study for the Nam Theun. While this basin study would consider watershed management as a major factor, the focus is more on water quality management, including targeting quality parameters for maintaining specific ecological and human beneficial uses. Terms of reference for the study are not included in the present EAMP.

The budget estimate is $506,000.

EPM 7 - Modify river morphology below dam
This is included as a possible beneficial measure to enhance wildlife adaptation in the 12 km reach of the Nam Theun between the proposed Damsite and the Nam Phao confluence. Any modifications to the stream channel should be based on recommendations of wildlife specialists engaged in any of the previous studies focusing on the downstream reach.

The budget estimate is $50,000.

EPM 8 - Exploratory fish surveys in adjacent basins
This is required to determine the endemicity of species of fish identified during earlier surveys in the Nam Theun and Xe Bang Fai Rivers. This study by Dr. Maurice Kottelat is expected to be concluded in June 1997.

The budget estimate is $50,000.

EPM 9 - Reservoir biomass clearing

The target for reservoir biomass clearing (Zone 1) is being established based on the results of the April 1997 water quality study, as well as cost-efficiency factors. Results of the water quality study indicate that good water quality will be achieved without additional clearing of biomass related to non-commercial timber sizes. NTECo may perform additional clearing in the inundation area in order to provide firewood for work camps, as detailed under another EPM. Provisions for navigation and fishing lanes will be included in clearing operations.

EPM 10 - Optimise salvage logging

Continuous technical assistance by NTECo within RAP studies and monitoring is recommended to determine the economics and means for increasing the timber take from the inundation zone. Current salvage logging is focused on removing the most valuable commercial species and large diameter boles. Although it is not necessary to remove vegetation for betterment of water quality within the reservoir, lesser value species including smaller diameter and poorly formed logs may be economically harvested for sawn timber, plywood, and chip board. Other merchantable timber should also be removed, in order to utilise the resource and to reduce the biomass load in the reservoir. The technical assistance for support of STENO and the EMU should also continue to target improving timber processing capability within the local industry.

EPM 11 - Firewood from inundation area

This is intended to reduce biomass from the inundation area and to reduce pressure on forests adjacent to work camps, by providing fuelwood to camp inhabitants and camp followers, thereby ensuring more effective utilisation of the biomass. A budget is proposed for trucks, equipment and crews, to be operated over the duration of construction. Fuelwood needs may be estimated on the basis of average monthly fuelwood use in the area of one m^3/person. This indicates that a total of nearly 0.5 million m3 of fuelwood may be required in the area during the course of construction. Fuelwood can be stockpiled prior to project start-up and collected throughout the construction phase. Local villagers can be involved in the effort providing an additional source of employment and income during the livelihood transition period. Fuelwood and charcoal markets outside of the project area might also be supplied with this otherwise wasted resource.

The budget estimate is $50,000.

EPM 12 - White Winged Duck mitigation

The study will survey potential habitats and locations of unknown populations of White Winged Duck between N-NT and the Cambodian border to establish threat and potential release and captive breeding sites. The purpose is to understand the genetic character and behaviour, retain the genome, and outbreed to other isolated populations at risk, increasing the global security of this globally threatened species. Captive populations can not only enhance the viability of depleted natural populations, but can provide a stock for re-introduction should the opportunity arise after more is known about distribution and habitats. Such programs have been successful (California condor). The remaining birds should be captured, or at the minimum, eggs should be collected and incubated. This is a tree duck and nest boxes offer an opportunity for accelerating collections.

This activity will most probably be contracted, along with others mentioned below, to a natural science organisation such as the Wildlife Conservation Society (WCS).

Elemental Budget cost is expected to be just under $ 100,000.

EPM 13 - Baseline monitoring for wildlife to establish guilds

This EPM is geared to setting the goals and standards for wildlife populations and measuring progress toward them to support biennial review and mitigation plan updating. Standards might include agreed natural baseline population densities for each habitat type, water quality parameters such as the ratio of wetted stream width to pools/km^2, percent sediment and cobble imbeddedness, and turbidity. The survey work to establish wildlife population data, and the monitoring of populations are repeated in each of four areas, Nakai Plateau, Dividing Hills, the resettlement area, and downstream Nam Theun. The wildlife monitoring should not begin until the basic survey confirms the species to be monitored; therefore, the initial survey is also described. The initial one year survey will take two weeks at each site. A team should probably conduct six-week inventory three times in one year: winter (December-January), dry season (March-April), and monsoon (July-September). A botanist will run transects in each of the major habitat types. The area will be surveyed for vegetation, fish, insects, birds, bats, rodents, herps, and small predators. Sampling will be as quantitative as possible to establish baseline species presence, density and habitat preference standards - e.g. standard catch/effort for snap traps on a Calhoun trap line (Wildlife Society 1996). During the 6 months not in the field, specimens will be identified with keys, sonogram, and genetic analyses, and data will be analysed. This initial objective sampling of the biota of the N-NT NBCA will permit a full application of the guild approach to monitoring. A fixed - price contract to a natural science organisation would be the preferred implementation method.

The budget estimate is $150,000.

EPM 14 - System dynamics analysis

Drivers of the Nakai Nam Theun ecosystems are the variables and rates (stocks and flows) of the primary feedback loops illustrated in the System Dynamic flow chart. These important elements should be monitored as indicators of stability or impending changes in the system. They should reflect the effectiveness of management of the system over time. Most of the data required are collected for other elements of the M&E program. The loop suggested for monitoring involves human population density, primary to secondary habitat conversion and enforcement effectiveness, density of birds, mammals, and fish, and human nutrition and population density. The project includes modeling and simulation over a thirty year time span, acquisition of STELLA software for modeling, species inventory, four years of monitoring and evaluation, and air photo acquisition and interpretation. This activity is most probably best contracted to a wildlife conservation organisation

The budget estimate is $150,000

EPM 15 - Public education concerning Environmental Issues

Instituting an education and public awareness program will require the preparation of materials, the training of trainers and guards, and the regular conduct of film, information and school tours on and around the Plateau. It will be a long-term commitment with a lag in returns in basic behavioural changes of several years. As such it is an investment, but it will provide the permanent solution for a currently lassez faire approach to the exploitation of the manifold natural resources of the Plateau, which are considered to be held in common by most of the population. This will be revised when NTSEP's budget becomes known. Four activities constitute the elements of this set of outreach activities:

- a quantitative survey of the attitudes to natural resources and decision-making processes of Plateau residents. This will need a social survey consultant and counterpart for 2 months

- translation of video and print media, and preparation of slide and poster materials with an emphasis on the visual. This will require a full-time media translator;

- teacher training and Conservation Officer training workshops on such topics as the accession and use of materials, and techniques of outreach and communication.

- acquiring and fitting a mobile audio-visual nature education unit with field study equipment for students (nets, hand lenses, field guides, binoculars, notebooks).

The cost for this component is estimated at $100,000.

EPM 16 - Regional Health Programme - *Project Area*

The lives of the people in the Project Area will be altered by the effect of construction activities during the Construction phase. To compensate for any directly non-mitigatable adverse effects on the population, to directly mitigate against any adverse health effects of the increased construction population on the preexisting population and to raise the health standards of that population, NTECo proposes to provide significant funds to raise the general health standards in the Project Area. In total NTECo will provide $1.5 million for this strengthening of Project Area Public Health. The RAP report has committed $906,000 in this area. NTECo proposes to commit to a further $594,000 to bring it's total commitment to Regional Public Health to $1.5 million.

There are specific GOL national and provincial health programmes which follow international health (WHO) guidelines and principles. Activities within the project area, as they affect the targeted communities, should therefore follow GOL national and provincial policies and targets; examples are: safe water supply, the EPI programme and malaria control. The objective of this approach will be to eventually combine health care activities with the GOL provincial and countrywide programmes. To achieve this long term plan it will be necessary to, at province, district and village levels:

- inform communities on endemic diseases, control programmes and correct health care measures which can be individually carried out
- ensure a sufficiency of essential drugs
- train and transfer appropriate technology among health workers and practitioners
- provide support to disease control programmes including their supervision
- ensure the timely monitoring of health status and health services implementation

Much will depend on the standard of the available health and volunteer personnel and the levels of expertise required for monitoring, and other activities. These should be upgraded through in-service and other forms of training and improved methods of supervision.

As with Ministries and other government departments, activities will be in collaboration and co-ordination with other influential and involved groups such as the Lao Women's Union (LWU), Japanese International Cooperation Abroad (JICA) and Save the Children Fund UK (SCFUK). The two latter agencies are already actively working on specific health programmes in parts of Khammouane province and to avoid duplication of effort their experience and collaboration will be sought. JICA is promoting a self-help programme through the establishment of village-based revolving funds for the purchase of medicines as well as providing diagnostic services for the identification and treatment of intestinal parasitic diseases. Save the Children Fund (UK) have teacher training programmes in districts of the Province and have acquired an extensive experience in training and the design and production of health related training aids appropriate to Khammouane province.

