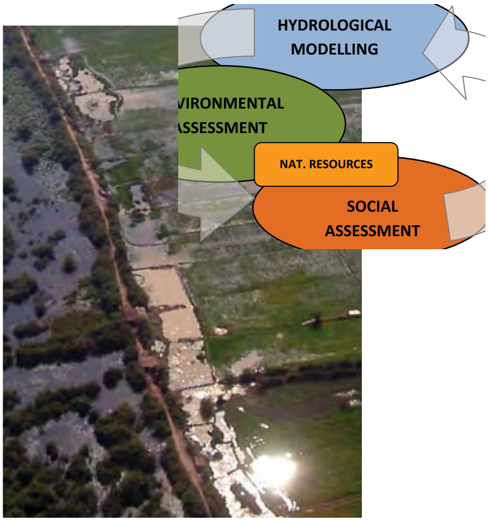
Mekong River Commission

Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment



Water Utilisation Programme

WUP-FIN Phase 2

Final Report – Part 2:

Research findings and recommendations

Finnish Environment Institute
Environmental Impact Assessment Centre of Finland Ltd
Helsinki University of Technology

Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment

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Final Report – Part 2: Research findings and recommendations

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This report is one of the WUP-FIN2 **main reports**. All the reports are listed below

WUP-FIN phase 2 – Main reports	
1	Inception report
2	Impact assessment report
3	Modelling report
4	Final report

The WUP-FIN2 report series includes eleven **working papers** as listed below

WUP-FIN phase 2 – Working papers	
WP1	Socio economics
WP2	Model development
WP3	Field measurements
WP4	Vientiane – Nong Khai model application
WP5	Nam Songkhram model applications
WP6	Lower Mekong Basin floodplain model application
WP7	Tonle Sap model application
WP8	Chaktomuk confluence model application
WP9	Tan Chau model application
WP10	Plain of Reeds model application
WP11	Tieu River mouth model application

WUP-FIN2 report series includes eight **technical papers** as follows

Technical paper	
TP1	EIA 3D model manual
TP2	VMod Hydrological model manual
TP3	HBV Hydrological model manual
TP4	RLGis manual
TP5	Tonle Sap Lake water balance calculations
TP6	Database report
TP7	Remote sensing study of Mekong River bank location in Vientiane – Nong Khai area
TP8	Sediment dynamics of Tonle Sap Lake

WUP-FIN2 report series includes five **socio-economic** reports as follows

Socio-economic reports	
SE1	Tonle Sap Review and Integration Report
SE2	In the Bend of the Bassac River – Participatory village survey in Chheu Khmau Commune, Cambodia
SE3	Living in the Mekong Floodplain – Participatory village survey in Preah Sdach Commune, Cambodia
SE4	Vientiane Village Survey Report
SE5	Mekong Delta Socio-Economic Analysis Report

This document can be referred as follows:

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ACRONYMS AND ABBREVIATIONS

0D	zero-dimensional
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
ADCP	Acoustic Doppler Current Profiler
BDP	Basin Development Plan of the MRC
BOD	Biological (biochemical) Oxygen Demand
CEA	Cumulative Effects Assessment
CNMC	Cambodia National Mekong Committee
DEM	Digital Elevation Model
DSF	Decision Support Framework – MRC's suite of computer-based numerical modelling and knowledge based tools
EA	Environmental Assessment (common term for different environmental assessment methods)
E-flows	Environmental flows
EIA	Environmental Impact Assessment
EIA Ltd.	Environmental Impact Assessment Centre of Finland (www.eia.fi)
EP	Environmental Programme of the MRC
FP	Fisheries Programme of the MRC
FR1, FR2, FR3	Flow regimes under IBFM, DSF model results
GIS	Geographical Information System
GUI	Graphical User Interface
HBV	Name of the lumped hydrological model
IA	Impact assessment
IAIA	International Association for Impact Assessment
IBFM	Integrated Basin Flow Management process of the MRC
IKMP	Information and Knowledge Management Programme of the MRC
IUCN	The World Conservation Union
IWRM	Integrated Water Resources Management
LMB	Lower Mekong Basin
LNMC	Lao National Mekong Committee
LU	Land Use
MoWRaM	Ministry of Water Resources and Meteorology, Cambodia
MRC	Mekong River Commission (www.mrcmekong.org)

MRCS	Mekong River Commission Secretariat
MWBP	Mekong Wetlands Biodiversity programme (UNDP, IUCN, MRC)
NMC	National Mekong Committee
NP	Navigation Programme of the MRC
OpenGL	Open Graphics Language / Open Graphics Library
PC	Personal Computer
PIP	Project Implementation Plan
PSIA	Poverty and Social Impact Analysis
RAM	Resource Allocation Model
RCM9	Recording current meter by Aanderaa instruments
RLGis	River Life GIS, a GIS programme used together with the EIA 3D model. Base for the spatial database.
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
SIM	Social Impact Monitoring system for MRC/EP
SIWRR	Southern Institute of Water Resources Research, Vietnam
SQL	Structured Query Language
SSC	Suspended Sediment Concentration
TNCM	Thai National Mekong Committee
ToR	Terms of Reference
TSS	Total Suspended Solids
UMB	Upper Mekong Basin
UNDP	United Nations Development Programme
VMod	Name of 2D distributed hydrological model developed by EIA Ltd.
VNMC	Vietnam National Mekong Committee
WAD	Waterways Administration Division of Lao PDR
WQ	Water Quality
WUP	Water Utilization Program of the MRC
WUP-FIN	Lower Mekong Modelling Project under Water Utilization Programme of the Mekong River Commission (www.eia.fi/wup-fin)

PART 1: INTRODUCTION

The WUP-FIN project has been facing challenging tasks throughout its two phases. The road was pretty much marked by the TOR of the first phase dealing with the hydrology, environment and water-related livelihoods of the Tonle Sap. The TOR, actually reflecting directly the ideas of the original WUP-A TOR, obliged the improvement of understanding the Tonle Sap system behaviour. This not only meant to develop advanced flood pulsing and hydrodynamic modelling, but also to dive into the lake-floodplain ecosystem process studies and field work. In addition, socio-economic and policy analyses were necessary to contribute to increased understanding of water-related livelihoods and policies, guiding modelling work and facilitating impact assessment.

The specific role and importance of the Tonle Sap within the WUP-FIN work has remained since the first phase due to its critical value in terms of its natural resources and source for livelihoods and food security as well as due to the increasing pressures posed to the lake and its floodplain by basin developments.

Along with the development of modelling, analysis and impacts assessment tools for the Tonle Sap, capacity was during WUP-FIN Phase 1 created to address other critical areas and issues in the Lower Mekong Basin. This lead to a cluster of new case studies in all four MRC member countries in the WUP-FIN Phase 2. The new applications in these case study areas meant new challenges for model development, socio-economic analysis and impact assessment; the delta with its complex channel-floodplain-livelihoods system, sediment and erosion processes, sub-basin modelling for supporting the IWRM and so forth.

The zest by the WUP-FIN team to dive into the large and wide spectrum of applications and problems has resulted very much from the enthusiasm and encouragement of our riparian colleagues. All WUP-FIN model and impact assessment applications have a clear need and relevance for practical problem solving, and tight linkage to regional processes and developments. As will be discussed in many of the following chapters, this kind of combination of local and basin wide issues forms, in our opinion, the most suitable basis for balanced and equitable basin planning.

1.1 BACKGROUND OF WUP-FIN PROJECT

WUP-FIN is a complementary project to the Mekong River Commission Water Utilization Programme (MRC/WUP). It is funded by the Development Cooperation Department, Ministry for Foreign Affairs, Finland. The project has **two phases**:

- **Phase 1 (2001-2004)**: Modelling of the Flow Regime and Water Quality of the Tonle Sap
- **Phase 2 (2004-2006)**: Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment

The WUP-FIN Projects have been realized by a consortium consisting of a governmental lead institute (Finnish Environment Institute - SYKE), a university for socio-economic and policy analyses (Helsinki University of Technology - TKK) and a small private company for modelling (Environmental Impact Assessment Centre of Finland Ltd. - EIA Ltd.). The consortium has collaborated closely with a large variety of project counterparts from MRCS and NMCs, governmental line agencies, universities, research institutes and civil society organisations in all four MRC member countries. In addition, the project has done cooperation with numerous international universities and organisations working in the region.

1.2 WUP-FIN PROJECT APPROACH

All modelling, analysis and impact assessment work carried out within WUP-FIN Project builds on integrated, research-based approach that is tailored to local needs. We do not believe in "one approach fits all"-solutions, but recognize that each case is different and requires therefore case-specific approaches and methods, and systematic understanding of the context and processes of each case. While considering research to be of high importance, the tailor-made approach means that we seek to find solutions for practical problems and our focus is therefore strongly on applied research that answers to real solutions on the ground.

Although having a strong belief in tailor-made solutions, we use common impact assessment framework under which all different case studies are applied. This multilevel and interdisciplinary impact assessment framework thus connects different case studies together and enables impact assessment in higher, basin-wide levels.

We believe that these overarching principles have to be visible also in the way we think about our work: after all successful work is very much about attitude. We take great pride in our project, and have a real passion in our work. We set our goals high –even too high occasionally– as we believe that without big goals you cannot achieve great things. This naturally requires high level of ambition both from us and from our counterparts, and we have been lucky enough to have many such people working with us. Finally, in the field as complex and political as water resources management, we think that integrity is the guiding principle in everything we do.

Our working principles and attitude have also strong influence on how we organise our work. The institutional structure of WUP-FIN supports strongly the cross-disciplinary and research-based approach, as WUP-FIN is not just a consortium of consultancy companies but consists of governmental research institute, university and small private company, and works together with a variety of counterparts from MRCS and NMCs, governmental line agencies, universities and civil society.

In addition to this overarching approach and impact assessment framework, there exist some overall themes common to all WUP-FIN cases and indeed to entire WUP-FIN approach: these can be described as WUP-FIN core themes:

- Multi- and interdisciplinarity
  - ➔ not only working with many sectors and disciplines, but also aiming at real interaction between different disciplines, starting already when framing the research questions and designing and deciding the methods used
- Process with continuous improvement & flexibility to change and adapt
  - ➔ not using only one pre-defined approach, but seeking to improve and adapt the methods applied as research progresses
  - ➔ comparing –and contesting– our interpretations and understandings with those of others
- Systematic understanding
  - ➔ seeking to understand the entire system on which we are working and doing research, including also broader socio-political context
- Open and transparent dialogue and interaction with stakeholders and collaborators from different fields and levels, including information sharing
  - ➔ collaborators include MRCS, NMCs and governmental line agencies, but also universities, civil society organisations as well as local communities

- ➔ open dialogue also requires openness and transparency in methods used and results achieved; we promote this by using open source modelling software and publishing our results in different forms (reports, scientific publications, posters etc.) and also in riparian languages when possible

- Special emphasis in capacity-building in different levels and with different actors
  - ➔ from MRC and NMCs to national line agencies and –importantly– to universities and research institutes

- Producing information that is of real relevance for decision-making
  - ➔ Working with real issues on the ground, and using socio-economic and policy analyses to guide modelling and impact assessment work

The Figure 1 below seeks to describe the WUP-FIN project approach and framework together with those six core themes defined above.

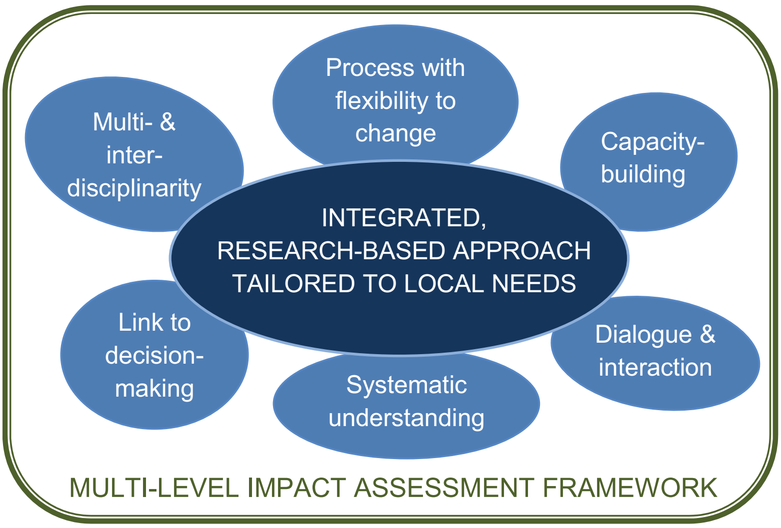

Figure 1. WUP-FIN project approach and impact assessment framework together with six core themes describing the core values of our work.

1.2.1 Model approaches

Overview of the MRCS modelling systems – DSF and WUP-FIN

Models in general can be divided into 4 categories according to their dimensionality:

0. 0D models don't describe spatial variability of simulated variables. 0D models can be used to simulate for instance small mixed ponds or stirred reactors
1. 1D models are used typically for river and channel networks. They describe variation of flow, sediment concentration and other variables in the longitudinal direction. In special cases 1D models can be used in vertical direction for instance for vertically stratified lakes.
2. 2D models describe variation of simulated variables in both horizontal dimensions (or is special cases in the vertical and one horizontal dimension). 2D models are typically used for flood wave/ pulse simulation on the floodplain, coastal wetting/ drying and in shallow lakes.
3. 3D models describe the calculation variables in all spatial directions. Typical application areas include lakes, reservoirs, floodplains, rivers, coastal and sea areas where processes are dominantly 3-dimensional or the variable values wary considerably.

The disadvantage of 2D and 3D models is, that description of a large channel network is not practical with them. 1D models are better adapted for that task. On the other hand 1D models for floodplains and other 2D/3D systems don't capture all important characteristics and tend to become rather complicated in their schematisations. The obvious **solution for model limitations is to use combined 1D/2D/3D model** which utilises the best features of all models.

The **MRCS modelling environment** consists of a number of separate and coupled models. Under the **DSF** (Decision Support Framework) three models are used: **ISIS 1D** hydrodynamic, sediment and salinity model for the Mekong mainstream and main tributaries, **SWAT hydrological** model for the Mekong catchment area for simulating rainfall/ runoff and hydrological processes and **IQQM water resources and allocation** model. Additional tools include **EIA 1D/2D/3D modelling tools** and **JICA MIKE11 1D** model application for the Cambodian floodplains.

WUP-FIN tools consist of a large set of environmental models and their support software. The core models calculate hydrological and hydrodynamic processes. Their results are used in a number of coupled modules or separate models.

The core models of WUP-FIN Project are:

- EIA hydrodynamic model: River, lake, reservoir, floodplain, coastal and sea area hydrodynamics (1D/2D and 3D)
- VMod hydrological model: Watershed hydrology, erosion and water quality (0D/1D/2D) including ground water (2D)

The secondary coupled models can simulate:

1) Water quality (1D/2D/3D) including dissolved substances such as oxygen, nutrients and acidity
2) Salinity intrusion (as a density difference influenced 3D process)
3) Sediment transport, erosion and sedimentation (2D/3D)
4) Oil and chemical accidents (3D)
5) Fish larvae drift.