NTECo would therefore be prepared to provide funds to assist the following activities:

Health workers will be strengthened through NTECo assisted programmes which:

- provide opportunities for individual and collective training through
  ⇒ some limited international training
  ⇒ short study and training tours in Thailand
  ⇒ locally organised training, and
  ⇒ the development of teaching and job aids

- improving supervision at all levels

Support to disease control programmes will be through the:

- provision of technical support
- availability of essential drugs and other supplies necessary to the programme
- collaboration in programme implementation
- development and production of health information materials
- assistance with evaluation and analysis of data

This cost for this component is estimated as:

• Resettlement Related (see RAP)	$	406,000
• Local Training and Study Tour	$	150,000
• Disease Control Program Support	$	694,000
• Technical Consultants & Logistic Support	$	250,000
Total		1,500,000

6.2.3 EPMs Delegated to TKC by NTECo

The following EPMs are recommended that are directly related to construction activities and commissioning, and will be performed by the TKC. Where a cost estimate is not provided, the EPMs will be integrated into the overall TKC budget. The monitoring of the EPMs is performance-based. Cost for monitoring is included in the NTECo monitoring budget and the budget allocations for the EMU.

EPM 16 - **Construction Phase Health Programme** ***Project Staff***
NTECo will ensure that disease control measures are in effect by the TKC at the time the construction camps are built. Siting of camps will be made with regard to good drainage, water supply, sewage disposal and disease transmission potential, especially malaria. Essential control elements such as fly-proofing will be incorporated during the camp-site construction. Where this cannot be done pyrethroid-treated mosquito nets will be issued. These costs will be part of camp-site construction costs but mosquito control, including DF/DHF control will be part of the health programme.

A polyclinic, adequately staffed, will be sited at the base camp with subsidiary treatment posts at smaller camps. While the purpose of these facilities is to provide high quality health services to TKC employees, some non-guaranteed assistance may be available to nearby communities for emergency matters and if spare resources become intermittently available. The cost of these components is estimated as :

• Main Camp Polyclinic, Subcamp mobile clinics, Equipment and Resident Health Staff		$	1,500,000
• Transport and Maintenance (including ambulance)		$	1,000,000
• Safe Water Supply and Sewerage and Waste Disposal		$	2,000,000
	Total	$	3,500,000

EPM 17 - Downstream Channel Alignment

The 1991 SMEC report recommended that Power Station discharge water be channeled to the Xe Bang Fai (and then the Mekong) by widening and straightening the Nam Kathang (Zone 9). The report acknowledged that there would be a need to construct levees in certain lengths of the Nam Kathang and that about 15% of the riverside population would need relocate some of their household activities a short distance within the same village area to allow levee construction.

During the conceptual design phase however NTECo took the view that it was possible to minimise this resettlement issue by constructing an artificial channel from the regulating weir, through some existing rice paddy, and then connecting to the Nam Phit Channel (Zone 8). The Nam Phit enters the Xe Bang Fai downstream of the Nam Kathang and is a minor wet weather channel and mostly unpopulated as a result. NTECo will widen and deepen the natural channel to ensure it has sufficient capacity to carry the power station discharge. A disadvantage of this route involves occupation of 65 ha of paddy land. Its advantage is in the much smaller number of people needing resettlement.

The Nam Phit alignment has a significantly higher construction cost than the initially selected Nam Kathang route. It is a longer route by about 10 km and excavation quantities are greater by about 4 million m^3. The differential cost for this alignment is estimated at $13 million.

EPM 18 - Construction related Mitigation Measures

These activities are described more fully in Annex J which details specific EPMs under eight categories which NTECo has already committed to implement during the Construction Phase.

In brief, they are

1. Site remediation
2. Stream monitoring
3. Reservoir impoundment management
4. Additional road maintenance
5. Additional security
6. Additional access and preparatory works, Dam Site
7. Spontaneous Resettlement
8. Local worker training

The differential cost for these measures is estimated at $8.2 million.

EPM 19 - Guaranteed minimum water release during filling of the reservoir (Zone 4).
Cost estimates are included in TKC budget.

EPM 20 - Installation of multiple off-take in Dam from reservoir surface to 2 m below MOL to discharge an average 2 m^3/sec with capacity for variation up to 20 m^3/sec to be discharged intermittently through radial gates (Zone 1)
Cost estimates are included in TKC budget.

EPM 21 - Installation of screen on off-take to prevent clogging of cone valve and entrainment of fish (Zone 1)
Cost estimates are included in TKC budget.

EPM 22 - Construct off take to provide for variations in instantaneous releases (Zone 4)
Cost estimates are included in TKC budget.

EPM 23 - **Installation of a cone valve for aeration of outflow (Zone 1)**
Cost estimates are included in TKC budget.

EPM 24 - **Development of wetlands, fish farm or similar facility setting at confluence of DS Channel and Xe Bang Fai, based on local agreement on land use (Zone 8).**
Cost estimates are included in TKC budget.

6.2.4 EPMs to be undertaken by NTECo as part of the Resettlement Program

Mitigation actions and EPMs to be taken under the RAP are detailed in that report. The following items are recommended as environmental mitigation measures which should be included as RAP activities. Cost estimates will be found in the RAP report.

EPM 25 - Provision of irrigation facilities in the Xe Bang Fai
This is included as an offset measure for loss of dry season terrace farming, potential increased flooding along the Xe Bang Fai (Zone10), and loss of land for construction of the channel (Zone8). The work is likely to be included in the RAP action plan.

EPM 26 - Provision of rural electricity
This is included as an offset measure to enhance irrigation works. The work is likely to be included in the RAP action plan.

EPM 27 - Investments in aquaculture
Aquaculture may prove to be viable both on the Plateau and in the downstream area below the Powerhouse. The RAP will include provisions for limited aquaculture development.

EPMs 28-32 - Reservoir Fisheries (Zone 1)
This may include, (EPM 29) fisheries management plan for reservoir, (EPM 30) fish marketing infrastructure for reservoir, (EPM 31) discourage cage culture in reservoir, (EPM 32) restrict introduction of new species to reservoir, and (EPM 33) stocking of endemic species. These EPMs will be undertaken at the direction of a reservoir fisheries management specialist. These EPMs will be further investigated and expanded upon by the RAP.

EPM 33 - Investigations for Plantation forestry on logged and degraded lands near the inundation area (Zone 3)
Pinus merkusii and other mixed native and exotic tree plantations should be established on logged or degraded lands nearby the proposed resettlement sites. More details recommended form the RAP.

EPM 34 - Sustainable forest management in resettlement areas (Zone 3)
Forestry operations should be included as a component of the Resettlement Action Plan, and a Co-operative established under whose responsibility would fall the task of 'sustainable forest management'.

EPM 35 - Prohibit shifting cultivation in resettlement areas (Zone 3)
Shifting cultivation should be prohibited in the resettlement areas and alternative agricultural and livelihood activities established to replace crops and income previously derived from it.

6.2.5 EPMs to be undertaken under the NBCA

The project has an undisputed effect on the environment in areas that are already substantially degraded. The proposal to offset these effects on degraded land by supporting protection of the NBCA leads to both environmental and economic improvements for Laos. NTECo and GOL also have a direct commercial interest in ensuring that catchment management practices maintain the quality, distribution and quantity of inflowing water from the watershed,

maintaining low sediment yield and nutrient content. Increased sediment loads could begin to impinge on the useful active volume of the reservoir. Increased nutrient loads could affect downstream discharges. For all these reasons NTECo wishes to support world-class management of the NBCA. It sees itself as a Founding Funder and hopes that many other local and international organisations will also wish to assist this funding process.

NTECo has committed to provide $1 million per annum for a period of 30 years to support management of the NBCA as part of its strategy for the Project Area. The relatively pristine habitats found in the NBCA will be protected to prevent further degradation. NTECo's committment is intended to more than offset environmental effects caused by the project, in addition assisting to mitigate mitigation impacts. Without the Project the protection funding would be unlikely. Without such funding the project should not proceed.

This Draft Final Report of the EAMP makes no recommendations for EMPs or environmental mitigation measures in the NBCA area.

The WCS/IUCN Study must recommend appropriate EPMs which preserve the current natural environment of the NT2 catchment area. The current natural properties of the NBCA form the basis for many of the assessments of environmental impacts in the EAMP. EPMs in the NBCA area are also closely linked to wildlife, forest and fisheries management issues in the adjacent Zones in the ESA.