ISIS, SWAT, IQQM and WUP-FIN modelling tools are connected off-line. For instance SWAT results are calculated firs providing information on watershed flows into to the Mekong, ISIS calculates after that the consequent flow in the river system and finally Tonle Sap 3D model uses ISIS Tonle Sap River flows as a boundary value. Off-line coupling doesn't work in areas where there is significant interaction between the different model domains. For such cases one needs a coupled model simulating the interaction between the channel and river network and the floodplain, reservoirs or lakes. The EIA combined 1D/2D/3D model is a system where the coupled flow, sediment and water quality can be simulated. In this document it is called **EIA-123D**.

In the EIA-123D the 1D characteristic are simulated with the **RNet** river network model that solves one-dimensional river flow and water quality in a river network. The solution is based on solving simplified St.Venant equations numerically. The river system is described to the model as a river network constructed from one-dimensional rivers, and river nodes that connect individual rivers to a network. The 2D and 3D characteristics are solved by the **EIA-23D** model. The combined model, EIA-123D, can take its boundary values from measurements, hydrological models or basin-wide model systems such as DSF.

In the EIA-123D-model the connection algorithm is devised to be flexible in the sense that basically any 1D model with capability to communicate outside itself can be coupled with the floodplain model. The structure of the combined model system is shown in figure xx.

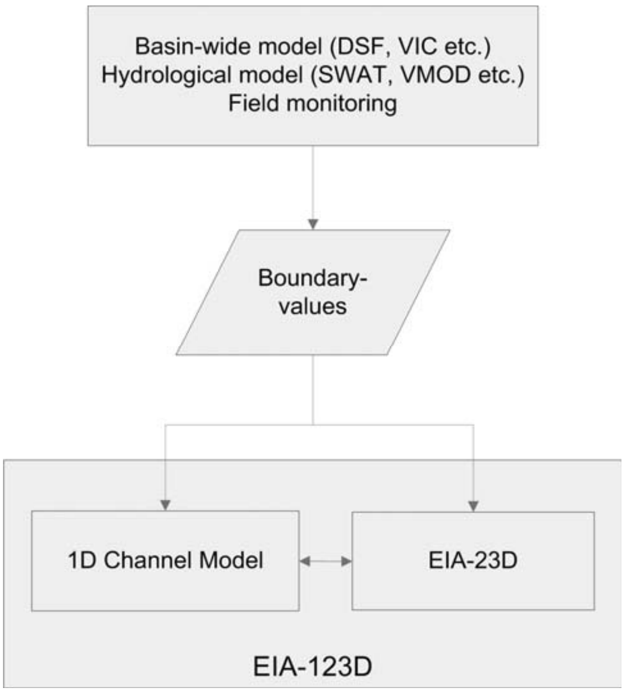

Figure 2. EIA-123D combined model simulation scheme overview.

DSF development

The DSF comprises a set of hydrological and hydrodynamic models and flood analysis procedures. There is a continuous need and widening scope to develop more advanced analytical methods for interdisciplinary and integrated assessment. These include water quality and ecosystem models and assessing environmental and social impacts under various flow regimes and development scenarios.

A major challenge for the MRC is to build a scientifically validated, credible and sustainable model platform in support of basin development planning, hydrological forecasting and integrated environmental and social impact assessment, just to mention a few of the key applications of such a system. There is still lot of work to do with the DSF and add complementary tools to improve the basin wide hydrological analysis, e.g. the cumulative effect of planned hydropower dams that presents a starting point and cornerstone for any consequent impact assessment. The present DSF contains a rather rudimentary scheme for calculating the hydropower dam impacts (Adamson 2006).

The MRC would benefit greatly from continuing validation and scientific review of the model system, which is necessary for its transparency and credibility, not least in trans-boundary context. Widening the platform to an ensemble of models for different scopes, involving model comparison and cross-validation would lead to increasing credibility and additional usefulness of the DSF. Without doubt, all this would lead to increasing potential of the MRC to inform Mekong basin development planning and decision-making on the impacts of various development scenarios.

Related to this, it is unfortunate that some important MRC Reports (such as BDP Scenario Report and IBFM Report 8 on development impacts) have remained in-house papers, without public distribution, screening and discussion. There exists an increasing variety of actors looking at the development impacts in the basin, and dialogue and information sharing with these actors would potentially benefit greatly also the development of DSF.

WUP-FIN model development history

The model system used in the WUP-FIN project has been developed over 30 years by the EIA Ltd. in Finland (since 1990 part of the Technical Research Centre of Finland) in connection with other national and international institutes. The most important one in this respect has been SYKE (the lead institute in WUP-FIN). The modelling software has been created for practical environmental and engineering projects and studies. The model system has been applied to over 300 domestic and international case studies. In each case outputs of the model used have been verified with field measurements. The customers consist mostly of industries, companies and authorities. More information about EIA Ltd and models can be found from the company's web-sites: www.eia.fi

The model system has been designed with a number of general principles:

- Data management and modification with an integrated GIS platform
- Common structural engine where application modules can be added
    - The application modules can be combined

    - The combined application modules will solve the actual modelling problem
- Data management and user interfaces are separated from the engine
    - Engine can be changed
- The ultimate design principles
    - Speed, calculation accuracy, robustness and error free code

The model speed can be partly explained with the long development history and the limited computational resources that were available in the start of the development work in 1970'ies and 1980'ies which necessitated adoption of efficient solution algorithms. Of course the final application speed is very much application dependent, and a model with grid consisting of millions of calculation points can not expected to be run in a few seconds.

The WUP-FIN first phase during 2001 – 2003 produced – as far as known – the first and still the only 3D hydrodynamic and water quality floodplain model in the world. 3-dimensionality is necessary for Tonle Sap description, because the lake and floodplain physical, chemical and biological characteristics vary dramatically both in horizontal and vertical directions. In order to understand even basic Tonle Sap dynamics and make reliable impact analyses it is necessary to have the 3D processed modelled. Because of the large water level variability, it was necessary to re-programme the original 3D lake, sea and coastal model from ground-up. The original model assumed only small water level variations compared to the total depth. Also flooding/ drying processes were not part of the original model. The 3-dimensionality complicated the work greatly when mass conservation, solution robustness and physicality were demanded.

WUP-FIN First Phase also included extensive field measurements for model calibration and verification, hydrological model (VMOD and HBV) development for 13 Tonle Sap sub-catchments, database development with graphical user interface and integrated GIS/ model / data processing user interface development. An important part of the work was socio-economic field studies, research and policy model development, that analysed and highlighted the livelihood and development issues in the area.

The second phase of the project, WUP-FIN II, has been applying the developed tools to all 4 countries building at the same time model user capacity in the riparian countries. Intensive model development including many model extensions and improvements, extensive capacity building in the four countries, large number of application areas (altogether 8), conduct of field measurement campaigns, versatile scenario work, analysis of DSF results, calculation of measurement based water and sediment mass balances for Tonle Sap and Mekong, large number of socio-economic studies in Vietnam, Cambodia and Laos and creation of comprehensive cooperation network with the riparian and international institutes and experts have kept the staff extremely busy throughout the project and after it during the extension period.

Model development challenges

The challenges specific for the combined 1D/ 2D/ 3D modelling can be divided into data and stability/ computational time related issues. Both can hamper practical model implementation.

The data issues and their solutions in the EIA-123D modelling system can be summarised as:

- Setting up the 1D sub-model takes lot of resources for complex system such as Plain of Reeds or the whole Vietnamese delta → (i) import required information from existing 1D models or couple existing 1D model with the floodplain model, (ii) use automated and graphical user interface assisted model input data processing.

- Setting up floodplain model can be also a resource consuming affair in large and complex areas → automated and graphical user interface assisted use of GIS and control structure data for model input data processing.
- Data is lacking especially on control structures → As model grids, river networks and data structures map directly to map coordinates and model floodplain processes translate directly to real world phenomena, remote sensing data can be used to clarify control structures directly or indirectly through flooding patterns.

It is common that combined models run exceedingly slow – even slower than in real-time! (Green 2007) In other words, one day simulation can take more than a day to run. Because of this special attention has been devoted to making the WUP-FIN models robust, stable and efficient. The resulting applications are not consuming intrinsically more time than the corresponding 1D counterparts although 2D/3D and combined models contain vastly more calculation points and variables than the pure 1D models.

Stability and computational time requirements are tied together. Often stability problems can be overcome by diminishing model time step, but this comes on the expense of computational time. Stability issues connected with the model coupling and their solutions are discussed in WUP-FIN Model Report. Similarly specific issues in the sub-models have to be dealt with for the system to be able to run with reasonable processing times. As an example, small water depths and handling of flooding and wetting in both the channel and floodplain models requires specific attention.

Other issues connected with the combined model running include data exchange between the models, synchronization of sub-model execution, maintenance of mass-balances, limiting of numerical errors arising from use of very large or small parameter or variable values and software development related problems such as module linking and error handling in multi-language programming[1]

[1] In case of the combined model Fortran – 2D/3D model -, C – interactive animation window during simulation - and C++ - RNet 1D model.

1.3 PURPOSE OF THIS REPORT

This report is a product of an extensive collaboration of Finnish, international and riparian experts. The purpose of the report is to describe and justify the approaches and strategies applied within the project as well as to summarize and synthesize the main results and findings of the WUP-FIN Project into general conclusions and recommendations. Some of our findings and recommendations may seem to be very general, even obvious. However, based on our experience with a variety of modelling and impact assessment processes in the basin, we feel that many of these processes are actually lacking focus and have got lost to the complexity and diversity of the issues involved; we therefore see that it is important to bring attention back to the main issues.

WUP-FIN has sometimes been said to be more of a research project than something serving practical and planning purposes. We hope that the report shows that these two aims can actually form a successful combination – and that this combination is often the most successful way forward. The report argues that without primary studies and data collection it is impossible to draw conclusions of process behaviour (nature, society) that is necessary to reliably assess the diverse impacts of different development plans.

The report also wants to bring the findings and recommendations into the discussion with experts, practitioners as well as with other stakeholders. A very basic objective in the Finnish development cooperation policy in the Mekong Basin is to increase understanding of and have an impact on the basin developments, based on results of the work done and, consequently, the knowledge produced on the development impacts – hydrological, environmental as well as social. The project has produced a great number of technical reports, working papers and publications that are available for studying the details of our field surveys, data analysis, model developments, socio-economic and policy analyses as well as impact assessment case studies. The main findings from all of these are presented also in this Final Report.

A kind request to the reader is to join in the discussion about the drawn conclusions and recommendations –intended to reflect the spirit of the IWRM and Mekong Agreement– in an open and transparent dialogue. The outcome of the discussions and the dialogue is particularly timely due to the rapid developments and expected impacts in the Mekong basin, and, simultaneously, for guiding the way forward for the Finland-funded activities in the region, both within the MRCS and with the national institutions and other collaborators.

1.4 OVERVIEW OF REPORT LAYOUT

WUP-FIN Final report has been divided into two parts:

- **Final Report – Part 1: Project activities and achieved outputs**
- **Final Report – Part 2: Research findings and recommendations**

This report has been divided to three main parts as listed and described below:

PART 1: Introduction: this chapter gives a background information of the project and purpose of this report including this overview of report layout

PART 2: Thematic entities: altogether nine (9) research themes have been selected by the WUP-FIN team to be issued in this Final report. Each theme follows the structure: 1) Research aims, 2) Methods, 3) Major findings + way forward

PART 3: Conclusions + way forward: in this chapter the conclusions of WUP-FIN project major findings and achievements are drawn.

1.5 THREE CROSSCUTTING THEMES OF THE REPORT

This report summarises the key findings from the WUP-FIN project's work since its beginning in June 2001. While there would be naturally many key findings and themes to be presented[2], we want in this report to focus few key research themes that we see to be particularly important: these are presented in more detail in Chapter 2.

In addition, there are few crosscutting themes that are in different ways related to all the research themes; and consequently cut across the entire report. These crosscutting themes are:

- **Poverty reduction** – *ultimate objective*
- **Critical natural resources, particularly fisheries & floodplains** – *thematic focus*
- **Impact assessment processes** – *methodological focus*

Poverty reduction

The first crosscutting theme related to poverty reduction forms the ultimate objective for the MRC, and consequently also for our work. Poverty reduction goals set the frame also for water management and development, and therefore also for the impact assessment work. Some of the key issues addressed in this report related to poverty reduction are: 1) good governance, 2) linkages between natural resources and livelihoods, 3) dilemma of economic development and poverty reduction, and 4) unequal distribution of risks and benefits. These are discussed in more detail below.

We see that good governance and well functioning and transparent management mechanisms are an absolute prerequisite for poverty reduction as well as for equal water resources management. Due to prevalent governance challenges in the region with shortcomings in truly representative democracy, we believe that also impact assessment processes should pay more attention to governance of water and related resources. Related to above, it is important to acknowledge the complexity of linkages between natural resources and livelihoods, and focus on ways to measure and describe the true value of natural resources particularly for the poorest groups of society. Due to people's deep dependency in natural resources, environment is in the Mekong Basin not only conservation issue, but also very much –even predominantly– a livelihood issue – and maintenance of critical natural resources is therefore of crucial importance for significant number of people in the basin, many of them poor.

The dilemma between economic growth and poverty reduction is almost an eternal source of debate, and also we discuss this challenge in one of the thematic chapters of this report. We think that there are severe limitations in so-called trickle-down effect that believe that the economic benefits from different development projects will ultimately –in one way or another– also benefit the poorest groups of society. One of the major challenges in the Mekong Basin lies in large-scale infrastructure projects that are said to benefit particularly the poorest, but are according to our experience often actually causing mostly negative impacts to the poor dependent on natural resources – particularly fish– for their livelihoods.

This issue is closely related to unequal distribution of risks from different development projects: in many cases the risks of infrastructure projects are borne by different people –often the poorest– than the benefits. Often the losses and benefits also have different geographic scales as well as time scales, and their comparison is therefore particularly challenging. For this reason we see that there is thus an urgent need for

[2] See separate WUP-FIN reports on some of the more detailed findings.

open discussion about trade-offs that water development in the Mekong Basin unavoidably requires, and the implications –both short-term and long-term– that the development is going to have particularly to the poorest.

Critical natural resources – particularly fish & floodplains

The second crosscutting theme of this report is more thematic and focuses on most critical natural resources in the basin, with a specific emphasis on two interlinked resources i.e. fisheries and floodplains. We consider these two resources to be particularly critical for two main reasons: Firstly, both fish and floodplains are socially and economically extremely significant as they have a major role in supporting the livelihoods and food security throughout the basin, and as so-called common pool resources they have a particularly important role for the poorest groups of society that e.g. lack access to agricultural land.

Secondly –as will be discussed also later on– both of these resources are particularly vulnerable to the changes in river flow, and consequently to the negative impacts of development within the basin. While the direct impacts on these resources are environmental, also the social and economic impacts of basin development are largely brought about through impacts on these resources, and particularly on fisheries production. At the same time reliable figures on fisheries production in the Mekong Basin are available only for small parts of the sector, and are not representative of the diverse fisheries as a whole.

Despite the highly critical nature of fish and floodplains for entire basin, we see that neither of these resources is having as large role as they should in regional discussions about the trade-offs and development impacts. We think that this needs to be changed, and considering them as crosscutting themes in this report –even though fish as such has not been one of the main research areas within WUP-FIN Project– is one attempt to raise their profile in the regional discussions.

In addition to these two natural resources, there are naturally other critical resources in the basin as well. Particularly important is rice that together with fish forms the staple food for majority of the people living in the basin and provides the main source of income for millions. In terms of flow changes, however, rice can be considered to be more persistent than fish and floodplains as it is possible to adapt –to certain extent– the rice cultivation practices to flow changes; this is, however, not the situation with all rice varieties as e.g. floating rice of Tonle Sap that is particularly vulnerable to flow changes. In addition, some of the basin development causing possible flow changes, namely different kinds of irrigation structures, are actually supporting rice cultivation. Consequently, the discussion about rice cultivation and the possible impacts –both positive and negative– that different development plans in the basin are likely to have related to it is in bit different level than with fish and floodplains. Interestingly, in some occasions these resources are actually located in the opposite side of the discussion about the impacts and related trade-offs between gainers and losers.

Impact assessment processes

The third and final crosscutting theme is more methodological by its nature, and deals with the importance of impact assessment processes and the challenges they are facing. The rapid changes taking place in the Mekong Basin due to different development plans and overall social and economic trends (e.g. urbanisation, population growth) are likely to cause significant environmental, social and economic impacts in different parts of the basin. At the same time there is a serious concern that most impact assessment practices don’t currently capture comprehensively the potential cumulative and combined impacts of basin development, but instead focus too narrowly either on certain project or just on certain impacts. These challenges with impact assessment are discussed throughout this report, and recommendations for way forward given in the concluding chapter.

Overall, we see that the impact assessment process in a basin as complex and grand as the Mekong Basin has to build on multi-level approach that looks at issues and impacts innovatively in different levels i.e. from local to national and all the way to regional level. Related to this, there is an urgent need for more involving process of impact assessment, with continuous dialogue with all concerned parties and easy access to information and methods that guide the impact assessment. In addition, capacity building remains of critical importance to ensure the true ownership as well as long-term sustainability of the impact assessment efforts.

All of these three crosscutting themes are dealt in different ways and levels of detail in the thematic chapters of this report. In the concluding chapters we then draw together some more overall findings on the crosscutting themes, and provide our recommendations related to them. These conclusions and recommendations reflect our own ideas and understandings and we believe there are also other views on these themes – we are happy to enter into a dialogue about these issues, so please get in touch and provide your comments!

PART 2: SELECTED RESEARCH THEMES

> The selected WUP-FIN research themes are presented in this part of the Final Report. Altogether nine themes were selected for detailed analysis. These are naturally not the only themes that WUP-FIN has been working with, but our team considered these to be considered to be particularly important in the context of our work and the current development in the Mekong Basin.

Most of the research themes are presented based on the following overall structure:

- Research aims
- Methods
- Major findings + way forward

The research themes selected to be presented in this chapter are:

- Flow alterations & flood pulse
- Sedimentation
- Tonle Sap ecosystem production
- The dynamics of Mekong Delta
- Bank erosion
- Climate change in Nam Songkhram
- Livelihoods impacts
- The dilemma between economic growth and poverty reduction
- Capacity building

An integral part of all the research themes presented above is the concept of flood pulsing hydrology, and it therefore forms one of the foundation stones for WUP-FIN work and is closely related to e.g. sediment transport and sedimentation, floodplain productivity and livelihoods. The Mekong Delta, on the other hand, forms a natural, large entity with complex internal set-up of infrastructures and developments, and has been a major focus during WUP-FIN Phase 2. The modelling and impact assessment work in the delta is largely summarized in this report.

Bank erosion is of concern in all four MRC member countries and has thus had a high priority also in WUP-FIN work; including model development and scenario applications that ultimately aim at providing support for bank protection planning. Related to this, the on-going work within the IKMP links the developed 3-dimensional (3D) flow and fluvial shear stress model to bank stability characteristics (bank topography and critical shear stress), and will result in estimates on actual erosion rates in the bank.

The climate change research has been performed within the Nam Songkhram basin application, among with several other focal issues such as flooding and land use changes. The study of Nam Songkhram sub-basin offers an excellent platform to continue addressing the rapidly increasing concerns about climate change impacts in the Mekong Basin. Nam Songkhram application itself has grown from its original fairly modest beginning as a training and demonstration application into an international

IWRM/E-Flows [3] study in support of the Nam Songkhram basin planning and development.

Assessment of livelihoods impacts is a challenging but critically important issue that WUP-FIN Project has paid special attention to. Socio-economic and policy analyses also provide means for utilizing the modelling and impact assessment results of WUP-FIN Project for general conclusions and recommendations for informing basin-wide decision-making, particularly on the diverse impacts in LMB floodplains. An approach to compare and link local (bottom-up) and regional (top-down) social and economic viewpoints is presented within this theme.

Success in capacity building should be of top-most priority in a project such as WUP-FIN. Sustainability, future use and practical utilization of the developed tools and approaches are not easy to guarantee, and therefore the approach used and results achieved must be continuously monitored and developed. By its nature, the whole task of WUP-FIN in ultimately closer to long-term cooperation and networking than to a consultancy project. However, the latter remains to be the format that these kinds of projects is usually given and applied, leading easily the projects to become too periodic and intermittent.

[3] E-flows = environmental flows. According to its basic definition, an "environmental flow" is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and/or where flows are regulated (Dyson et al., 2003).

2.1 FLOW ALTERATIONS & FLOOD PULSE: FUTURE OF TONLE SAP LAKE?

The monsoon floods of the Mekong River are a key driver of productivity in the Tonle Sap Lake ecosystem (Lamberts, 2006). This ‘pulsing’ system with its large floodplain, rich biodiversity, and high annual sediment and nutrient fluxes from Mekong is believed to be one of the most productive freshwater ecosystems in the world (e.g. Rainboth, 1996). The floodplain vegetation is one of the key elements of Tonle Sap ecosystem (Lamberts, 2006; Kummu et al. 2006a). Among it, the gallery forest stripe on the edge of the permanent lake covers only a small part of the floodplain but it constitutes an important physical barrier between the open lake and the floodplain (Figure 3). It creates favourable conditions for effective sedimentation within the forested zone (Kummu et al., 2008). For many of the Mekong fish species, the floodplain of the lake, and particularly the flooded forest and shrublands, offers favourable conditions for fish to breed and grow.

Livelihood linkages: The floodplains surrounding the Tonle Sap support local people in many ways; a large variety of floodplain products provide food, traditional medicine, firewood and income for villagers, and flooded forests provide shelter for floating villages during the floods. In addition, flooded forests and shrubs form a key element of Tonle Sap’s ecosystem, and play a critical role in sustaining its aquatic production which supports directly and indirectly millions of people around the Tonle Sap.

The extent of the flooded gallery forest stripe along lake shore is presented in the map below (Figure 3). In addition to the permanent lake edge and the river banks, isolated stands of trees are scattered throughout the floodplain.

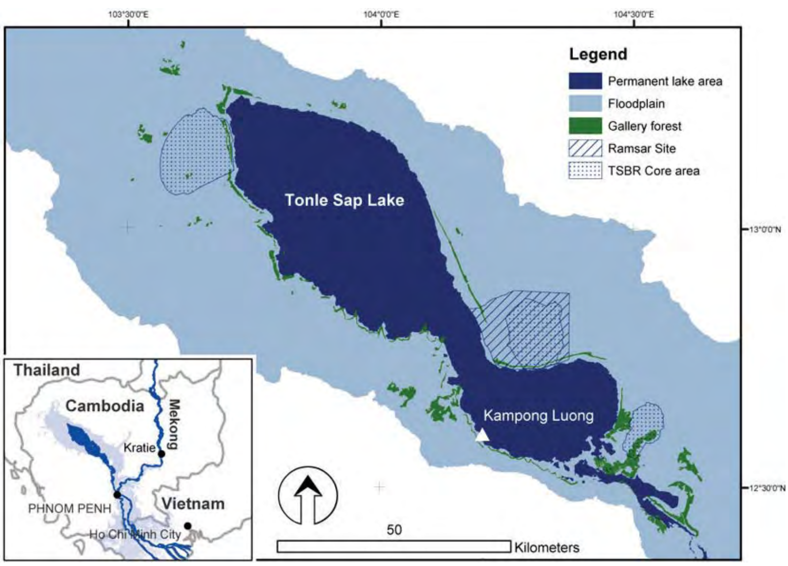

Figure 3. Map of Tonle Sap Lake and its location including the distribution of gallery forest and the protected areas.

Human impact on hydrology – global perspective

During the last decades the human impact on water resources has increased remarkably, and will continue increasing although probably not that rapidly as in 20th century (Vörösmarty, 2000). The standing stock of natural river water has increased seven fold due to 8400 km3 of water stored in reservoirs behind dams (Vörösmarty, 2000). The water renewal time of the world's rivers has increased dramatically from 20 to 100 d as a consequence of dam and reservoir consumption (Golubev, 1993). Changes in land surface, i.e. land use/land cover, play an important role in watershed management due to their influence on soil erosion, hydrology and water quality. Land cover change may be the most significant agent of global change: it has an important influence on hydrology, climate, and global biogeochemical cycles (Skole et al., 1997).

Flood pulse and importance of floodplains:

n floodplains, the fluctuation of the water level over time is the principal factor that causes the biota to adapt and produce characteristic community structures (Junk, 1997). Ecosystems that experience fluctuations between terrestrial and aquatic conditions are called pulsing ecosystems, and can be described in terms of the flood pulse concept. Junk's flood pulse concept has been widely accepted as describing highly productive floodplain environments and the ecology of pulsing systems.

In the Mekong basin floodplains are the key areas for ecosystem productivity and extremely important for fish production, as other aquatic production. In LMB millions of people are dependent for their livelihoods on the floodplains, even if not that many people live inside the floodplains.

2.1.1 Research aims

The Tonle Sap gallery forest and flood pulse research aims to

- Estimate the changes in Tonle Sap flood pulse based on the basin wide cumulative impact assessment studies
- estimate the possible changes in flood pulse parameters
- estimate the loss of the gallery forest stripe due to possibly increased dry season water level, based on the existing studies, as a consequence of upstream development as dam and reservoir construction, and irrigation

This Chapter is based partly on article of Kummu and Sarkkula (2008).

2.1.2 Methods

The water level data from Tonle Sap Lake for years 1997-2006 have been used for statistical analysis of the flood pulse parameters. Daily water level data are available from the Kampong Luong station in the lake. The water level data in the article are always expressed as above mean sea level (AMSL) in Hatien, Vietnam.

Recent cumulative impact assessment (CIA) studies made by the Mekong River Commission under the Integrated Basin Flow Management project, by ADB (2004), and by Adamson (2001) are used. The results of those CIAs are used to analyse the possible changes of upstream development and its impacts on the Tonle Sap flood pulse. The statistical analysis and EIA 3D model (MRCS/WUP-FIN, 2003) is used to calculate the changes on Tonle Sap flood pulse due to upstream development.

The GIS analyses are used for calculating and mapping the impacted areas of to the changes in flow regime due to the upstream development.

2.1.3 Major findings + way forward

Water balance study

Based on the water balance analysis made during the WUP-FIN project[4] the following characteristics for the Tonle Sap Lake could have been summarised. Table 1 gives a summary of the water balance calculation results in annual timescale including inflow (tributaries, Mekong, and precipitation) and outflow (Mekong and evaporation). Mekong includes in this connection both the Tonle Sap River and overland flow.

Inflow: Around 57% of the Tonle Sap water originates from Mekong either through Tonle Sap River (52%) or overland flow (5%) while tributaries share is around 30% and precipitation 13%. The average annual inflow during the study period was 79.0 km^3. It varies from 44.1 km^3 (1998) to 106.5 km^3 (2000).

> **“ 57% of the Tonle Sap water originates from Mekong**

Outflow: Around 88% of the total outflow flow to Mekong through Tonle Sap River (87%) and overland flow (1%) while 12% evaporates directly from the lake. The average annual outflow during the study period was 78.6 km^3 varying from 43.5 km^3 (1998) to 104.8 km^3 (2000).

Table 1. Summary of the in-flow and out-flow in km^3. Mekong part includes both, flow in Tonle Sap River and overland flow.

	In-Flow				Outflow			Balance	
	Tribs km3	Mekong km3	Prec km3	TOTAL km3	Mekong km3	Evap km3	TOTAL km3	km3	
1997	23.1	47.3	8.5	78.9	64.2	8.7	72.9	6.0	
1998	12.6	24.8	6.7	44.1	36.8	6.7	43.5	0.6	
1999	27.4	41.0	11.3	79.8	72.9	10.5	83.3	-3.6	
2000	39.7	51.8	15.0	106.5	93.3	11.5	104.8	1.8	
2001	27.1	52.9	12.4	92.5	83.0	10.5	93.5	-1.0	
2002	21.7	56.8	11.3	89.8	84.3	10.0	94.3	-4.5	
2003	15.2	38.5	7.9	61.6	50.4	7.5	57.9	3.7	
avg	**23.8**	**44.7**	**10.4**	**79.0**	**69.3**	**9.3**	**78.6**	**3.0**	from absolute
% of total	**29.7%**	**57.0%**	**13.3%**		**87.8%**	**12.2%**		**3.8%**	values

Thus, the possible changes in flow regime in Mekong impact directly on the Tonle Sap floods. Also, the water level in the Tonle Sap Lake is controlled by the Mekong water levels and thus the upstream developments related to the water resources have impact also on the lake.

Statistical flood analysis

According to the statistical flood analysis, the timing of the peak flood is very regular in the Tonle Sap Lake. The start and end date of the flood[5] are, however, varying a lot depending on the main stream flood and local rainfall in the Tonle Sap tributaries. The flood starts on average 23rd of June, having its peak on 7th of October and ends on 3rd

[4] See MRCS/WUP-FIN, 2006. Technical Paper No.5 – Tonle Sap Lake water balance calculations. WUP-FIN Phase II – Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR. 32 pp

[5] flood level here determined to be 2.5 m amsl, around 1 meter above the dry season average water level

of March. The start of the flood is here determined to be the date when the water level exceeds the flood level (2.5 m) and end on a date, equally, when the water level is below the flood level.

The average flood duration is 255 days, around 70 % of the year. During the analysis period it varied from 202 days (1998) to 297 days (2000).

The average water level varies from lowest 1.32 m AMSL (above mean sea level) to the peak flood of 9.14 m AMSL. At the same time the flooded area varies from 2,210 km^2 to 13,260 km^2 and volume from 1.6 km^3 to 59.7 km^3. All this information is summarised in Table 2.