The final report will include the EPMs identified and addressed in the IUCN NNT-NBCA Report and ensure that all impacts identified in Chapter 5 of the EAMP are covered by satisfactory corresponding EPMs in the WSC/IUCN document.

It is recommended that the EPMs in the NBCA management plan must address at least the following biological and physical issues which impact on, and are impacted by the Project:

- Elephant Movement Mitigation
- Fisheries Management
- Watershed Management
- Access Control and Enforcement into the Dividing Hills (Zone 2)

6.2.6 EPMs to be undertaken by NTECo during Operations phase

EPM 36 - Compliance with water quality standards (Zones 4 and 8)
Engineering works will be designed to comply with the agreed water quality standards at various points in the purpose-built system, including the point of release into the Nam Theun below the Damsite (Zone 4), and releases from the downstream channel (Zone 8) into any natural watercourse or location of use. The water quality standards are set in order to assure that beneficial uses of the water are maintained. The proposed water quality standards are shown in Annex I. NTECo has the right and responsibility to mitigate direct impacts on people through alternative means if water quality standards might not be met.

EPM 37 - Monitoring water quality (Zones 1, 4 and 8)
Water quality monitoring should begin as soon as possible after the EMU is formed and the technical assistance project begins. The proposal for water quality monitoring is contained in Annex E and the cost is included in the budget for the EMU and the technical assistance.

NTECo will also conduct water quality monitoring, especially during the operations phase, in order to control the quality of discharge of water at the Damsite and through the turbines.

EPM 38 - Downstream surveys (Zone 4)
The impact analysis points to the unusual potential for the project to both rectify a nutrient-poor environment downstream of the proposed Damsite which is limits fish and invertebrate productivity and diversity (a positive impact), followed by the possibility of an overshoot of nutrients and a crash in aquatic diversity and productivity. It is possible to control nutrient levels and develop mitigation measures to enhance diversity and productivity. Such management would benefit the top trophic level of terrestrial vertebrates (predators like otter and eagle). To do so, a study of the hydrology and aquatic trophic ecology (food chain energetics) is required. Much as a study of seasonal movements in elephants is required to clarify management options, a seasonal study at the Nam Theun canyon is also necessary. Such a study would need a bathymetric and hydrologic survey, inventories of seasonal nutrient dynamics, aquatic invertebrates, fish, and riverine dependent birds and mammals. The efficiency of energy transfer, and the diversity within each taxon will constitute a baseline (standards) for mitigation management. Within a year, the mitigation package would respond to these findings with a variety of actions. As a contingency, the outlet supplying the 2 m^3/sec should be constructed to accommodate periodic greater flows, should flushing or additional release be an indicated mitigation. Timing is important. The work should be started with a survey late in the construction period and continue during the initial decade of project operations. The estimated cost for the survey and monitoring is $127,000.

EPM 39 - Operations adaptive management
Operations adaptive management is intended to continue with wildlife, biodiversity and fisheries studies, as well as the duties and functions of the EMU, during the operations phase of the project. It is intended to cover all costs during the construction phase that are incurred by NTECo associated with previous programs, as itemised in this EMP, that are not already covered by an itemised operations period EPM.

EPM 40- Guaranteed minimum water release (Zones 1 and 4)
The NTECo preferred minimum riparian release flow is two (2) m^3/sec . The Final Report will include a rationalisation of the preferred release based on economic and ecological factors. GOL, NTECo and WB will decide on the riparian flowrate as an average amount. The fisheries study should consider whether variation of the flow within a diurnal period is advisable. The cost for the release is borne by NTECo.

EPM 41- Compensation for lost fish production (Zone 1)
Any direct losses to fishermen resulting from a loss in fish production in the Nam Theun below the Damsite will be mitigated through reservoir productivity. Any directly affected persons will receive direct compensation from NTECo, under provisions contained within the RAP. As the area between the dam and the Nam Phau confluence is in an uninhabited gorge very few people fish there.

EPM 42- Monitoring discharges (Zones 4 and 8)
NTECo is responsible for monitoring discharges at points where water quality standards apply downstream of the dam (Zone 4) and in the downstream channel (Zone 8), and for reporting results to STENO. The EMU will also monitor discharges on occasion, to provide a check on results provided by NTECo.

EPM 43- Maintain minimum flow in canal when powerhouse not operating (Zone 8)
The purpose of this EPM is to sustain fish populations that will develop in the Downstream Channel during times when power is not being generated. Alternative means are possible for

mitigating these impacts, such as providing localised low points in the channel to provide temporary ponds for fish, in the event the powerhouse is shut down. This is an NTECo cost.

EPM 44- Diversion of water into Nam Kathang (Zone 9)
The EMP recommends that water be diverted into the Nam Kathang channel in order to maintain and enhance beneficial uses. The quantity and timing of the diversion can be determined flexibly by user groups.

6.2.7 EPMs to be undertaken by GOL

EPM 45- Implementation of watershed management plan (Zone 2)
GOL will need to work with NBCA to ensure that the entire watershed is incorporated in the management plan, not just the NBCA area. This general recommendation serves to highlight the need for watershed protection to minimise sedimentation into the reservoir, along with the broader issues of biodiversity protection in and around the NBCA.

EPM 46- Restrict use of pesticides in watershed (Zones 2 and 3)
Pesticides may enter the reservoir and contribute to mortality of fish. Pesticide use will be prohibited or otherwise restricted to controlled use in the watershed. The responsibility rests with the RAP action plan to implement the measure. A cost is not provided, since it is included in RAP operating budgets.

EPM 47- Ban fishing with explosives throughout the Basin (Zones 1, 2, 3 and 4)
This responsibility falls on GOL, with back-up from the EMU, during the period it is active in the area.

EPM 48- Conservation of Pinus Merkusii (Zones 2 and 3)
Over 40,000 hectares of *Pinus merkusii* and mixed conifer/ broadleaf forest will remain unaffected by Plateau inundation (NOFIP 1997). These areas include, primarily, a large stand at the southern end of the reservoir, several sites adjacent to the reservoir on its eastern bank, and in the Nam Malou basin on the north-western escarpment. All areas on the eastern bank should be included in the NBCA and protected from logging. Half of the major stand south of the reservoir should be considered for inclusion in the NBCA, with the remainder allocated to low-yield sustainable harvest. Revenues from commercial exploitation of these areas could be divided among BPKP, PAFO, DAFO, and resettlement communities. Logging should be confined to removing senescent trees and silvicultural thinning. Pre-monsoon controlled burning where senescent trees have been culled will stimulate germination of replacement seedlings. This will be amplified in the IUCN/WCS document.

EPM 49- Prohibit logging above FSL (Zones 2 and 3)
The prohibition of logging above the FSL is one of the more critical measures to preserve forest resources on the Nakai Plateau, specifically in Zones 2 and 3, and should be strictly enforced by the NBCA Authority. The monitoring can be supported by the Protected Area Specialist, the EMU and RMU, all of whom should be equipped with the necessary field instruments, such as GPS devices, to determine whether logging operations are occurring above the FSL.

EPM 50- Register resettlement families (Zone 3)
Formal registration of families determined to have legitimate residence rights within the resettlement area will help restrict and control any influx of new in-migrants. This is the responsibility of the RMU, and does not require a separate budget.

EPM 51- Register guns in resettlement area (Zone 3)

Weapons owned by families resident in the resettlement area should be registered, and all high powered automatic weapons should be prohibited. This is the responsibility of the RMU, and does not require a separate budget. A program should be implemented facilitating exchange of high caliber weapons for lower gauge rifles with appropriate monetary compensations provided as necessary. Following closure of a well-publicised moratorium period, fines, confiscation, (and possibly incarceration) should be assessed against anyone found in the reservoir area possessing unregistered firearms, high powered automatic weapons, and other prohibited materials (explosives, poisons, long snare lines). Based on recommendations from wildlife specialists, animal species for which hunting will be prohibited should be well-publicised, and hunting seasons and cull limits specified for permitted species. An awareness raising program regarding sustainable wildlife management should be implemented in conjunction with alternative income generation activities including ecotourism. Villagers should be deputised and remunerated as forest guards, with clear lines of communication established for reporting abuses through proper channels. Provisions in the contracts of all companies and sub-contractors working in the NT2 project area should stipulate assessment of stiff penalties against companies if workers are found engaging in any hunting or wildlife trading. Check-points should be established along roads leading into and out of the Project area with regular unannounced monitoring by senior GOL and BPKP wildlife officers.