Table 2. Flood (WL>2.5 m amsl) characteristics of the Tonle Sap Lake

Flood characteristics of the Tonle Sap Lake
years as flood-years [01/05 of year indicated - 30/04 of next year]

year	min wl [m] amsl	max wl [m] amsl	area [km2]	volume [km3]	start date	peak date	end date	duration days
1997	1.40	9.33	13542	61.5	08/07	08/10	12/02	220
1998	1.24	6.86	9637	33.0	16/07	12/10	02/02	202
1999	1.38	8.97	12950	56.8	29/05	17/10	13/03	290
2000	1.48	10.36	15278	76.1	28/05	28/09	20/03	297
2001	1.42	9.89	14478	69.2	15/06	05/10	15/03	274
2002	1.19	10.10	14834	72.2	20/06	06/10	14/03	268
2003	1.27	8.26	11805	48.1	04/07	08/10	07/02	219
2004	1.25	9.20	13327	59.8	22/06	04/10	04/04	287
2005	1.26	9.29	13475	61.0	09/07	11/10	27/02	234
avg	**1.32**	**9.14**	**13258**	**59.7**	**23/06**	**07/10**	**03/03**	**255**

Figure 4 illustrates the timing of the flood, including start date, peak date and end date. As can be seen from the figure, the start date and end date have greater variation in the timing than peak date.

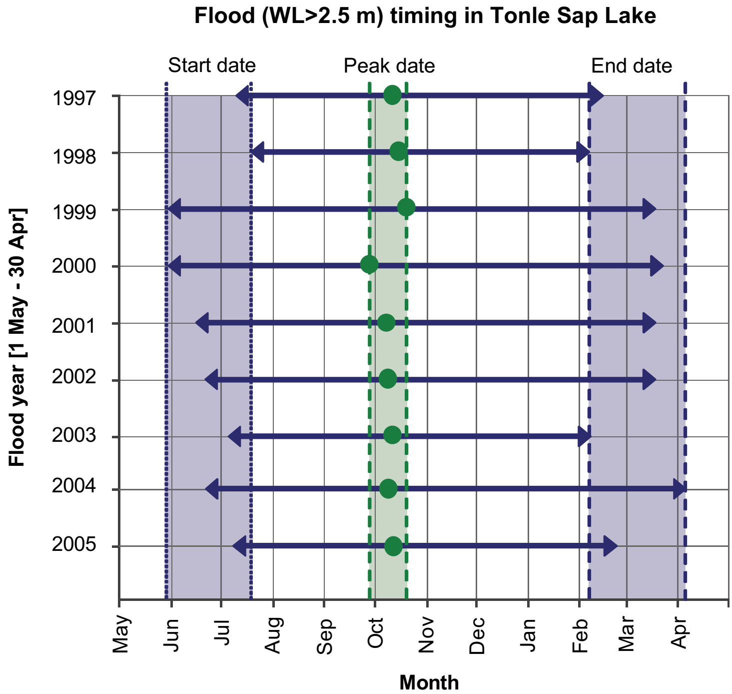

Figure 4. Summary of the flood timing, start and dates; and flood peak date in the Tonle Sap Lake.

In Figure 5 the daily water levels for the Tonle Sap Lake are presented for years 1997-2006.

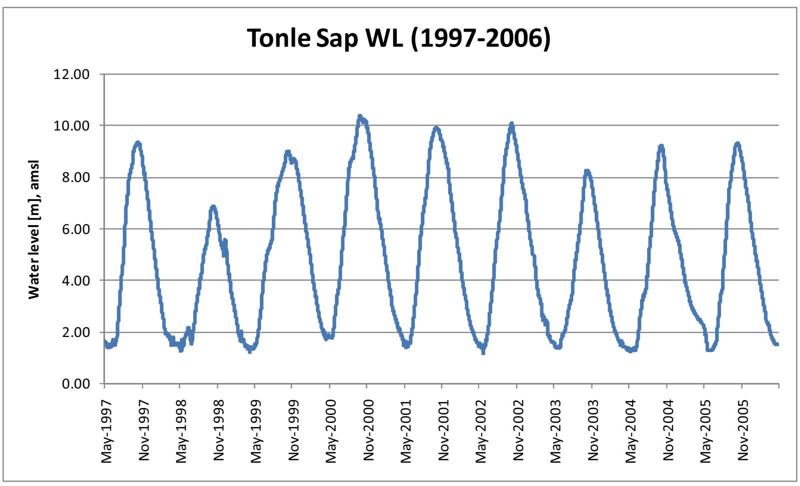

Figure 5. Tonle Sap daily water level during the years 1997-2006.

Figure 5 illustrates the rapidity of the water level change which is plotted together with the average water level over one flood cycle starting from May. The rapidity of the water level change is greatest during July being around 8 cm/d. During the dry season the most rapid water level change occurs during December being around -6 cm/d.

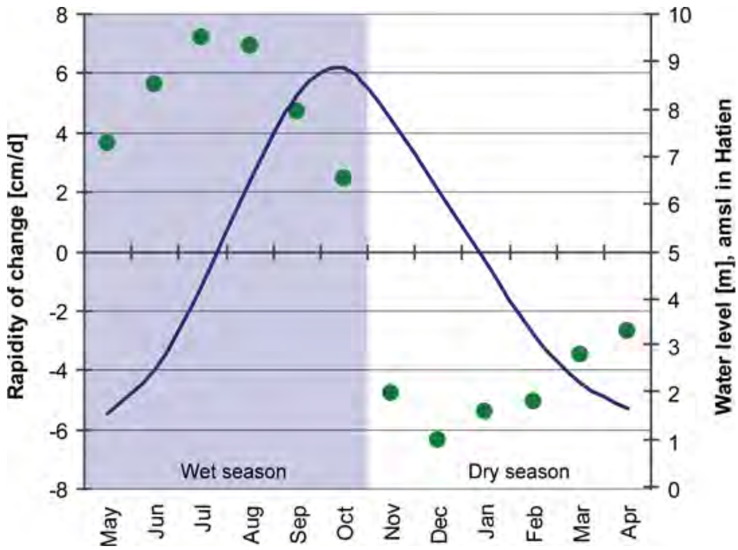

Figure 6. Rapidity of water level change (green spheres) and water level (continuous line).

Changes in Tonle Sap flood

The dry season water level (WL) rise due to Mekong upstream development has been estimated to

- 0.15 m (DSF, data prepared for IBFM),
- 0.30 m (Henrik Garsdal, in DHI (2004) – based on Adamson (2001) analysis in mainstream Mekong), and
- 0.60 m (ADB 2004)

Impact of the WL rise on the dry season lake area is presented below. The 30-day minimum water level during the analysis period of 1997-2006 for May was 1.44 m (AMSL) and this has been used as a reference level. The bottom of the lake lies in 0.6 m (AMSL), and thus during the low water level the depth of the lake is only around 0.8 m. The lake area during low water level is 2,300 km^2. The rise of 0.6 m (ADB, 2004) would result an area of 3,200 km^2. Thus, the permanent lake area would increase by nearly 1,000 km^2 or 40%.

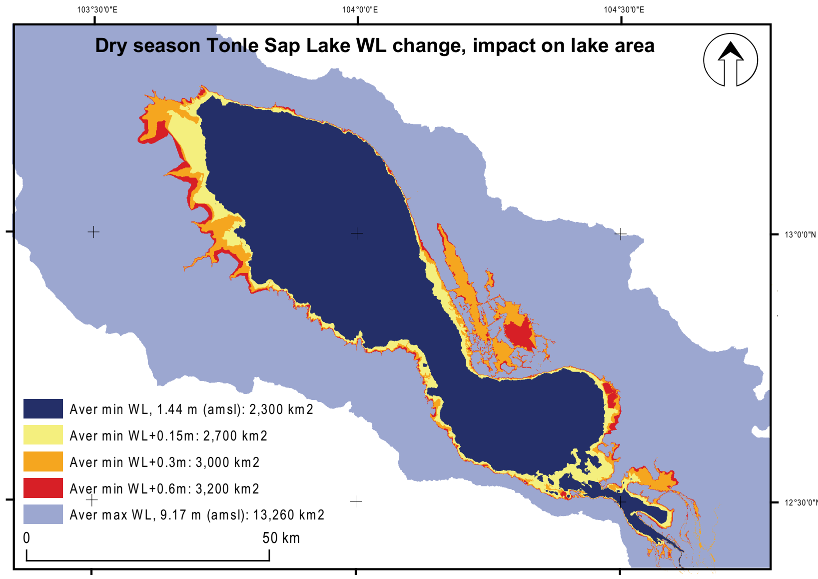

Figure 7. Inundated areas due to the increased dry season water level.

The dry season water level rise would mean extension of the permanent lake (Figure 8) and significant reduction of the gallery forest and consequently, loss of important habitats. The CIA predicts also that the peak water level would decrease and thus reduce the inundated area of the lake, as presented in Figure 8. Thus, the area of the floodplain would decrease, depending on the CIA, by 10% to 16%. E.g. in ADB (2004) case the total floodplain area would decrease from present 10,750 km^2 to 9,060 km^2 (year 2025). The cumulative flooded area and volume would decrease 18% and 15%, respectively.

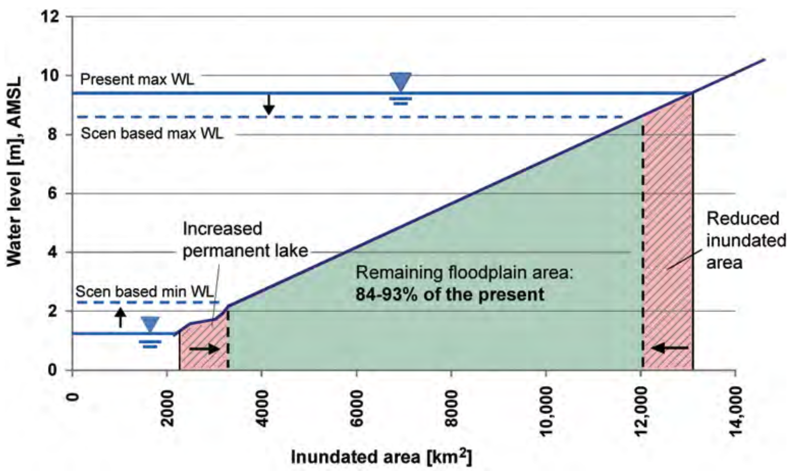

Figure 8. Schematic presentation of the possible impacts on the floodplain extent due to the changes in flow regime.

Figure 9 shows the change of flood duration over the floodplain in 1997 conditions based on the EIA 3D model results and input of the MRC flow regimes developed for IBFM project. The period of inundation is decreasing in most parts of the floodplain by

1-2 weeks (5-10 %). In the lowest parts of the floodplain the inundation is prolonged due to the increase of the dry season lake level. Due to permanent inundation these areas would be transferred from floodplain habitats to become part of the lake proper.

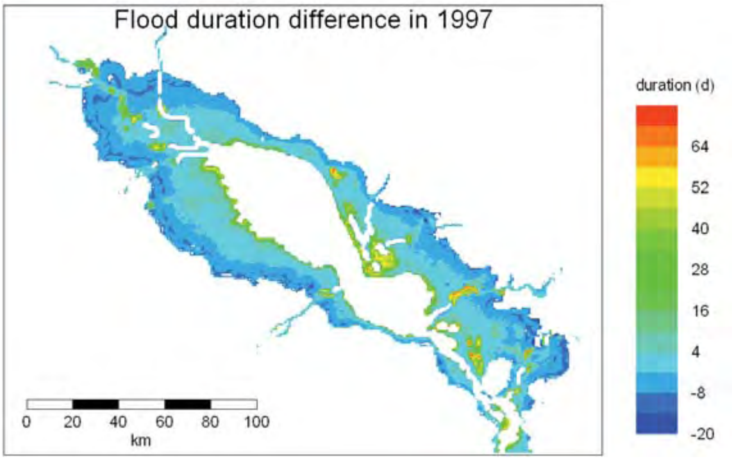

Figure 9. Flood duration difference based on simulation results.

Impact on gallery forest on the floodplain

The predicted dry season water level rise of 0.15-0.60 m would mean permanent inundation of large areas of gallery forest stripes located in the vicinity of the lake shore (illustrated in Figure 10). This significant reduction, and with the 0.60 m dry season water level rise total extinction of the gallery forest stripe could have a significant impact on the entire Tonle Sap ecosystem.

“Large parts of the gallery forest would be inundated

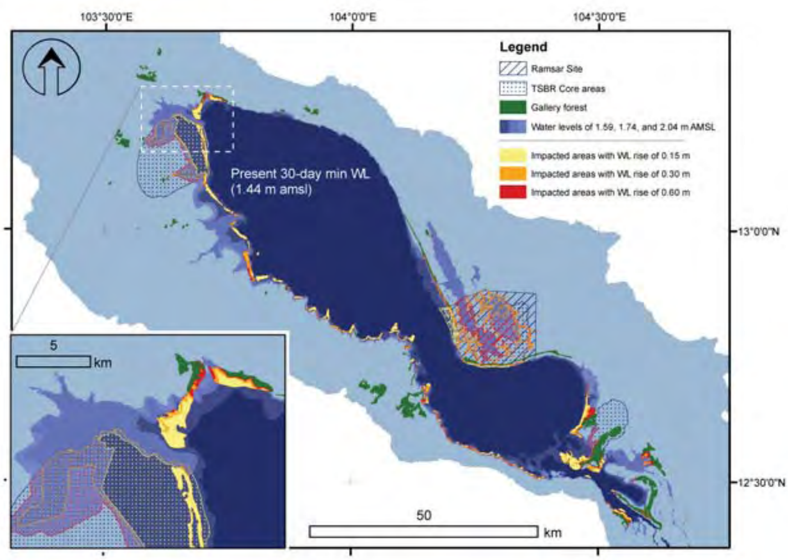

Figure 10. Impacted gallery forest areas (solid polygons) and protected areas (hatched areas, TSBR areas in points and Ramsar site in lines).

Main findings

- flood pulse is the key driving force for the lake's productivity
- Mekong upstream developments will alter the flow regime downstream and impact on the flood characteristics of the Tonle Sap Lake. The predicted dry season water level rise of 0.15-0.60 m would mean permanent inundation of large areas of gallery forest stripes located in the vicinity of the lake shore.
- relatively small rises in permanent lake water level permanently inundate disproportionately large areas of floodplain, thus rendering it inaccessible to terrestrial vegetation and eroding the productivity basis of the ecosystem

Way forward:

- High quality cumulative impact assessment of planned and on-going development in the whole Mekong Basin and of the impact of climate change
- When making the IA, the time-span of the different human impacts are critical to be taken into account
- CIAs should be transparent, all the information and scenario settings, as well as modelling results, should be presented based on the good scientific ethics. The scenarios should be consistent and realistic.
- quantification of the impacts of the predicted flood pulse changes on the ecosystem productivity of the Tonle Sap lake and floodplain
- consequences of ecosystem productivity change for fisheries, food security and livelihoods in and around the Tonle Sap

Additional information:

Kummu, M., Koponen, J. and Sarkkula, J., 2004. Upstream impacts on Lower Mekong Floodplains: Tonle Sap case study, Proceedings of the International Conference on "Advances in Integrated Mekong River Management", Vientiane, Lao PDR, pp. 347-352.