EPM 52- **Register boats on reservoir (Zone 1)**
All boats located in the reservoir must be registered in order to control fishing and use of the reservoir for access into the NBCA. The means for registering the boats will need to be worked out at a future date.

6.3 INSTITUTIONAL FRAMEWORK FOR UNDERTAKING EMP

As indicated in Section 6.2, the 52 EPMs will be undertaken by several bodies. An institutional framework is required that can ensure smooth and coordinated functioning of these bodies leading to efficient implementation of the recommended EPMs.

6.3.1 Institutional Approach

In accordance with the provisions of the relevant legislation a number of GOL agencies at central and provincial levels will be involved in providing services directed at mitigating impacts, and in monitoring and community consultation. Though it is possible to delineate specific functions for various groups, it is probably more constructive to look on the overall scope of work as a joint enterprise among the TKC and NTECo, and the various agencies making up the EMU, as well as many agencies involved in infrastructure, services and community support. The EPM Implementation and Monitoring Framework is given in Figure 6-2, in which both mitigation activity and monitoring are carried out in a tiered arrangement, depending on the specific activity being targeted. Precise divisions of responsibility are best described within the context of specific mitigation measures.

It is recommended that an Environmental Management Unit (EMU) under the direction of STENO be established, with representation from HPO/MIH, EdL, the Khammouane Provincial Office (KPO), and the District Offices of Nakai (NDO) and Gnommalat (GDO). STENO, through the EMU, will guide the effort using support staff from all agencies and levels in specific tasks related to project monitoring and participation in EPMs during the construction phase. EMU activities can also be extended into the operations phase. The EMU will monitor the successful completion of the EMP, including the specific EPMs, as undertaken by the bodies responsible for undertaking the EPMs proposed in Section 6.2.

STENO and the provincial offices need extensive institutional strengthening in order to provide effective oversight for implementation of the EPMs specified in the present EMP through their

proposed EMU. The proposed technical assistance provides a beginning for development of the monitoring and analytical skills that are required for such an undertaking. The technical assistance project will extend over a three year time period beginning six to nine months in advance of the actual start of construction. Organisation, external working relationships, and the proposed technical assistance are described in the institutional section of the EMP. The roles of participants in the EMU, as well as participants in supporting technical groups, will necessarily include a significant degree of "learning on the job". All these individuals will need to work alongside the technical assistance experts as well as the NTECo Environmental Management Office (EMO) staff, in order to secure the skills needed to maintain monitoring over the duration of construction. The technical assistance will terminate before the mid-term of the construction and it will be the duty of the EMU itself to carry forward with the effort, with some occasional support from the Panel of Experts. The EMP and NTECo understand that NTSEP is providing for such needed institutional strengthening.

The roles of each of the EPM implementors, are defined in Section 6.3.2, below.

It is recommended that activities conducted by the Environmental and Social Panel of Experts (POE) be continued, with the inclusion of Lao professionals in addition to the current membership. In the coming years the POE will fulfill an overall review function. POE will make semi-annual visits to review monitoring and execution of EPMs, and recommend means for improving environmental and social performance of the project to the EPM implementers and to the EMU.

6.3.2 Institutional Roles

Primary and auxiliary roles can be defined for most, if not all, environmental protection measures (EPMs). The primary roles include implementation of EPMs, monitoring and record keeping. Standardisation is considered an auxiliary, yet important, role. It involves establishing EIA protocols and setting criteria for hydropower social and environmental analysis, monitoring and other aspects of the work. The concept is to utilise the lessons learned from the NT2 project to develop criteria for similar projects.

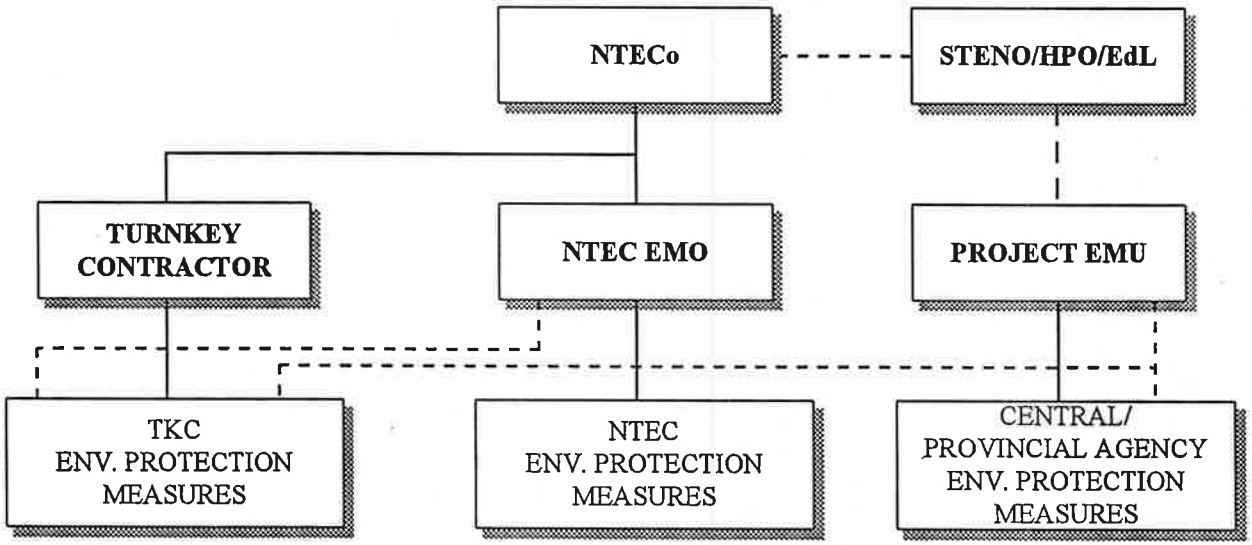
6.3.2.1 Role of STENO

STENOs primary role will be through the formation and management of the EMU. The EMU shall oversee the successful completion of the EMP and its 52 EPMs.

STENO, through the EMU, which serves as its Project Secretariat, should monitor and direct the S&E programs described in this EMP. The existing Resettlement Committee and RMU are separate, and should remain so. The scope of EMU activities includes:

- Coordinating any necessary NTECo and EAMP interfaces with National Provincial and District organisations.
- Advising STENO/GOL on the adequacy of proposed EAMP mitigation measures
- Agreeing with NTECo on performance criteria and QA procedures
- Monitoring adequate EAMP performance by NTECo
- Advising STENO/GOL on EAMP performance status

FIGURE 6-2 : ENVIRONMENTAL PROTECTION MEASURES IMPLEMENTATION AND MONITORING FRAMEWORK



Note : TKC, NTEC and the respective Central and Provincial GOL agencies will be responsible for implementation of the environmental protection measures as well as continued monitoring of the EPMs under their purview.

Acting as a single GOL point of contact for NTECo on EAMP issues. GOL, NTECo and the Bank will need to determine the extent to which the EMU should cover RAP and N-NTNBCA implementation, monitoring and post-evaluation of environmental issues.

The EMU, through STENO's active involvement, is intended to link the project area to Vientiane, and representatives from environment, hydropower, forestry, and local administration sectors in Lao, within a framework that provides vertical integration of both national and local agencies. It is intended to be a Lao organisation that will be supported at different times by technical assistance (TA) and aided by the POE.

The internal organisation of the EMU should be determined by GOL. The recommendation herein is for STENO to chair the committee, with otherwise equal representation from the other groups. The EMU is proposed to have six linkages between MIH and STENO at possibly three levels of government. These form a decision making body for all environmental and Social aspects of NT2 development, with a responsibility to link their respective organisations, and the affected communities, into a working whole. It is shown schematically in Figure 6-3. At the local level, the EMU mandate should assist to monitor perceptions of environmental and social issues, and mitigate problems as they develop during the construction phase. At the national level, the EMU should be used to build consensus over appropriate environmental management for NT2, including application into the planning phase, and the long term S&E costs and benefits.

6.3.2.2 Role of NTECo

Many EPMs will need to be performed by NTECo directly. The Environmental Management Plan (EMP) relies on establishment of an environmental management office (EMO) within NTECo to monitor the TKC completion of EPMs, to undertake EPM activities itself, and to monitor any contractors hired to implement the EPMs on behalf of NTECo.

NTECo is responsible for establishing a Project Environmental Management Office (EMO). The NTECo EMO organisation is not prescribed under the present document. Internal organisation for environmental management at NTECo deserves careful study following final agreement on the work needed to be undertaken under the EMP and RAP action plans. A possible organisational framework is shown in Figure 6-4, which describes only some of the skills and divisions of responsibility that might be included in the NTECo EMO. This will be based on NTECo's estimate of the operations budget during construction phase, which covers quality assurance, internal auditing, as well as Environmental and Social (E&S) work. The RAP funding is also part of the budget process required to be resolved within the next six months (as part of appraisal by the World Bank).

NTECo scope of activity will involve program management, with some application of environmental skills, primarily under contract to short term specialists. NTECo will also have specialists on staff for watershed, forestry and related issues. TKC performance will need to be audited on a routine basis, but a commitment to international practice reduces the need for monitoring and record keeping. NTECo subcontract various studies related to the RAP and the EMP. Over 60 separate EPM proposals are contained in the present EMP, most of which will demand some involvement from NTECo.

The EMP contains proposals for a multi-level mitigation and monitoring organisation, and for a built-in adaptive management function. Adaptive management (AM) has been developed extensively as a means for improving wildlife management approaches; however the concept is commonly used in virtually all other social and scientific disciplines. AM involves the enactment of a plan of action, the observation of effects, and the correction of actions in order

to mitigate effects and improve outcomes. The NTECo liability under the EMP ends at the point of performing the AM feedback, with some well defined response options. AM activities are likely to fall mostly under NBCA financed work.

6.3.2.3 Role of TKC

The TKC is responsible to NTECo for implementing EPMs directly related to the project construction, and to assure the various sub-contracting groups likewise carry out EPMs related to their activities.. The Environmental Management Plan (EMP) relies on establishment of an environmental management office (EMO) within NTECo to, amongst other duties, monitor the TKC completion of EPMs.

The provisions of the Contract between NTECo and the TKC will include clear descriptions of the TKC's obligations to provide various Resettlement infrastructure and the manner in which works may be conducted to minimize and/or mitigate their effects on the preexisting environmental and social situation. Also clearly defined will be the International Standard Quality Assurance (QA) procedures to be followed to ensure these obligations are met. The independent external auditing of these QA procedures gives an added level of confidence that the TKC's obligations to NTECo, back to back with those of NTECo to GOL, will be precisely met.

6.3.2.4 Role of NBCA

IUCN, has the task of establishing the management strategy for the NBCA (ESA Zone 2). A number of issues are at stake, including boundaries, inclusion of extensions and the corridor, definition of customary uses by in-holders within the NBCA, training and staffing, and mobilising the administrative structure for the NBCA. This development challenge shares a number of issues with the NT2 project which are addressed by the EMP, such as wildlife and forestry concerns in the boundary area between Zones 1 and 2, respectively the proposed reservoir and the NBCA; and Zone 4, the downstream corridor, which is a directly affected area and one which is proposed to become part of the NBCA. Under the EMP, NBCA will be responsible for completing EPMs related to Watershed management, including in forestry and biodiversity. Seatec International has advised the IUCN of its assessment of these issues for its consideration in developing the NBCA Management Plan.

6.3.2.5 Role of GOL

GOL's Panel of Experts (POE), combined with Lao representatives, will discharge an oversight function.

Khammouane Provincial Office (KPO), and the district offices of Gnommalat and Nakai (GDO and NDO) all have important contributing roles for social and environmental problem solving and quick-response mitigation during the five to seven year implementation period. The roles will need to be defined as the EMU begins to function, and the action plan for implementing EPMs becomes clearer. The work by these agencies will be done at district levels and in the countryside, and at the provincial level in Thakhek, as it relates to public infrastructure and services.

The provincial and district level functions will be in public health, community services and local security, and dealing with human issues that develop out of project construction, since large numbers of workers will be housed in both districts which will need to be incorporated into the local setting. The EMU should work through representatives from GDO and NDO to resolve conflicts that may develop at the local level due to the influx of outside workers. Because services could be strained at the provincial level, the EMU will work with the KPO representative to resolve any difficulties.

FIGURE 6-3: ORGANISATIONAL CHART FOR PROJECT EMU

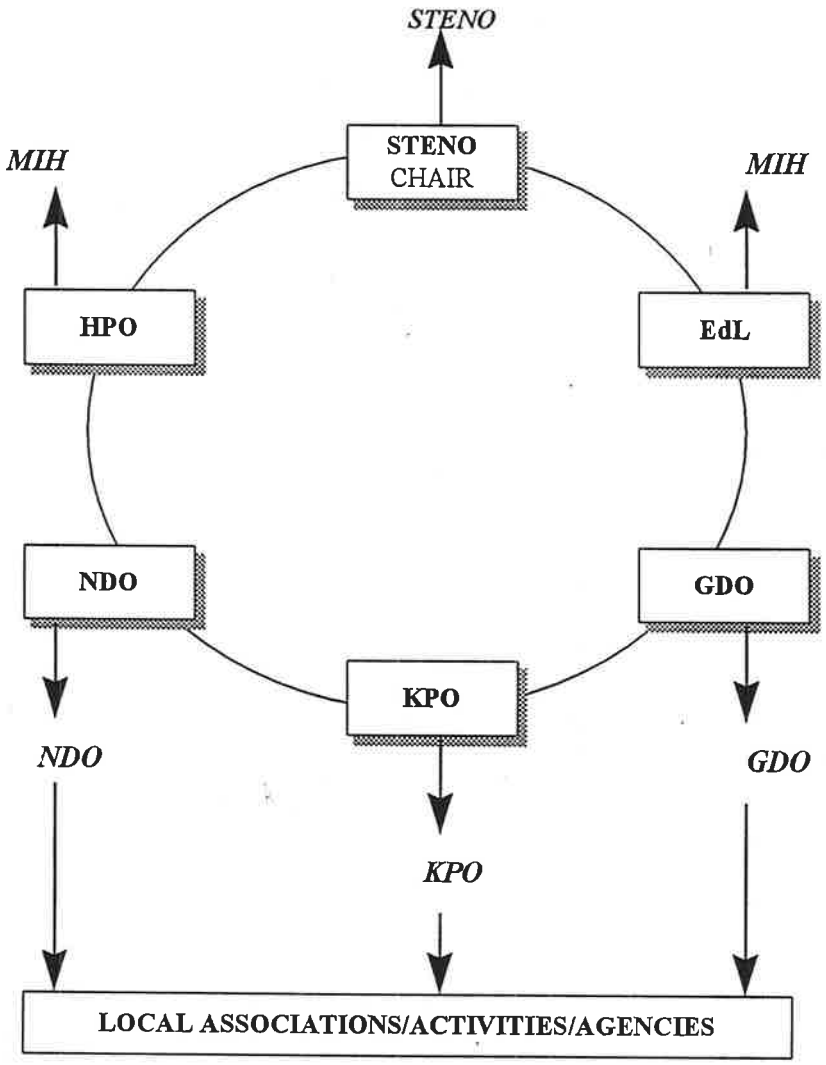
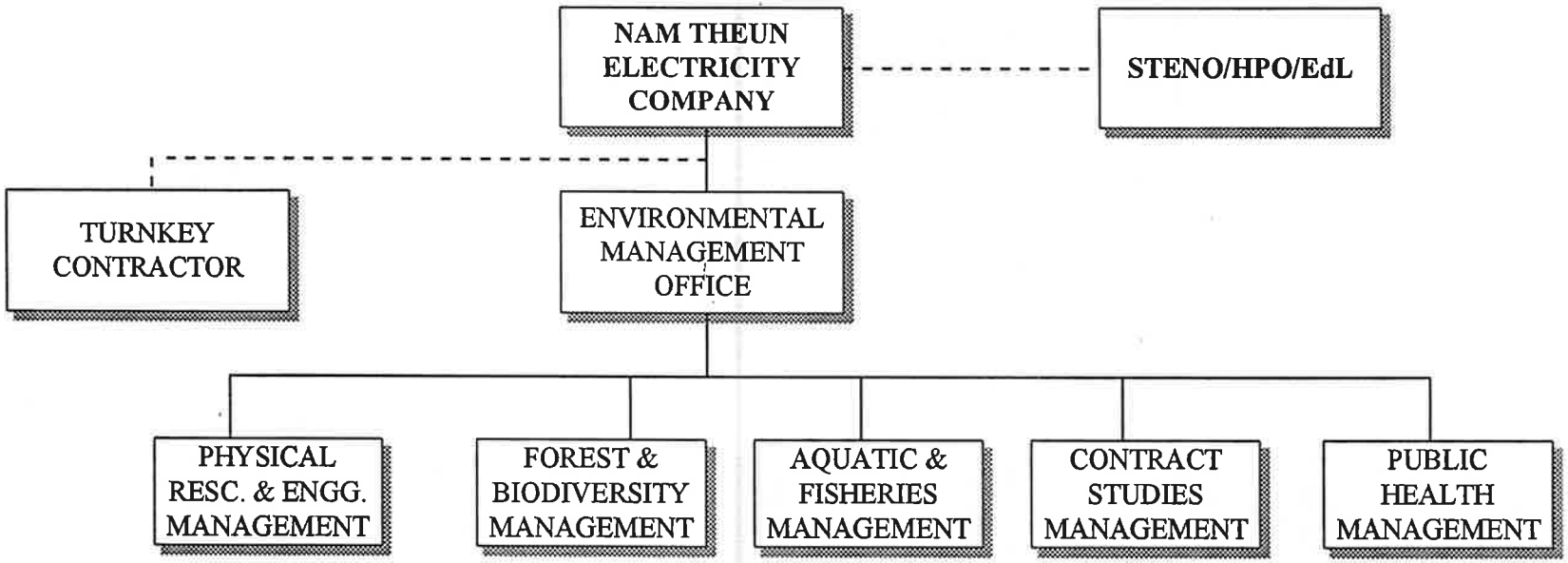