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Lamberts, D., 2006. The Tonle Sap Lake as a productive ecosystem. International Journal of Water Resources Development, 22(3): 481–495.

Lamberts, D. & B. Neou (2006). Major floodplain ecosystems governance issues in the Mekong Region. Mekong Region Waters Dialogue Event Report, Vientiane, Lao PDR, 6-7 July 2006, IUCN, TEI, IWMI and M-POWER, available online on 14 October 2006 at http://www.mpowernet.org/UserFiles/File/docs/Lamberts_Bonheur_Floodplain_Session_draft%2030Jun06.pdf

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MRC/WUP-FIN, 2006. Technical Paper No.5 - Tonle Sap Lake water balance calculations, WUP-FIN Phase II - Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR.

MRCS/WUP-FIN, 2006. Working Paper No.7 - Tonle Sap Lake model application, WUP-FIN Phase II - Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR. 65 pp. Available on-line at http://www.eia.fi/wup-fin/wup-fin2/publications.htm.

Nikula, J., 2005. The lake and its people - Review and integration of hydrological, ecological and socio-economic information in the Tonle Sap Lake. Master's Thesis, Helsinki University of Technology, Espoo, Finland, 118 pp.

2.2 SEDIMENT ISSUES

Sedimentation can be a curse or a blessing, depending on the viewpoint. For the natural environment, sedimentation is crucial, providing nutrients and other materials that fuel biological productivity of the ecosystem. For humans, however, sedimentation can also be problematic, potentially causing problems for transportation and maintenance of aquatic infrastructure. This is also the case in the Mekong River basin. The basin yields approximately 475 km^3 of water each year from a catchment area of 795,000 km^2, and transports around 150×10^9 kg of total suspended sediment (TSS) to the South China Sea annually (e.g. Milliman and Meade, 1983; Milliman and Syvitski, 1992). More than half of the total sediment flux originates from China (Walling, 2005; Kummu and Varis, 2007).

In the Mekong region rapid economic growth has increased the pressure for greater hydropower production and other water-related developments, such as large-scale irrigation. In 2007, China had completed two hydropower dams on the Mekong, and has two more under construction and four dams planned. Thailand, Laos, and Vietnam have built several dams on the Mekong tributaries, and plan more, while the irrigation structures in both the tributaries and the mainstream are also increasing (Hori, 2000; ADB, 2004).

Dams as a threat for global sediment budget:
Reservoir construction currently represents the most important influence on land–ocean sediment fluxes (Walling and Fang, 2003). Around 70% of the world's rivers are intercepted by large reservoirs. A notable threat to the sustainability of reservoirs is sedimentation. It is estimated, that 1% of the existing storage volume in the world is lost each year. The theoretical sediment trapping efficiency in these reservoirs are high, half of the reservoirs showing a local sediment trapping efficiency of 80% or more (Vörösmarty et al., 2003). In some basins, such as the Colorado and Nile, sediment is trapped completely due to large size of the reservoirs and flow diversion (Vörösmarty et al., 2003; Walling and Fang, 2003).

Sediments are a key factor in many Mekong processes. Navigation, bank erosion, filling up reservoirs, aquatic and agricultural productions are all dependent in some extent on sediment processes. The sediment input from the Mekong to the Tonle Sap Lake is one of the key factors of the high productivity of the lake. The changes in sediment regime that will results from basin developments, especially the hydropower reservoirs, will affect the sedimentation and erosion processes in the downstream river channels and the connected floodplains, lakes, the delta and the coastal areas. The varying conditions and processes along the Mekong set high demands for sediment monitoring methodology and modelling to respond to the complexity of the system.

> **"Sediment is one of the key factors of the Tonle Sap Lake's high productivity**

2.2.1 Research aims

The main aims of the sediment related studies have been

- getting an overview of the sediment issues in Mekong
- analysing the sediment trapping efficiency of the dams in Yunnan cascade
- enhance the knowledge and data of the sediment transportation related issues in hot spot areas as Vientiane – Nong Khai, Chaktomuk junction, Prek Kdam, and Tonle Sap Lake
- Tonle Sap Lake sediment studies

2.2.2 Methods

Data analysis

The data used for the analysis of concentration and fluxes of suspended sediment concentration (SSC) and total suspended solids (TSS) in the Mekong mainstream are from the Mekong River Commission's databases (Mekong River Commission, 2004). The following two databases were used:

The MRC hydrological database (HYMOS) includes SSC data from 1962 until 2002. Measurements are based on the depth integrated method, with varying sampling frequency. There are 14 stations in the Mekong mainstream and 46 in the tributaries, all within Thailand or Lao PDR territory.

The MRC Water Quality Monitoring Network (WQMN) database includes TSS data from 1985 until 2000. TSS is sampled just below the water surface once per month. There are 18 stations in the Mekong mainstream and 37 stations in Mekong tributaries in all four LMB countries.

The Brune (1953) method was used to estimate the theoretical trapping efficiency for the Yunnan cascade of dams.

Dams change two critical elements of the geomorphic system: the ability of the river to transport sediment, and the amount of sediment available for transport (e.g. Grant et al., 2003). If the transport capacity exceeds the available supply, the flow may become sediment-starved and the channel can be expected to erode sediment from its bank and/or bed. If the transport capacity is less than the available supply, the channel can be expected to accumulate sediment. Typical downstream responses are channel bed degradation or incision, textural changes such as coarsening or fining of surface grain-size distribution, and lateral adjustments, including both expansion and contraction of channel width (e.g. Grant et al., 2003). Grant et al. (2003) and Brandt (2000) methods have been used to estimate the downstream responses on the changes due to the reservoir building.

Field work

During the WUP-FIN project the sediment related **field work** has been conducted in several sites as listed below:

Vientiane – Nong Khai section of Mekong: ADCP runs combined with the TSS measurements

Chaktomuk confluence: ADCP runs combined with the TSS measurements

Prek Kdam at the Tonle Sap River: ADCP runs combined with the TSS measurements

Tonle Sap Lake: water quality samples, sediment traps, and HydroLabs

Modelling Tonle Sap sediment transport

In Tonle Sap sediment studies the modelling, field work and results from paleontological studies have been used.

During the MRCS/WUP-FIN Tonle Sap Modelling project three dimensional (3D) EIA Hydrodynamic and Water Quality Models (Koponen et al., 2003; Koponen et al., 2004) were applied to the Tonle Sap Lake and its floodplain to assess and evaluate the impacts of physical and environmental changes in the lake in relation to the whole Mekong basin, as well as more locally in Cambodia (MRC/WUP-FIN, 2003). The EIA 3D models include a sediment transportation model which is described in more details in Kummu et al. (2005).

Vertical sections (cores) of sediment have been collected from the Tonle Sap by Carbonnel and Guiscafré (1965), Tsukawaki et al. (1997), Penny et al. (2005) and by Kolata and Cunningham (2005). Absolute dating of these sediment cores using radiocarbon techniques permits the calculation of sedimentation rates that can be used to test the predicted sedimentation rates determined numerically by the 3D EIA flow model.

2.2.3 Major findings + way forward

Basin wide

After the dam at Manwan was closed in 1993, a sharp decline in the **suspended sediment flux** was seen at Chiang Saen, the most upstream MRC gauging stations on the Mekong, approximately 660 km downstream from the Manwan dam and 290 km from the China border. The annual SS flux dropped from 71×10^9 kg to 31×10^9 kg (Figure 6), while the TSS concentration dropped from 484 mgl^{-1} to 216 mgl^{-1}. However, Walling (2005) reported that no such a trend is visible in the SSC data.

The same trend was seen at Luang Prabang (647 km downstream from China) and Nong Khai (1104 km downstream from China), next stations downstream from Chiang Saen. In Mukdahan (1534 km downstream from China) and Pakse (1787 km downstream from China), the HYMOS data show an increasing trend in sediment flux after the closure of Manwan. Interestingly, the data for Pakse in WQMN database show a decreasing trend in sediment concentration. Only data for post-dam period are available for Kratie (2095 km downstream from China), the most downstream station considered.

It is possible to calculate the **theoretical trapping efficiency** for the dam and its reservoir by using the Brune (1953) method. Theoretical trapping efficiency for Manwan is 68%, which correlates well with the measured trapping efficiency of 75%. The Dachaoshan Dam, closed in 2003, has a theoretical TE of 66%, while the bigger dams Xiaowan and Nuozhadu at present under construction, have trapping efficiencies as high as 92%, basically trapping all the sediment. The whole cascade of eight dams has a total theoretical trapping efficiency of 94% (Kummu and Varis, 2007). This might have significant impact on the whole Mekong sediment budget.

> **“ Cascade of eight dams has a total theoretical trapping efficiency of 94%**

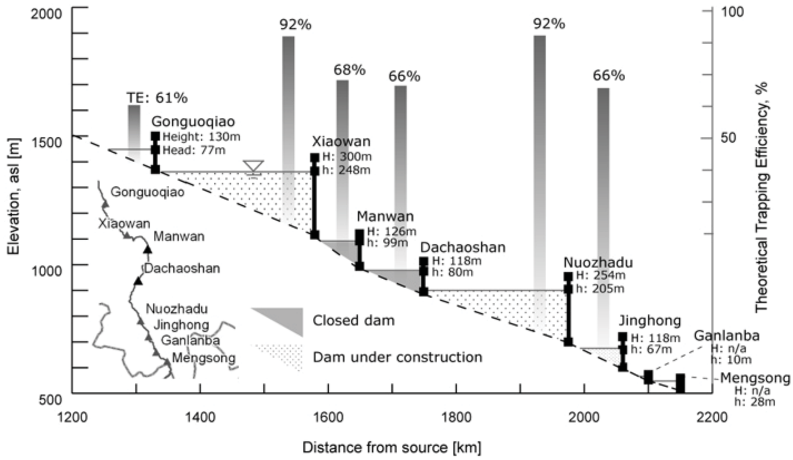

Figure 11. Theoretical trapping efficiency of each reservoir in Yunnan cascade (after Kummu and Varis, 2007).

According to the technique developed by Grant et al. (2003), the **geomorphological impacts of the dams** include bed scour, armouring of the channel, bar and island erosion, and channel degradation and narrowing, the intensity of change decreasing downstream (Kummu and Varis, 2007). Based on the method developed by Brandt (2000) the possible impacts are a degrading bed level and cross-sectional changes, depending on the local condition. Impact on floodplains is difficult to predict, but riffles and pools are likely to be eroded. These methods for impact estimation are highly useful (ibid). However further studies are more than justified. An unrestricted flow of information between the countries of the lower and upper Mekong Basin is urgently needed, to enable more quantitative estimations of possible development-related impacts (ibid).

Tonle Sap Lake

Among the international, national and local observers it is often stated that the Tonle Sap Lake is rapidly filling up with the sediment. However, the rapid rates of infilling cited in the literature have not been proven. The sedimentation in the lake proper, i.e. dry season lake area, is very low, around 0.1-0.16 mm/year (Tsukawaki, 1997; Penny, 2002; Penny et al., 2005). However, even though the overall net sedimentation within the Tonle Sap Lake is not a problem, there are many local problems associated with high sedimentation and erosion rates in the area (Heinonen, 2005). This is the case especially in the Tonle Sap delta (Snoc Trou) and in the mouths of the major tributaries, i.e. areas which are morphologically very dynamic.

The Mekong River is responsible for the majority (ca. 75%) of the sediment delivered to the Tonle Sap Lake, based on measurements taken at Prek Kdam on the Tonle Sap River during 1996-2002 (MRC database) and suspended sediment measurement from tributaries during 2001-2003 (WUP-FIN, 2003). The average suspended sediment flux into the Tonle Sap Lake from Mekong and lake's tributaries is 7 million tons (MT) and 2 MT, respectively (Kummu et al., 2005; Kummu et al. 2008). The outflow flux from the lake is only 1.6 MT. Thus, more than 80 % of the sediment the system receives from the Mekong River and tributaries is stored in the lake and its floodplain.

“ Tonle Sap Lake is not filling up with sediment – however, local problems of sedimentation and erosion do exist

Recent long-term sedimentation studies show that net sedimentation within the Tonle Sap Lake proper has been in the range of 0.1-0.16 mm/year since ca. 5500 years before present (BP) (Tsukawaki, 1997; Penny, 2002; Penny et al., 2005). This means an accumulation of only 0.5-0.7 m of sediment in the lake over that time period. These data are in good agreement with the modelling results, indicating conclusively that the rate of sediment accumulation within the lake is relatively low, and that there is no threat of the lake filling up with sediment in the short term. On the contrary, sediment is not a threat to the lake but an important part of its ecosystem, providing nutrients that drive the productivity.

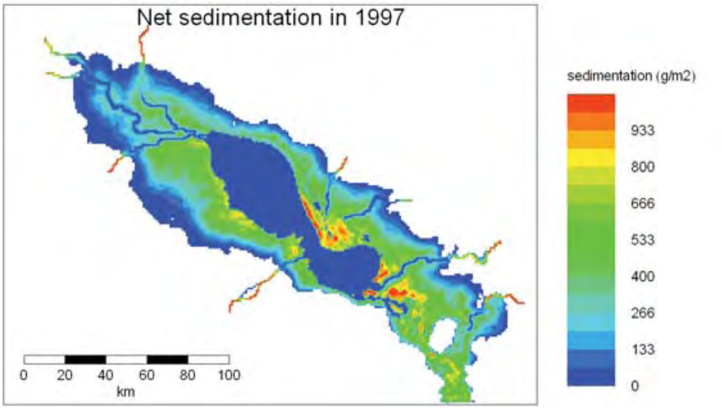

Figure 12. Simulation results of the net sedimentation during the period 01/05/1997 – 30/04/1998. 1600 g/m^2 represent around 1 mm of net sedimentation.

Main findings

- The sediment is important part of the ecosystem functions and productivity
- The trapping efficiency of the large dams e.g. in Yunnan cascade is high and thus, the impacts of the decreased sediment flux on downstream ecosystems and bank stability should be further studied
- onle Sap Lake is not filling up with the sediment, although severe local sediment related problems exist in many location

Way forward

- Basin wide sediment transport model coupled with the hydrological model
- Enhance the field monitoring, coupled with the ADCP discharge measurements
- Data and information exchange between LMB and UMB actors
- Field measurements of the sediment quality in different parts of the river, i.e. biological availability

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2.3 TONLE SAP ECOSYSTEM PRODUCTIVITY

The Tonle Sap Lake and floodplain ecosystem is the element of the Mekong basin where the flood pulse is the most prominent in terms of its ecological importance and livelihoods impact. There is conclusive evidence now that the flood pulse is the driving force behind the fish production of the ecosystem, which is believed to be very large, even though even approximate figures of fish production are not available. Nonetheless, there is compelling evidence of the importance of the Tonle Sap fisheries for the livelihoods of those living on or near it, and for the food security of Cambodia as a whole.

The Tonle Sap flood pulse is largely (60%) driven by the water that is pushed up into the lake by the reversed current in the Tonle Sap river when the Mekong River is at its highest level. The remainder is run-off from its own catchment. The flood waters not just bring water and floods but also nutrient laden sediments which are mostly deposited in the floodplain. The flood water integrates the terrestrial vegetation into the aquatic phase of the ecosystem, and this interaction between the terrestrial and aquatic phases is the driving force of ecosystem productivity. Nothing is known, however, on the relation between ecosystem productivity and the flood pulse as determined ultimately by the flows in the Mekong River.

2.3.1 Research aims

The research aimed to identify a quantitative model of the ecosystem productivity of the Tonle Sap Lake and floodplain, with a particular focus on ecosystem productivity response in function of altered flow regimes in the Mekong River.

The underlying assumption is that the Tonle Sap secondary production (including fish production) is mostly endogenous, i.e., based on primary products generated within the ecosystem rather than imported with the flood waters. While there are no specific data to support this, the assumption is reasonable based on the low organic matter contents of the inflowing rain and Mekong waters and the known migration of fishes between the Tonle Sap and the Mekong. This is believed to be largely a net export of fish biomass, with mostly fish juveniles, larvae and eggs drifting into the Tonle Sap ecosystem with the flood waters. Further, the assumption is made that most of the organic matter in the Tonle Sap ecosystem is produced locally by four categories of primary producers.

> **“The flood pulse is the driving force of the productivity of the Tonle Sap**

Based on analytical descriptions of the primary production potential of the four categories of primary producers, a spatially explicit assessment can be made of the impact of changes in the production parameters.

Productivity and flood pulse:

The productivity of the Tonle Sap lake-and-floodplain system is driven by the flood pulse of the Mekong and by the rich floodplain biodiversity. The flood pulse transfers terrestrial primary products into the aquatic phase during flooding and creates extremely favourable conditions for the aquatic life through the rich ecosystem. The primary production (phytoplankton, periphyton, plants) fuels the food webs resulting in one of the world's most productive fisheries grounds. The floodplain of the lake offers ample opportunities and conditions for fish to breed and grow.

Hydropower development changes the natural flood pulse and the hydrograph, directly undermining the productivity of the system by reducing the inundated habitats, delaying the onset of flooding and shortening its duration (growth period for aquatic organisms), all having a negative impact on fisheries productivity. It also reduces the supply of sediments and nutrients to the downstream ecosystems because of the sediment trapping in the reservoirs. Fisheries productivity is further likely to be affected by worsening conditions for fish reproduction due to slowly rising flood, and the associated poor water quality. Lower flow velocities will limit the drift of eggs, larvae and juveniles to the floodplain habitats, and fish migrations will be obstructed by dams. Additional, more local threat to the ecosystem productivity of the Tonle Sap is posed by new irrigation structures that are rapidly emerging in different parts of the floodplain, mainly with private funding and without proper coordination or impact assessment.

Declining fisheries production is directly consequential for the food security and health as well as the livelihoods of the people in the LMB, and Cambodia in particular, affecting particularly the poor living in a subsistence economy and dependent on natural resources for their living. Fisheries belongs to the greatest assets of the Mekong Basin, not only because of its enormous financial value but also of its importance for livelihoods and social benefits.

Quantification of the loss of fisheries productivity is difficult because of the complex floodplain ecosystem and the diffuse fisheries. Nonetheless, the tentative estimates point out that the loss is to be counted in tens of percentages of the present level (MRCS/WUP-FIN 2006a), with unexpected inherent risks of the biological system collapse due to its sensitivity and complexity.

The risk of losing a major part of the fisheries productivity of the LMB is not at all properly taken into account in the decision-making process on basin developments.. This key development issue is practically excluded from the discussion, seemingly due to the tempting financial benefits offered by hydropower development for the governments and investors. Still, if one has to select only one important matter to be solved and properly managed for a sustainable future in the basin, in the spirit and to the letter of the Mekong Agreement of 1995, it is to find the balance between acceptable level of hydropower developments and maintenance of fisheries productivity as the vital environmental and social resource in the basin.

2.3.2 Methods

Functional categories of primary producers present in the Tonle Sap ecosystem were identified based on primary productivity parameters, spatial characteristics and ecological features. For each of these groups, a review was carried out of the knowledge and specific data available for the Tonle Sap ecosystem. This was complemented with a number of productivity data from similar and dissimilar ecosystems throughout the world. For each group, the primary production and primary productivity were described in function of environmental parameters.

This was then used to formulate a quantitative approximation of the primary production by each of the four groups.

The resulting description of the primary production of the Tonle Sap ecosystem allows for relative assessments of the impact of alterations to the environment, and in particular to the flood pulse and all its characteristics. For all groups, it is possible to calculate quantitative changes in absolute terms but the availability of specific data for the Tonle Sap is a limiting factor. Data from similar ecosystems and conditions collected from literature can be used to approximate the situation in the Tonle Sap as long as this limitation is clearly recognized. The data requirements for each primary producer group to come to full quantitative impact assessment have been identified.

2.3.3 Major findings + way forward

The primary producers of the Tonle Sap ecosystem (i.e., the lake proper, its contiguous flood plain and the Tonle Sap river) were identified as periphyton, phytoplankton, rooted macrophytes also referred to as the flooded forest, and floating macrophytes. These groups were identified based on their ecological characteristics and spatial features, the latter with a view to the spatially explicit modelling of the primary production.

Periphyton primary production is directly related to the area of colonisable substrate on which it can develop. In the permanent lake, this is mostly on the sediment, while in the floodplain this mostly involves submerged leaves, branches and stems. As periphyton production is exclusively aquatic, flood duration, water depth and substrate surface area per unit of ground area directly determine primary production. Furthermore, primary production is limited to the euphotic volume of water.

> **“ Primary production determines the potential for fish production**

Contrary to periphyton, phytoplankton is mobile and moves throughout the water column in all directions. Few studies have been carried out on the species composition of the phytoplankton of the Tonle Sap ecosystem. Based on volumetric phytoplankton primary production rates, the volume of the euphotic layer and the exposure time, it is possible to calculate net primary production by phytoplankton for an ecosystem.

Rooted macrophytes are the terrestrial primary producers of the ecosystem. The primary production rate of the rooted macrophytes is determined by the amount of drought and flood stress they are subjected to, as well as nutrient availability and input. This will differ in function of the location in the floodplain and in function of the hydrological regime. Permanent flooding of terrestrial rooted macrophytes will result in their demise within few years, permanent non-flooding will render an area unsuitable for aquatic rooted macrophytes.

The portion of the primary production by rooted macrophytes that enters the aquatic phase and the aquatic food webs is of particular importance in flood-pulsed ecosystems. This portion is determined by the flood levels in two ways: if the rooted macrophytes are outside the flood zone, none of their primary products will enter the aquatic phase. When they are flooded, organic matter will be transferred as the litter that has collected over the dry season and as live organic matter that is submerged.

The share of primary products transferred from the rooted macrophytes to the aquatic phase is described by a transferability factor, which needs to be established empirically.

The primary production of rooted macrophytes also affects that of other elements of the ecosystem. Rooted macrophytes are the main substratum for periphyton and have many other habitat functions as spatial structures in the floodplain.

Floating macrophytes are the fourth major group of primary producers in the Tonle Sap ecosystem, but their contribution to overall ecosystem production is believed to be rather small. Contrary to phytoplankton for which a homogenous distribution can be assumed, floating macrophytes tend to develop into discrete dense, thick mobile mats, with internally varying growth rates. Other than a preliminary list of species, there is no quantitative information on the occurrence or growth rates of floating macrophytes in the Tonle Sap ecosystem. Unlike the other groups, no representative information can be readily collected either.

Feasibility analysis of modelling the fisheries production of the Mekong River and the Tonle Sap lake

Modelling the production of any fisheries is difficult bar the most simple of cases. Progress has been made recently in modelling the production of fish in multi-species fisheries.

In addition to the complexity of the population dynamics of the species concerned, there is that of the fishing activities as such. Over 150 different kinds of fishing gear have been described for the Cambodian Mekong. Three categories of fishing are distinguished, small, medium and large scale. A few hundred species may be involved in the fisheries, albeit that the bulk of the catches is probably made up of only a dozen species.

The fisheries of the Mekong and the Tonle Sap lake are in urgent need of a tool to assess the impact of upstream water use. At the same time, the fisheries of the Mekong basin are poorly documented, in particular when it comes to catch statistics and inventories of fishing efforts.

In the absence of a sufficiently large volume of baseline data on a fishery, modelling may be considered to provide a useful tool to overcome to an extent the data gap. Caution is required.

The requirement of modelling is not just to have academic relevance but to be useable and useful as a planning tool in the immediate future. The extent to which a model meets these requirements depends on the nature of the model (deterministic, stochastic), the extent to which the biological and fishing realities are incorporated, and the solidity of its findings. Important into obtaining this image of solidity is a transparency and peer review. Furthermore, it needs to be tailored to the needs of the different groups of users.
A detailed analysis of the feasibility of modelling the fisheries production of the Mekong River and the Tonle Sap Lake would highlight the most urgent data gaps and indicate which elements of the fisheries can be modelled. While is it unlikely that a robust model for the entire basin can be developed, this may be the case for parts of it, which would be important first steps.

2.3.4 Conclusions

The main results from this research are a spatially explicit model of Tonle Sap ecosystem primary production, which is at the basis of the secondary food webs and determines to a large extent the overall productivity of the system. The modelled production is based on environmental factors, most of which are directly or indirectly dependent on the hydrological cycle. The model allows quantitative assessments of the impact of environmental changes (relative or absolute) in ecosystem primary production. It employs the few data that are specific for the Tonle Sap and depends on the hydrodynamic model for making the results spatially explicit. It has demonstrated where the main data and knowledge gaps are, and the model has been developed so that its accuracy can be improved by relatively few field measurements. In this way, it can be constantly refined while already providing the best available quantitative assessments of the impact of flow alterations in the Mekong River on the primary production of the Tonle Sap ecosystem.

> **“Small rises in dry season water levels in Tonle Sap have a disproportionately large impact on productivity**

The link between primary production of the ecosystem, its fish production and the fish catches is very complex, and there is no specific information on the links, nor are there good data on fish catches. However, with the reasonable assumption that most of the productivity of the Tonle Sap is located within the ecosystem rather than imported, and taking into consideration the high fish production, and given the dynamic character of the ecosystem, it can be assumed that any loss of primary production will directly result in loss of secondary production, and hence in fish catches. The precise nature of this relationship is unclear and may be impossible to establish at all.

Main findings

The primary production of the Tonle Sap ecosystem is mostly situated inside the ecosystem. It determines the potential of the ecosystem for the production of secondary organisms, including fish, amphibians, snakes, birds and insects, all of which are of critical importance to the livelihoods and food security of over a million people.

The ecosystem processes of the Tonle Sap depend on the flood pulse, the annual event of flooding and drought, which is mostly driven by water from the Mekong River. Assessing the impact of flow changes on the flood pulse, and hence on the productivity of the Tonle Sap ecosystem is one of the major challenges in integrated water resources management for the Mekong basin.

Knowledge of the production of fish and other organisms in the Tonle Sap is extremely limited. Modelling can provide a tool to maximise the existing knowledge or that from similar locations to assess the impact of flow changes. The fisheries are too complex for modelling at the moment, and require a huge data collection effort even for qualitative modelling. The primary production of the Tonle Sap ecosystem can be modelled solidly based on existing information and a comparably minimal, manageable amount of data collection. The primary production of the ecosystem is a limiting factor for its secondary production, and an assessment of the impact of flow alterations on the primary production will provide direct insights into the impact on the secondary production, and thereby on livelihoods and food security in the region.

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2.4 THE COMPLEX DYNAMICS OF MEKONG DELTA

The Mekong Delta is the most southern region in Vietnam, and due to its remarkable rice production it is often dubbed as Vietnam's rice basket[6]. The diverse hydrological characteristics vary greatly between different parts of the delta: while the upper part is characterised by flooding, lower part is dominated by close interaction with the sea, including strong tides and saline water intrusion. The delta is one of Vietnam's most populated region and the largest agricultural area in terms of agricultural production. In this way the Delta symbolises the Vietnam success story in agricultural growth and increased incomes, but it also highlights the challenges with agricultural development: despite successful agricultural expansion, parts of the Delta remains to be among the poorer areas in the country.

The first six sections of this research theme on Mekong Delta are based on the WUP-FIN socio-economic analysis carried out in the delta in cooperation with our counterparts particularly from Can Tho University and Southern Institute of Water Resources Research (SIWRR). The overall objective of the socio-economic analysis was to deepen the understanding of the water-related socio-economic issues in the delta with specific focus on the WUP-FIN model application areas. The work was carried out in form of case studies[7] including village surveys, key informant interviews in different levels of administration (provincial, district and commune), and statistical analysis of available socio-economic and related statistics. The socio-economic work aimed also to enhance the participation in different levels as well as to build capacity and networks within the project framework.

The aim of analysis work was not to give straight answers on the social impacts in terms of economical costs and calculations, but rather to give perspectives to the linkages between water issues and people's lives and social structures and in this way to help to focus the modelling and impact assessment work. The report from the socio-economic analysis (MRCS/WUP-FIN, 2006d) highlights the many ways that water is present in the every day life of the Mekong Delta as well as in the political and socio-economic processes, and describes the different approaches to water that exist in different scales.

2.4.1 Introduction: delta as highly controlled agricultural area

The combination of the agricultural modernization and fertile alluvial rich soils has made the Mekong Delta an incredibly productive rice cultivation area. However, this progress has also had its price: push for higher yields and productionist goals have also lead to environmental consequences such as worsening water quality and diminishing biodiversity. Also the strengthening saline water intrusion is partly caused by the increased water demand and use within the delta. The dry season irrigation has increased significantly in the last two decades and according to some estimations the agricultural activities in the Mekong Delta require twice as much water during the driest months (February-May) than the other Lower Mekong Basin's watersheds all together (Nesbitt et al. 2004).

“ Push for higher rice yields have also led to unwanted environmental consequences such as worsening water quality

[6] With on-going diversification of agricultural and aquacultural activities also other attributes related e.g. shrimp production could soon be added.

[7] The four provinces where case studies were carried out were An Giang, Tien Giang, Long An and Can Tho, although the report covered only the first three as these were provinces with the WUP-FIN model application areas.

All of these changes have naturally had socio-economic impacts as well. As water is strongly present in all the aspects of life serving for transportation, communication, fishing, agricultural and aquacultural needs and all kind of daily domestic uses all the water-related impacts are closely interconnected with the livelihoods and people's everyday life. The distribution of the costs has not been even, but it seems that the most vulnerable group consists mainly of the poorest farmers and landless people.

The Mekong Delta's water management has tenaciously developed towards centralized modernist solutions in large scales. This development has been in line with the 1960s Mekong Delta Development Program with the objective being "closing off" the delta to floods and saline water intrusion in order to make farming systems less dependent on natural conditions and expand multiple cropping to former flood-prone and brackish areas. The water control projects have also corresponded to the policies of 1980s and early 1990s that emphasised the intensification of rice production in order to enhance the country's food security. The rapid growth in Vietnam's rice production in the 1980s and 1990s has often been explained by the *doi moi* i.e. economic reform policy that was commenced in mid-1980s. While it is true that the re-allocation of the lands and liberalisation of the production initiated by *doi moi* gave more incentives to the farmers, the experiences from the delta indicate that water control works together with the expansion of modern farming techniques have played a significant role in Vietnam's agricultural growth as well.