FIGURE 6-4 : ORGANISATIONAL CHART FOR NTEC EMO



Note : The external links of the Turnkey Contractor and the Science, Technology and Environment Office with EMO are shown

6.3.2.6 Institutional Functions Summary Table

NTECo and the TKC as separate entities are involved in mitigation and monitoring activities. As previously mentioned, an Environmental Management Unit (EMU) will be created under STENO, with representatives from HPO/MIH, EdL, the Khammouane Provincial Office (KPO), and district offices of Nakai and Gnommalat. In addition, GOL's Panel of Experts, combined with Lao representatives, will discharge an oversight function. The following table identifies functions for the general case. Many of the actual duties and arrangements will need to be defined at the time components of the project are mobilised.

Organisation	*Construction Related Mitigation and Monitoring*	*NBCA Management Trust*
NTECo/TKC	Mitigation aimed at impact-related effects on biological and social environment. Self-monitoring and tracking.	Provision of funding for Management Trust. Interest in protection of watershed for conservation and water management.
STENO/EMU	Monitoring Mitigation and Assistance in Problem Solving.	Policy elements of Conservation Area Management. Human issues and protection of wildlife and forest habitats. CPAWM Involvement alongside STENO.
GOL Province/District	Public Services and Problem Resolution. Training and Information Dissemination	Quasi-Governmental Functions within reserve as link to local groups and form of employment and training.
GOL POE	Broad Oversight on Primarily Human Issues. Review of Workplace measures.	Standing as guaranty that Management Aims are or are not being met.

Note that the functions of internal monitoring, record keeping and standardisation will occur for internal purposes within any of the above organisations, in particular the TKC and NTECo, and review of such records and criteria may in fact be part of monitoring performed by the POE and EMU.

6.4 SCHEDULE AND IMPLEMENTATION

The 30 years time horizon for the EMP is considered to commence five years before Commercial Operation Date (COD) and then include the full time period of the concession of 25 years past COD. Most EPM activities will occur during construction, and then during the first five years of operations. The major environmental mitigation action for the project is the establishment of the NBCA on a sound basis. This is planned to occur well prior to COD. Most activities occur in Zones 1 -- 4 on the Nakai Plateau, with other centres of activity at the base of the escarpment (Zone 7) and the remaining zones making up the ESAs for the project. At the time of writing, assuring coverage of all environmental concerns over the extended time span of operations is not intended. The list of mitigation measures is inclusive rather than exclusive: it is defined by the work tasks included in it, rather than by long term performance criteria. A timetable for implementing mitigation measures and completion of studies is given later in this chapter.

It is assumed that most work, and all funding commitments listed, occur over a period of 15 years beginning on 1 November 1998, assuming the current construction schedule is met. By that schedule, construction commences with the beginning of the dry season in 1998, or the beginning of the 1999 Water Year. Commercial Operations Date (COD) for the Power Station is then 51 months or, for the purposes of budgeting, 9 semi-annual periods after the schedule's start date. The schedule for mitigation activities commences with institutional measures in late 1998, along with some special studies (the guild monitoring and systems dynamics, both of which are under scrutiny by NTECo as to whether either are necessary), with other studies beginning around the time of construction, along with construction phase mitigation measures.

All costs are considered expended by Year-15, and are so budgeted, even though the activity could in some cases extend longer, even up to Year-30, the end of the Concession Period. This is considered reasonable and adequate at this stage in the process of identifying costs and clarifying mitigation commitments. The cost estimate will be refined to reflect a more accurate estimate of annual costs once the full slate of mitigation measures is agreed with the World Bank and GOL.

The Operations Phase mitigation measures are generally estimated to begin in about 3-1/2 years following the start of construction, or seven semi-annual periods after the Schedule's start date.

The schedules shown in Tables 6-3 through 6-8 show recommended implementation of EPMs by the GOL and NTECo:

The total cost to NTECo of these recommended mitigation measures during the Construction Phase up until the commercial operation date is $33.62 million which is made up as follows :

STENO	US$ 1,166,000
NTECo (Core Activities)	US$ 6,750,000
TKC	US$ 25,700,000
Total	US$ 33,616,000

Of this recommended amount of US$33.62 million, NTECo has already advised of its commitment under the EAMP to fund US$ 31,294 in the Construction Phase made up as follows :

NBCA Support	US$ 5,000
Construction Mitigation	US$ 25,700
Regional Health Programme	US$0.594
Total	US$ 31,294

The EAMP recommends for NTEC consideration the expenditure of a further US$ 2.5 million for EPMs.

In the operational phase NTECo has already advised of its commitment to fund US$25 million worth of EPMs made of its contributions to NNT-NBCA management. This EAMP recommends for NTEC consideration the funding of a further US$ 0.2 million for EPMs in this period.

Detailed cost estimates for select NTECo mitigation measures for STENO and NTECo Core are presented in Attachment I (to this Chapter). These costs contribute to an estimated cash flow for the construction and operations period. NTECo costs occur in every category of mitigation except those assigned to GOL, which are legislative in nature. NTECo or GOL may

provide for STENO/GOL-responsible activities through support for the EMU and for activities of the POE. All costs identified in the EMP are NTECo costs that will be combined with other identified E&S targets coming from the RAP and EASP, with various avenues for participation of GOL through NTSEP funding. The EMP does not provide information on funding channels, or how GOL and WB (e.g. NTSEP) proposes to participate in cost sharing or the flow of funds.

ATTACHMENT I

INDICATIVE COST ESTIMATES FOR SELECT MITIGATION MEASURES

Ref.	*Environmental Protection Measure*		*US$*	*US$*
6.6.1.1	Formation of the EMU			
	1. Meetings and Public Relations	1 LS	20,000	20,000
	2. Travel in Lao	1 LS	20,000	20,000
	3. Technical Support	1 LS	10,000	10,000
			TOTAL	50,000
6.6.1.2	Performance of Duties by EMU			
	1. Monthly allocation for local activities	60 Mo	2,000	120,000
	2. Technical Books, Subscriptions and Services	1 LS	30,000	30,000
			TOTAL	150,000
6.6.1.3	Strengthening EMU with Technical Assistance			
	1. Expatriate Remuneration and per diem	12 MM	15,000	180,000
	2. Local Remuneration and per diem	100 MM	3,000	300,000
	3. Expatriate International Airfare	4 Trp	4,000	16,000
	4. Local Transport and Communications	1 LS	35,000	35,000
	5. Field Sampling and Equipment	1 LS	100,000	100,000
	6. Report Preparation and Meetings	1 LS	40,000	40,000
	7. Vehicles	2 Ea	35,000	70,000
			TOTAL	741,000
6.6.1.4	Panel of Experts for Oversight of Work			
	1. Expatriate Remuneration and per diem	9 MM	20,000	180,000
	2. Local Remuneration and per diem	9 MM	3,000	27,000
	3. Expatriate International Airfare	18 Trp	4,000	72,000
	4. Local Transport and Communications	1 LS	17,000	17,000
	5. Report Preparation and Meetings	1 LS	4,000	4,000
			TOTAL	300,000
6.6.2.1	Funding of NBCA Authority			
	1. For 5 yr during construction	5 yr	1,000,000	5,000,000
	2. For 25 yr during operations	25 yr	1,000,000	25,000,000
			TOTAL	30,000,000
6.6.2.2	River Basin Management in Adjacent Basins			
	1. Expatriate Remuneration and per diem	10 MM	18,000	180,000

2. Local Remuneration and per diem	80 MM	1,500	120,000
3. Expatriate International Airfare	5 Trp	4,000	20,000
4. Local Transport and Communications	1 LS	80,000	80,000
5. Field Sampling and Equipment	1 LS	66,000	66,000
6. Report Preparation and Meetings	1 LS	40,000	40,000
		TOTAL	506,000

6.6.2.3 Modify River Morphology Below Dam

1. Expatriate Remuneration and per diem	0.25 MM	18,000	4,500
2. Local Remuneration and per diem	4.5 MM	1,000	4,500
3. Casual labor to clear channel	1 LS	17,000	17,000
4. Equipment	1 LS	24,000	24,000
		TOTAL	50,000

6.6.2.4 Exploratory Fish Surveys in Adjacent Basins

1. Expatriate Remuneration and per diem	2 MM	15,000	30,000
2. Local Remuneration and per diem	6 MM	1,500	9,000
3. Expatriate International Airfare	1 Trp	4,000	4,000
4. Local Transport and Communications	1 LS	5,000	5,000
5. Field Sampling and Equipment	1 LS	1,000	1,000
6. Report Preparation and Meetings	1 LS	1,000	1,000
		TOTAL	50,000

6.6.2.7 Firewood from Inundation Area

1. Truck and Teams Equipped	36 Mo	1,250	45,000
2. Contingency			5,000
		TOTAL	50,000

6.6.2.8 White Winged Duck Mitigation

1. Stage 1			
A. NGO and Local Consultant	4 MM	7,000	28,000
B. Airtime	4 Trp	750	3,000
C. Field Costs	1 LS	14,000	14,000
D. Transport and Per Diem	1 LS	5,000	5,000
2. Stage 2			
A. Transport of Captures to Breeding Location	1 LS	66,000	-
B. Support Over Time to Breeding Location	1 LS	40,000	40,000
C. Technical Support for Breeeding Program	1 LS	10,000	10,000
		TOTAL	100,000

6.6.2.9 Baseline Monitoring for Wildlife to Establish Guilds

1. NGO and Local Consultant	12 MM	7,000	84,000
2. Airtime	6 Trp	1,000	6,000
3. Field Costs	1 LS	45,000	45,000
4. Transport and Per Diem	1 LS	15,000	15,000
		TOTAL	150,000

6.6.2.10 Systems Dynamics Analysis

1. NGO and Local Consultant	10 MM	7,000	70,000
2. Airtime	7 Trp	1,000	7,000
3. Field Costs	18 Mo	1,000	18,000
4. Transport and Per Diem	1 LS	30,000	30,000
5. Fixed price extended monitoring	5 yr	5,000	25,000
		TOTAL	150,000

Attachment II : Reconciliation with NTSEP and E2 mitigation proposals

NTSEP DISCUSSION DRAFT PROPOSALS - RECONCILIATION WITH EAMP ACTIVITY

Management Objective	Environmental Concern	No.	Possible Mitigation	Mitigation Priority	EAMP Activity (and related Section of Ch 6)	Comment
Reduce or offset impacts on aquatic bio-diversity and river-dependent terrestrial species as a result of modified stream flow and degraded water quality downstream of the dam (including the area downstream of Nam Phao)	Disruption to fish growth, reproduction, and migration related to both reduction and timing of downstream releases below the dam	1.	Guaranteed minimum water release based on biological requirements with particular attention to simulating seasonal flow patterns;	High	Release of 2 cumec riparian release as described in 6.2.6	This release rate is considered to represent a justifiable balance between ecology and economics
		2.	Monitoring of fish and spawning grounds in Nam Theun	Moderate	Downstream fish surveys described in 6.2.6	Focus on better characterization of aquatic habitat for support of fish
		3.	Protection of nearby streams as offset;	High	River basin management study as described in 6.2.2	Focus on water quality in Nam Phao and contribution to conditions in Nam Theun below dam
		4.	Modify river morphology to maintain stretches of pools, fast rapids, sand bars;	Moderate	Evaluation and execution as described in 6.2.2	Funds to modify channel to better accommodate fish and wildlife
		5.	Construction of biologically appropriate fish-ways;	Low	No mitigation provided	Decision that fish-ways are not effective in overcoming effects of dam on migration, due to presence of Theun-Hinboun Dam
		6.	Compensation for lost fish production for villages dependent on fish;	High	Provision as described in 6.2.6	Compensation amount allocated, for use as specific requirements arise
		7.	Exploratory fish surveys in adjacent basins;	Moderate	Provision as described in 6.2.2	Provided to establish whether species are, or are not, endemic
		8.	Attention to fish management as compensation under the NBCA management plan;	High	Provision as described in 6.2.5	Provides emphasis on aquatic environment in NBCA
	Impacts caused by poor water quality of release (e.g. pH, salinity, oxygen levels, nutrient level, toxicity)	1.	Meet agreed water quality standards through reservoir clearing and water treatment;	High	Section 6.2.2 focus on removal of biomass from inundation area; items 4 – 8 under 6.2.3 guarantee water quality below dam.	Biomass removal has been shown not to be significant for maintaining water quality; however safeguards are still in place. NTEC will treat discharged water through aeration in a cone valve, and by other means.
Reduce or offset impacts on aquatic bio-diversity and river dependent	Possible disruption to fish growth, reproduction, and migration related to year	1.	Maintain canal water levels during periods when powerhouse not operating;	High	Section 6.2.6 addresses this need.	NTEC will maintain canal water levels or by other means guarantee viability of fish in DS channel.

NTSEP DISCUSSION DRAFT PROPOSALS - RECONCILIATION WITH EAMP ACTIVITY

Management Objective	Environmental Concern	No.	Possible Mitigation	Mitigation Priority	EAMP Activity (and related Section of Ch 6)	Comment
terrestrial species as a result of modified stream flow and degraded water release into the Nam Phit, Nam Kathang, Xe Bang Fai, and Mekong rivers downstream of the powerhouse	round modifications to timing, volume and velocity of stream flows in rivers below the powerhouse (e.g., elimination of dry season rapids; permanent flooding of shallow water gravel beds; conversion of Nam Phit to constant flow regime)	2.	Diversion of water into Nam Khatang to increase dry season flows;	Moderate	Section 6.2.6 addresses this need.	This provision will be built into the construction and operations plan
		3.	Creation of artificial wetlands in Nam Phit flood plain near confluence with Xe Bangfei;	Moderate	Section 6.2.3 provides for the construction of the wetland	NTEC considers that local preference should be observed in the use of the land, with a strong option being aquaculture facilities at the site.
	Potential impact on fish growth reproduction related to changes in water chemistry (e.g. salinity, temperature, oxygen, nutrients, etc.);	1.	Meet agreed water quality standards to be met for downstream water release through construction of artificial rapids or drop structures in canal;	High	Section 6.2.6 ensure that monitoring and compliance of water quality standards will be in effect.	Though these measures are shown as occurring in the operations phase, construction phase monitoring also applies.
		2.	Water quality monitoring of downstream release;	High	The above referenced requirements applies to this condition as well.	Special monitoring for low dissolved oxygen in pools below the dam will be performed, with releases made in case DO falls below a threshold level.
Reduce/offset potential economic impacts or enhance economic benefits resulting from modified inundation patterns in the vicinity of Mahaxai and along the alignment of the water conveyance canal	Possible increment damage to crops and property as a result of modified flood regime or poor water quality	1.	Investment in regional irrigation facilities to take advantage of increased dry season water availability (e.g. weir below powerhouse, irrigation canals, and other related infrastructure);	Moderate	Section 6.2.4 is provided to meet this requirement.	Provision of regional irrigation facilities will be described more fully in the RAP.
		2.	Provision of rural electricity supply to communities living along the Xe Bang Fai;	Moderate	Section 6.2.4 is provided to meet this requirement.	Provision of rural electricity will be described more fully in the RAP.
		3.	Investments in aquaculture infrastructure near Nam Phit and XBF confluence;	Medium	Section 6.2.4 is provided to meet this requirement.	NTEC will consult with local people to determine the extend and arrangement of aquaculture facilities
Reduce or offset impacts of poor water quality in, and habitat modifications resulting from creation of the reservoir	Disruption to growth, reproduction and migration of aquatic and terrestrial organisms resulting from poor water quality in the reservoir (e.g.	1.	Reservoir biomass clearing;	High	Section 6.2.2 focus on removal of biomass from inundation area.	Biomass removal has been shown not to be significant for maintaining water quality; however safeguards are still in place.
		2.	Implementation of watershed management plan;	High	Section 6.2.7 provides for this need.	Watershed management is in the best