The three WUP-FIN socio-economic case studies in An Giang, Tien Giang and Long An introduce different hydraulic methods that are being used to manage the extremes of water surplus and scarcity as well as soil acidity. The main findings from the case studies presented below show how the productionist goals in the delta's agricultural development have resulted in different kinds of hydraulic projects in different parts of the delta. The findings also highlight some of the negative consequences and new risks that these projects have brought up along with many improvements and gains.

The trajectory of water management and agricultural production

(Adopted from Miller, 2003; Biggs, 2004; Khiem et al., 2005)

I 1890-1930 Opening up the Delta

- settlement and reclamation of the land following the canal excavations. The amount of digging exceeded the Suez canal, the approximate amount of earth dug being 180 million cubic meters between 180-1936 (Pham 1985). Population increased rapidly along the hydraulic works. Fiona Miller has well concluded this phase saying that "during the colonial era a spreading web of 2400 km of navigable canals opened up the delta to the flow of water, people and goods, and international economy. (s.180)"
- extensive and adaptive farming systems

II 1960's Beginning of the Green Revolution

- intensifying rice cultivation with the introduction of new technologies (mechanisation, HYV rice, agrochemicals)

III 1966-1975 Delta-wide development plans

- 1966-68: U.S. shifts its strategic interests from the region to the delta
- David Lilienthal, the chief of the Tennessee Valley Scheme, was commissioned to plan the water resources development that would contribute to the pacification of the delta
- The plans included structures that would control the water flow into and out of the entire delta

IV 1975-90 Building of Intensive Production System with fragmented water control efforts

- 1976-80: Collectivisation which however was not effective in the Mekong Delta due to farmers' reluctance. Expansion of the Green Revolution and investments on irrigation, but with the prohibition of private trade and the state monopoly on external trade farmers had difficulties to get agricultural and yields decrease dramatically. The record level of national food deficit was reached in 1978.
- 1980-89: The Contract Production System introduces some reforms and land re-allocation but farmers still lack incentives. From 1990 liberalization and export orientation strengthen and the rice production grows fast
    - irrigation and water control efforts to back up the intensive farming and cropping patterns
    - control systems a a secondary level (500-100ha)
    - intensive farming systems spread around delta

V 1990 → Closing off the delta

- Liberalization and export orientation in production, by 1995 Mekong Delta produces 80% of the country's exported rice and by 1997 Vietnam is the second largest rice exporter of the world
- By the 1990 close to 5000 km of canals
- Building of structures to close off the delta to floods and the intrusion of salt water from the sea
    - massive saline water protection systems (from 50 000 – 450 000 ha) along the cost
    - border embankments to control over-flow from Cambodia in An Giang province and Plain of Reeds area
    - flood protection and high dike systems in An Giang and Dong Thap province
- Last major irrigation works constructed by 2000
- Further intensification of rice production
- Aquaculture starts to develop in the end of 1990's: Catfish boom in the upper delta and shrimp boom in the cost and brackish areas
- Increased need for fresh water and increased saline intrusion
- Emerging water quality problems

2.4.2 *Flood protection, high dikes & agriculture in upper parts of the delta*

So-called green revolution took place relatively late in the upper parts of the Mekong Delta due to the area's long inundation periods that posed a special challenge for agricultural development. The most extensive agricultural development in these flood-prone areas of the delta has taken place in An Giang province that is also the case study area for WUP-FIN socio-economic analysis. There the shift from floating to irrigated rice after the re-unification in 1975 was very fast. Between 1975 and 1994 the cultivated area of floating rice in the province decreased by almost 80% and the irrigated rice rose from 35'000 ha to 175'000 ha. At the present time 80'000 ha, which is over one third of the total cultivation area, produces three crops of rice per year. According to the master plan of the province, the area for triple cropping in 2010 is planned to be 110'000 ha.

The third crop of rice[8] has been made possible by a vast hydraulic flood protection system of embankments, high dykes and sluice gates that have been built mainly between 1997-2000. Due to the effective water controlling system also the damages caused by floods on people and their property have lessen in An Giang significantly. Officials state that the livelihoods have up-graded due to the 3rd crop not only because of increased production but also because it gives more working opportunities and increases the demand for agricultural products and services.

Also a more critical discussion of benefits and costs and environmental and socio-economic impacts of the high dykes has started, even in the provincial level. There are studies showing (Howie, 2005) that after a few years, the total yield from three crops within the diked areas is less than the total yield from two crops outside because of the reduced soil fertility. The increased use of agro-chemicals also harms the environment, especially in terms of worsening water quality. There is also evidence that the socio-economic group that mostly suffers from the changes caused by the high dikes consists of poor farmers who are loosing the "free sediment" from floods and must invest now more on agro-chemicals. The poorest group of farmers and the landless people have also been the ones for whom fishing in the fields in the flood period was the only chance to create some savings. This opportunity is gone with the high dikes. Howie (ibid.) has suggested that one social cost to be considered is the change in farmers working pattern. As the traditional "resting time" in the flood season is taken away, the farmers may experience more stress and exhaustion. The work load grows even more with reduced soil fertility as farmers then have to work harder to maintain their income.

The main structures that control the overflow from Cambodia include seven sluice gates and two dams along the border canal in northern part of the province next to Cambodian border, and these are complemented with improvement of drainage canals flowing to Gulf of Thailand. The height of border canal's embankment is up to 3.8 metres. The operation scheme is influenced by the rising flood from Cambodia and the cropping calendar of An Giang and Kien Giang, but it is designed by the Vietnamese interests. The impacts that they have on Cambodian side make these water control structures to be a transboundary issue. Unlike An Giang, Kien Giang is affected by saline water intrusion which is why the cropping calendar there is different second crop being harvested one month later than in An Giang. This is the reason why the sluice gates along the Cambodian border are opened only at the beginning of September. The late timing is problematic because it worsens the flood on Cambodian side[9].

> **"The water control structures in the delta are also a transboundary issue due to their impacts on Cambodian side**

[8] In some areas, two crops of rice and one another crop such as vegetables are cultivated.

[9] For more information on the impacts of the border embankment, see e.g. Bown (2003) and MRCS/WUP-FIN (2006b; 2006c).

The flood control systems built in the upper parts of the delta have created also other kind of new risks. As the livelihoods have adjusted to the new controlled environment, there are bigger risks related to the exceptionally big floods. If the water level exceeds the safety marginal of the control structures the damages would be greater than before as the crops and infrastructure that the dikes have enabled would be destroyed (cf. Nikula, 2006). What is also typical with high dikes is that they protect one area, but cause more problems in another area. The changed flooding pattern by the control structures and increasing infrastructure thus make the estimations of the flood impacts more complicated (Thuc&Thuen, 2005.) There have been also cases of conflicting provincial interests, for example the high dikes built in Dong Thap province raised water levels and strengthened the damages of floods in the side of Long An. Another issue is the work with improving the flood drainage that has partly resulted for example in Long An province in that the flood is receding much faster than before (ibid.). The fast receding is problematic because it causes shortages of good quality water for the dry season.

2.4.3 Costal areas: from brackish to fresh water - and back to brackish again?

Already the French acknowledged in colonial times that building and widening of the extensive canal network provoked salinisation; there are documents from the 1930s stating that protective infrastructure will be needed at the end of the canals. (Lienhard et al., 2001). In the plans of the 1960s such as the Mekong Delta Development Plan, the salinity control projects played a major role in the delta’s coastal area. However, it was only in the 1990s when the most massive salinity protection systems were finally built.

In accordance with the national policy to enhance food security by maximising land usage for rice cultivation, the aim of salinity control was not only to protect formerly fresh water systems from increased salinity but also to transform artificially former brackish areas into fresh water areas. The coastal areas of the delta thus experienced a huge amount of construction projects including irrigation canals and systems of dikes and sluices. The main project, Quan Lo Pung Hiep, located in Ca Mau peninsula include major part of Ca Mau, Bac Lieu and Soc Trang provinces and cover 450’000 ha and require 40 secondary canals (250km). The one that is often claimed to be the most successful saline water protection project in the delta is Go Cong project in Tien Giang province next to WUP-FIN case study area. The Go Cong project area protects an area of 54’700 ha, out of which 37’000 ha is agricultural land.

Now the saline water protection structures in different parts of the delta are facing new challenges as particularly the boom in shrimp culture has given new value for the brackish water. In the beginning of the year 2000, the pressure from the shrimp farmers particularly in Bac Lieu resulted government permitting diversification of land use, allowing re-entry of sea water to the formerly salinity controlled area. From the major projects only the boundaries of Go Cong still remain as they have been in the first place. The diversification has not been easy as the centralized water management systems were designed solely for rice cultivation.

> **“Saline water protection structures are facing new challenges due to the boom in shrimp culture**

The shifts in water systems have had great ecological as well as social impacts. As the sensitive ecosystems in the coastal areas have been forced to freshwater system the habitat has been very unstable, aquatic resources have declined and water quality has degraded. (Long 2005) The cultivation requires high amounts of agro-chemicals. The social aspects of these shifts are linked to differing interests between different livelihoods. The rice priority policy was harmful for farmers interested in or already involved in aquaculture. But now the new diversification policy is a potential threat to the poor rice farmers as aquaculture is not an accessible opportunity to the poorest due to the required levels of capital. The poorest groups have suffered from both the creation of artificial freshwater system and the shrimp boom as they both have limited the availability of aquatic open-access products (Luttrel, 2001).

2.4.4 Reclaiming the acid soils in the Plain of Reeds

The Plain of Reeds floodplain system covers an area of 414’400 ha i.e. just over 10% of the entire delta. The agricultural potential of the area has traditionally been very low, the limiting factors being the high concentrations of sulphates, deep and prolonged inundation during the rainy season, and insufficient freshwater during the dry season. In the higher-elevation parts of this area, one or two rice harvests can be produced each year. 1990 marked almost a complete shift from floating traditional rice to short life rice varieties. This shift increased the yields and enabled multiple cropping and was very closely connected to hydraulic works, with widening and extending the irrigation and drainage systems. The average yield of the single crop in 1979 and 1980 was only 1,5-3 tonnes/ha. Currently the yields of winter spring (WS) crop can reach to 7-8 ton/ha. The average yield of the summer-fall crop, which is more affected by the acidity, is 3.5 tons/ha.

In order to cultivate in acid sulphate soils, improving soil quality is essential. Consequently, heavy leaching requiring a large amount of fresh water is a common practice in many parts of Plain of Reeds. The leaching practice and the irrigation and drainage systems that support it are the main factor of enhancing the yield of the first crop. But as the leachate is ultimately discharged into the river the result is acidification of water which is very harmful for the aquatic life and the fish population suffers from this practice. This situation could even be interpreted as a conflict between land and water uses.

Plain of Reeds is the area where inland wild capture fishery plays the most important role in the Mekong Delta. Before 1980 the main source of livelihood in Plain of Reeds consisted of fishing (Aquatic Resources Management Programme 2000). Nowadays even the fishery of Plain of Reeds is declining due to over exploitation and habitat loss. Previously the flooded Melaleuca forest was a good ecological niche for the aquatic life, but now the forests have been replaced by rice paddies and the leaching practice and agro-chemicals (especially increased pesticides) have worsened the water quality thus damaging the once so abundant aquatic resources of Plain of Reeds.

2.4.5 Consequences of agricultural intensification & water control projects

Increasing the Mekong Delta’s agricultural productivity to current levels is due to large variety of factors, such as introduction of modern techniques and varieties of rice with major hydraulic works for irrigation, drainage and water control, the rice priority policy of the 1980s and 1990s, and the shift to the market-oriented *doi moi* economic policy. But these changes have also contributed to new risks and environmental and social consequences of which the three previous case studies gave some examples.

The case study from the upper part of the delta shows how “too efficient” flood control results in losses of the benefits from floods bringing new problems like lessening soil fertility. The flood control projects in one area also increase the risks of flooding in new areas. In the coastal areas, on the other hand, the salinity control efforts have challenged the whole brackish ecosystem and proved to be too centralised for changes in livelihoods. In the Plain of Reeds, the drainage and leaching practices of acid soils brings problems of water acidification risking the once so abundant wild fishery.

The losses in wild fishery is common in all case study areas, and has generally happened in the whole delta as the reclamation of wetlands and the water control systems have all had adverse effects on fishery and aquatic productivity. This has been most harmful for the poorest groups of farmers, especially for the landless who are the most dependent on the open access products (Luttrell, 2001; Aquatic Resources Management Programme, 2000).

One of the most important findings from the WUP-FIN village surveys was that along the problems related to water quantity, there are rising water quality problems that affect the daily life of rural people for whom surface water is the principal source for domestic uses. The quality problems bring risks also for aquacultural development. In some cases like in An Giang, the control of the water flow with high dykes has increased the usage of agro-chemicals thus resulting in worsening quality. The transformation of saline soils into rice paddies increases dry season water use and use of agro-chemicals, and the reclamation of acid soils produces acidity problems in water through heavy leaching. All together it can be stated that water related issues that would deserve more attention in the delta are linked to the losses of common pool resources including rising water quality problems that affect the daily life of rural people for whom surface water is still the principal source for domestic uses and losses of fishery. It is also important to note that so far the water quality problems are caused mostly by delta's internal processes.

All in all it can be stated that the side-effects of the productionist gains in the delta are closely linked to the losses of common pool resources including fishery, good water quality and free alluvium. Particularly challenging is that the poorest groups seem to be impacted most negatively by these changes. The poorest farmers have not been able to benefit so greatly from the modernization of agriculture as they cannot afford the adoption measures such as fertilizers and irrigation support system that would be required with new agricultural schemes. In addition, the poorer farmers are usually not able to take advantage of the economics of scale, since they have so small landholdings with often less than 0.5 ha of arable land (Houssain et. al., 2002b.) There is a clear resonance in this sense with the observation that the local largely subsistence based livelihood activities that are directly based on natural resources are the ones that degrade the most along the "development" (Bryant & Bailey, 1997).

"The side-effects of the development are closely linked to the losses of common pool resources

Generally an alarming recent socio-economic trend in the delta has been the growing social differentiation. Despite the delta's present great volume of agricultural production, an increasing number of farmers has less access to the profits produced there (Taylor, 2005). In the process of land allocation the proportion of the farmers who lost their land altogether was the nation's highest in the delta (Shanks et al., 2004). The role of aquacultural development has been paradoxical. One of its justifications has been the poverty alleviation, but it seems that the result is on the contrary increasing social differentiation since the poor people have had no resources to make the high and risky investments required for starting with aquaculture.