NTSEP DISCUSSION DRAFT PROPOSALS - RECONCILIATION WITH EAMP ACTIVITY

Management Objective	Environmental Concern	No.	Possible Mitigation	Mitigation Priority	EAMP Activity (and related Section of Ch 6)	Comment
	oxygen levels, nutrient loads, toxic compounds, salinity)					interests of NTEC and GOL.
		3.	Managed continuous releases from reservoir;	High	Release of 2 cumec riparian release as described in 6.2.6	This release rate is considered to represent a justifiable balance between ecology and economics
		4.	Restricted introduction of new fish species into reservoir;	Moderate	Section 6.2.4 addresses all issues related to reservoir fisheries.	The referenced item excludes introduction of new species and cage culture from reservoir.
		5.	Water quality monitoring for reservoir;	High	Section 6.2.6 ensure that monitoring and compliance of water quality standards will be in effect.	These measures are applicable to the reservoir as well as downstream areas.
	Disruption to growth, reproduction and migration of aquatic organisms resulting from modification of riverine habitat to reservoir environment	1.	Landscaping of reservoir floor to avoid formation of small lakes (e.g. accumulations of boulders and stones to replace lost habitat)	Moderate	Not provided.	Effective improvements in local drainage of the reservoir floor have not been deemed feasible.
		2.	Reservoir stocking and breeding of key species found in lower Nam Theun;	Moderate	Section 6.2.4 addresses all issues related to reservoir fisheries.	The referenced item calls for stocking of native species in the reservoir.
Economic impacts of incremental or modified flood plain inundation near the confluence of the Xe Bangfei	Possible incremental wet season flooding and associated crop and property losses downstream of Mahaxai	1.	Possible investments in irrigation facilities to permit dry season irrigation;	Low to moderate	Section 6.2.4 is provided to meet this requirement.	Provision of regional irrigation facilities will be described more fully in the RAP.
		2.	Financial support for planned flood control and drainage infrastructure;	Low to moderate	No provision.	Direct intervention in flood occurrence is not deemed as effective as provision of dry/shoulder season irrigation.

E2 MITIGATION MEASURES RECONCILIATION - RECONCILIATION WITH EAMP ACTIVITY

Mitigation Plan Component	No.	Elemental Measure	EAMP Activity	Comment
Hydrology and flood	1.	Hydrological and flood studies	These are complete at this time.	
	2.	Study of irrigation potential along N. Kathang and DS Channel	Studies are underway as part of the RAP.	
	3.	Formulation of integrated development plan XBF basin	No provision.	
	4.	Detailed studies of flood mitigation measures (central XBF)	Studies are mostly complete. To be covered in detail in the RAP.	
	5.	Implementation of flood mitigation measures (central XBF)	Section 6.2.4 is provided to meet this requirement.	Provision of regional irrigation facilities will be described more fully in the RAP.
	6.	Implementation of integrated development plan XBF basin	No provision.	
	7.	Hydrological monitoring	Will be done ar part of Operator's normal duties	
	8.	Study implementation of water gate on re-regulating weir (N. Kathang)	Section 6.2.6 addresses this need.	Provision is in place for installation of the water gate on the Nam Kathang.
Water quality	1.	Studies and implementation of facilities for water re-aeration at dam site and along DS channel	Section 6.2.3 guarantee water quality below dam;sills are built into the downstream channel for reaeration of water.	NTEC will treat discharged water through aeration in a cone valve, and by aeration over sills.
	2.	Measures for protection of water quality during construction	Section 6.2.3 provides for construction related mitigation.	NTEC guarantees international standards of workmanship during construction.
	3.	Hydrogeological studies along Nam Kathang, water uses and formulation of mitigation programme	No provision.	
	4.	Irrigation potential studies along Nam Kathang	Section 6.2.4 is provided to meet this requirement.	Provision of regional irrigation facilities will be described more fully in the RAP.
	5.	Hydrogeological studies along Xe Bang Fai, water uses and emergency plan formulation	No provision.	
	6.	Re-assessment of future water quality	Numerous provisions are in place concerning maintenance of water quality into the future	Water quality will be expected to improve over time.

E2 MITIGATION MEASURES RECONCILIATION - RECONCILIATION WITH EAMP ACTIVITY

Mitigation Plan Component	No.	Elemental Measure	EAMP Activity	Comment
	7.	Provision for water supply mitigation programme implementation in SBF and N. Kathang	No provision.	Water supply is not expected to be threatened by the project.
	8.	Water quality monitoring	Section 6.2.6 provides for monitoring water quality.	
Fisheries	1.	Additional studies i Fish surveys	Downstream fish surveys described in Section 6.2.6	Focus on better characterization of aquatic habitat for support of fish
		ii Fishery development plan (Reservoir, N. Kathang, Xe Bang Fai, DS channel, pond culture, feasibility for hatchery development)	Section 6.2.4 address issues related to aquaculture and reservoir fisheries.	Fisheries management elsewhere in Xe Bang Fai not considered needed.
	2.	Staff training (3 senior staff abroad, 1 year)	Staff training will occur in conjunction with all technical assistance efforts (such as that described in 6.2.4). Overseas training is not specifically addressed.	Training will make use of counterparts from Government addressed.
	3.	Fishery plan implementation i Construction; building, demonstration pond, hatchery ii Setting-up of Fisheries Extension and Management Center, demonstration and training for villagers	All provisions for infrastructure are addressed in 6.2.4	
Forestry	1.	Demarcation of reservoir boundary and logging areas and monitoring of BPKP logging operations	Already done. See also 6.2.7	
	2.	Investigations into applicable agroforestry for resettlement and restoration	Mainly addressed in the RAP. See also provisions under 6.2.7 and 6.2.4	
	3.	Construction site re-afforestation program including nursery and Management of the surrounding zones of the reservoir	Item 6.2.4 addresses the issue specifically.	
Wildlife & Conservation	1.	Specific substudies for critical species affected by reservoir	6.2.2 (White Winged Duck) and 6.2.5 (elephant) address mitigation requirements for specific species	
	2.	Investigations relating to reptiles and amphibians	Section 6.2.2 addresses habitats and guilds, to include previously unclassified species.	

E2 MITIGATION MEASURES RECONCILIATION - RECONCILIATION WITH EAMP ACTIVITY

Mitigation Plan Component	No.	Elemental Measure	EAMP Activity	Comment
	3.	Planning and executing required wildlife rescue and relocation	No provision.	
	4.	Nakay/Nam Theun NBCA Management Program i Planning and supervision ii Facilities and Equipment iii Staffing and Training/Communication Support iv Operating Costs	See Section 6.2.2 for NTEC's support of the NBCA.	
Archaeology and Culture	1.	Research on Nakay Pagoda and Prince Phetsarath Residence	No provision.	
	2.	Public information prior to removal of artifacts	Required by TKC EMP.	
	3.	Assistance for artifact removal	TKC will remove from workzones RAP will remove from exisitng villages	
Public Health	1.	Pre-employment medical screening of workers	TKC provision.	
	2.	Workers safety/Malaria control in worker camps	TKC provision.	
	3.	Malaria/transmissible diseases control in nearby population	NTECo	
	4.	Health monitoring of resettled communities	RAPprovision.	
	5.	Electrical connection to network of 3 District Hospital	No provision.	
	6.	Supply of equipment and drugs to local district Hospitals and Health Centers	NTECo provision.	
	7.	Study for regional public health improvement plan	NTECo provision.	
	8.	Implementation of plan	NTECo provision.	
Resettlement	1.	Detailed Planning Actions i conduct detailed soil survey ii conduct 2nd preference survey iii finalize the resettlement site selection iv physical lay-out of each resettlement site v detailed design of infrastructure and supporting facilities of each resettlement site vi detailed planning for agricultural development package, non-agricultural employment packages,	All resettlement provisions are addressed in the RAP.	

E2 MITIGATION MEASURES RECONCILIATION - RECONCILIATION WITH EAMP ACTIVITY

Mitigation Plan Component	No.	Elemental Measure	EAMP Activity	Comment
		monitoring arrangement, and environmental protection		
	2.	Grievance Hearings and Participatory Planning Process	All resettlement provisions are addressed in the RAP.	
	3.	Construction of Infrastructure, Supporting, Facilities and Land Development at Each Site	All resettlement provisions are addressed in the RAP.	
	4.	Implement Agricultural Extension Program	All resettlement provisions are addressed in the RAP.	
Evacuation	1.	Information Campaign	Related to resettlement	
	2.	Maintenances Arrangements Planning and Program	Related to resettlement	
	3.	Relocation of Families to designated Sites	Related to resettlement	
	4.	Transition Monitoring	Related to resettlement	
Compensation	1.	Policy Formulation and Approval by GOL	Related to resettlement.	
	2.	Negotiation and Finalization of Compensation Amounts and Schedules	Related to resettlement.	
	3.	Implement Compensation Program including Replacement Houses	Related to resettlement.	