The case studies also indicate that there hasn't perhaps been enough attention paid on that the poor farmers could access properly the credits and governmental services. One reason for this is that the poorly resourced extension offices have been pressured to meet production targets rather than poverty alleviation objectives (Aquatic Resources Management Programme, 2000). The losses of common pool resources in this situation have not made the life easier for the poor farmers. (see e.g. AusAID, 2004; Luttrell, 2001)

One major water related issue linked to the more intensive farming is the increased water use. The traditional extensive farming systems were adapting to the prevailing water availability. As shown by the case studies above, the intensification of agriculture and shifts to multi-cropping have meant a significant increase in dry season cropping and thus increased water demands. The water control projects have thus for they part increased water consumption and by rising the dry season water use, the saline water intrusion has strengthen. This shows that the threat of saline intrusion is not only a matter of upstream development, but also an internal risk which includes e.g.

conflicting provincial interests. The intensity and the losses from saline intrusion vary yearly, but they clearly have had an up-ward trend. In 2005 the seawater intruded about 60-80 kilometres into the Tien, Hau, Ham Luong and Co Chien rivers and up to 120–140 kilometres to the Vam Co Tay and Vam Co Dong rivers. The losses were estimated to be 723 billion VND i.e. US$45 million (Vietnam News Agency, 2005).

2.4.6 Need for pro-poor alternatives

The diversification of livelihoods could be seen taking place in two forms: 1) in cash crops orientating to larger markets and to export and 2) in complementing crops and activities that aim to bring sustainability to the livelihoods. The cash crops especially in aquaculture are often of high-investment and high risks but in case of a success also high profit alternatives available mainly for the better off farmers. High risks of the cash crops is also related to the fluctuating prices which for great part derive from the encouragement of the officials and the copying mode of the Vietnamese farmers that create a situation where a successful model or cash crops quickly spread to all farmers creating oversupply and declining prices. The booms of shrimps and catfish in the delta are world wide known as they have affected the world markets and prices of these products. The most known pro-poor form of diversification in the farm scale aiming for sustainability is the Agriculture-Fishery-Animal Husbandry model (VAC models) and its more ecological variation VACB model where B indicates biogas which is created from the pig manure. (Chiem et al., 2004).

The blue revolution has brought economic growth in the delta, but also negative impacts for the environment and the poor. The impacts of aquaculture on fishery should be studied further. Generally one problem is that the poor people's dependence on open access products seems often to be largely ignored by the official level. The diversification of livelihoods requires thus also more pro-poor versions of which so-called VACB-models and fish sanctuaries could serve as an example. The diversification of livelihoods is a major challenge for water management as requirements of flexibility for structures basically built for rice monoculture are rising. There has been also questions raised that once these structures are changed the government supported works should not aim only for satisfying the needs of better off farmers e.g. intensive large scale shrimp farmers, but also the needs of the poorer farmers should be acknowledged and specifically supported by the government. Publicly funded water works should thus be based on the needs of all stakeholders and pay special attention to the most vulnerable groups.

> **"Diversification of livelihoods in the delta requires more pro-poor approaches**

2.4.7 Addressing the complexities – overview of the WUP-FIN models in the delta

Focal issues

The analysis in the previous chapters illustrates the complex interlinked issues involved in Delta management. The analysis shows the concern areas – water quality, hygienic conditions, flood management, bank erosion problems, sustainable rice cultivation connected with flood born sediments, optimal flood control, acidic sulphate soil management, equitable construction and operation of control structures, transboundary water resources management and securing of livelihoods for the rural poor. The project modelling system has been developed keeping in mind the complexity and focal issues. The final applications have been requested by the VNMC. It has selected three application areas:

1. Plain of Reeds
2. Tan Chau
3. Tieu River Mouth.

In addition Lower Mekong Basin pilot model for Cambodian floodplains, Tonle Sap and most of the Vietnamese Delta has been constructed, although not specifically requested by the MRCS or the VNMC. The purpose of the application has been 2D/ 3D feasibility testing in regional scale.

The applied WUP-FIN models compute main Delta characteristics including:

- overland flow from Cambodia
- flood propagation in the floodplain as a 2D (3D) process
- control structures and their operation
- tides
- coastal flow
- saline intrusion as a 3D density driven process
- sediment transport, sedimentation and erosion
- acidic water transport and dilution (at the moment no chemical reactions or modelling of the source term included)
- other water quality variables as necessary.

Plain of Reeds approach (applicable to the whole Delta)

Plain of Reeds area reflects whole Delta processes, management problems and complexities. It was decided early on that the way to create added value compared to the existing modelling tools would be by using 2D/3D approach for floodplain modelling. On the other hand it has been clear that in the Plain of Reeds or Delta scale 2D/3D model can represent only the largest rivers and channels accurately. The combined 1D/2D/3D approach provides best features of both worlds. It provides accurate description of the floodplain 2D/3D characteristics, floodplain structures, river network and control structures connected to the channel network including roads, bridges, dikes and gates.

Figure 13 present the basic principle of coupling river channel and floodplain models. 1D river channel and 2D/3D floodplain models are coupled through a connection zone. The connection zone can be a dike, gate, bridge opening etc. or floodplain area without any control structure. The 2D/3D domain is not restricted to floodplain - as well lakes, reservoirs or coastal areas can be handled with the model. The flow in the connection zone is calculated depending on the control structure. Manning's equation is used when no control structure is present.

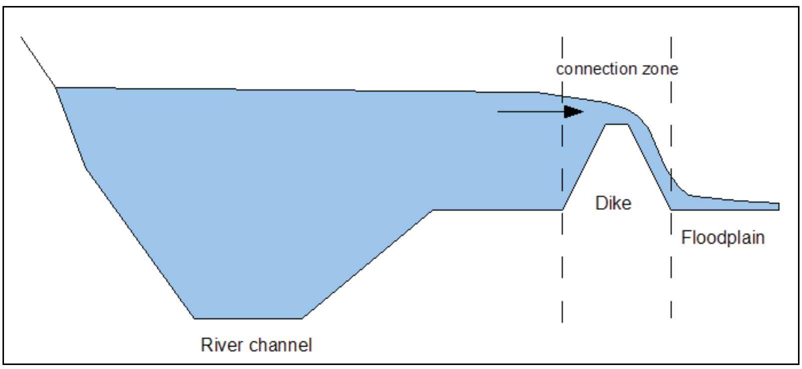

Figure 13. Schematic representation of the river channel (1D) and floodplain (2D/3D) connection. The connection zone can contain a control structure (in figure a dike) or exist without specific control structure.

Examples of the 2D/ 3D floodplain model results are shown in Figure 14 – Figure 18. The case in the figures includes a flood pulse travelling through the channel network and spilling to the floodplain as well as overland flow from Cambodia. The colours signify sediment concentration (Figure 14), flood maximum depth (Figure 15), flood arrival time (Figure 16), close-up view of the floodplain flow and water depth (Figure 17) and net sedimentation (Figure 18). The figures demonstrate the complex 2D nature of the processes.

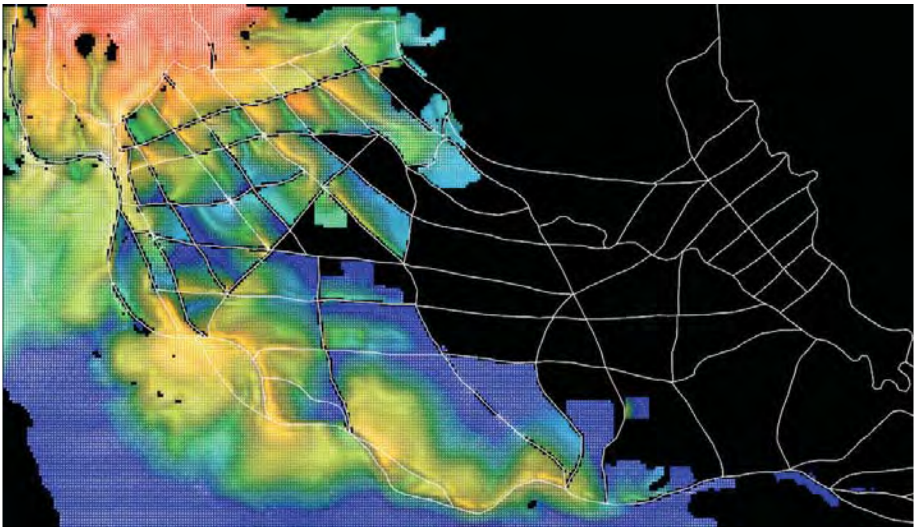

Figure 14. Flooding and sediment simulation. Colour signifies sediment concentration. Figure shows overland flow from Cambodia and flood pulse travelling in the river network and spilling to the floodplain.

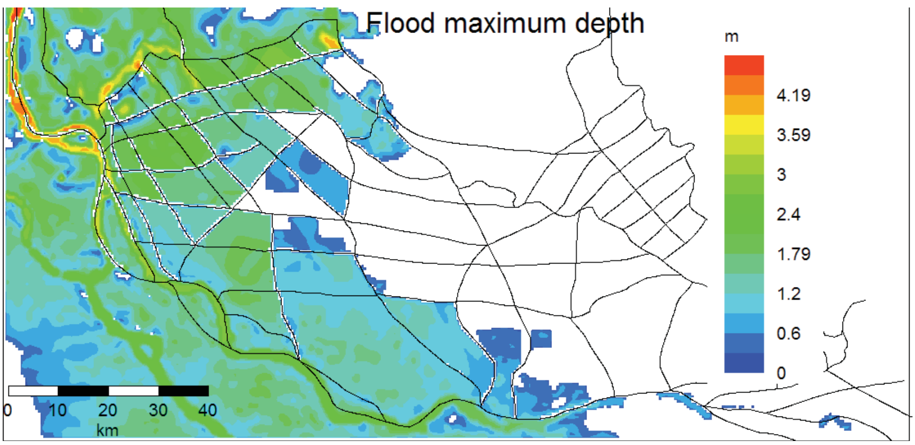

Figure 15. Simulated flood maximum depth.

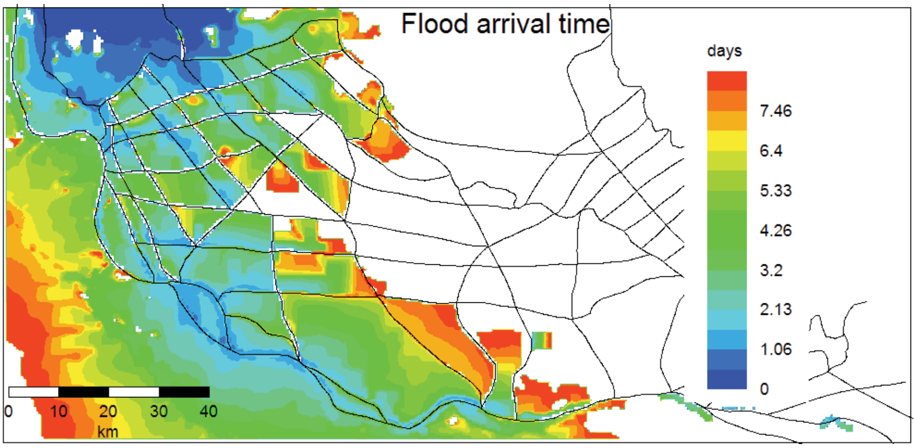

Figure 16. Simulated flood arrival time in days since start of the simulation.

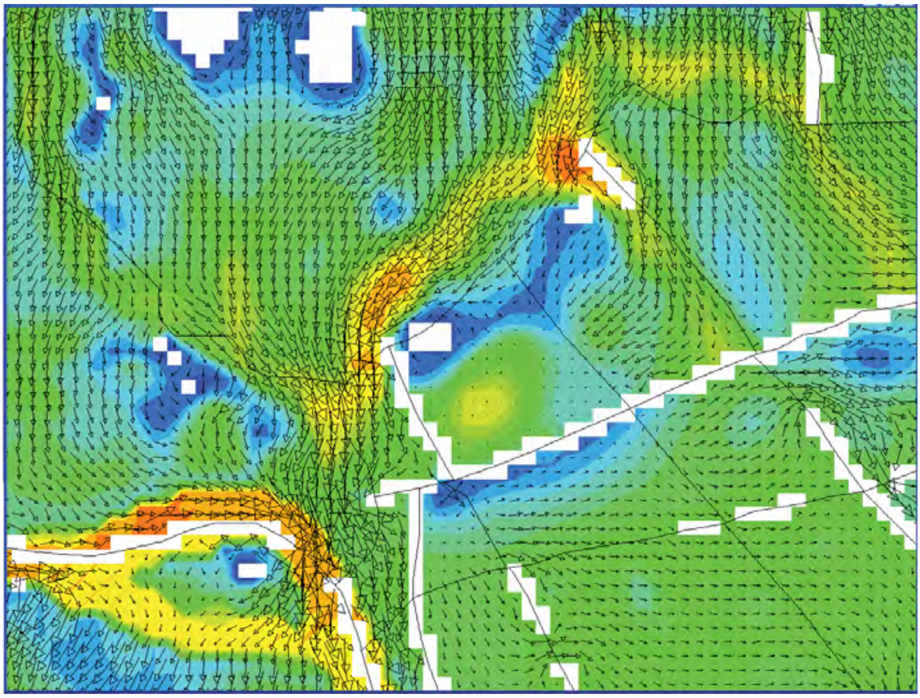

Figure 17. Close-up view of simulated water depths and floodplain flows.

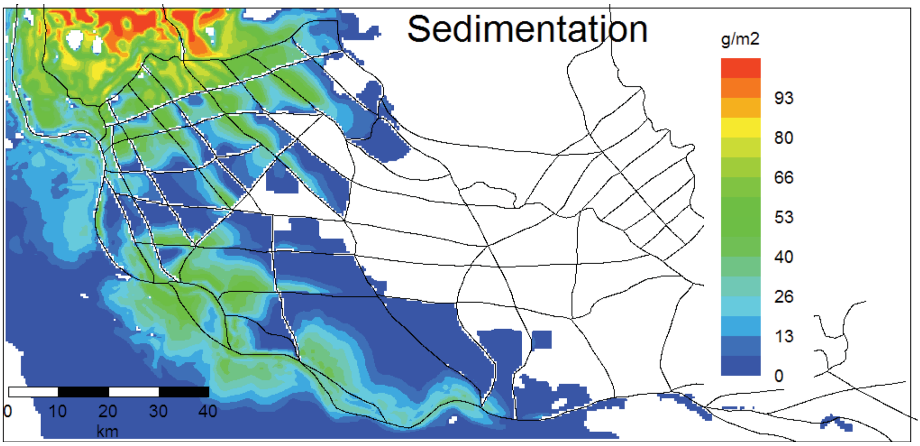

Figure 18. Simulated net sedimentation.

Tan Chau and Tan Tieu applications

The Tan Chau and Tieu River Mouth applications are both more local than the Plain of Reeds application. They focus mainly on the main river channel. In addition Tieu River Mouth model includes adjacent coastal area. Part of the modelling work has been conducted by the Vietnamese WUP-FIN Project Modelling Team.

Tan Chau work has concentrated on river bed changes and bank erosion studies. Tan Chau is highly susceptible for bank erosion and in general river morphology changes. Figure 19 shows simulated sedimentation in the critical area (simulation work and figure by the Vietnamese Team). Impact of protection structures on bank erosion and bed level changes is one of the main model uses.

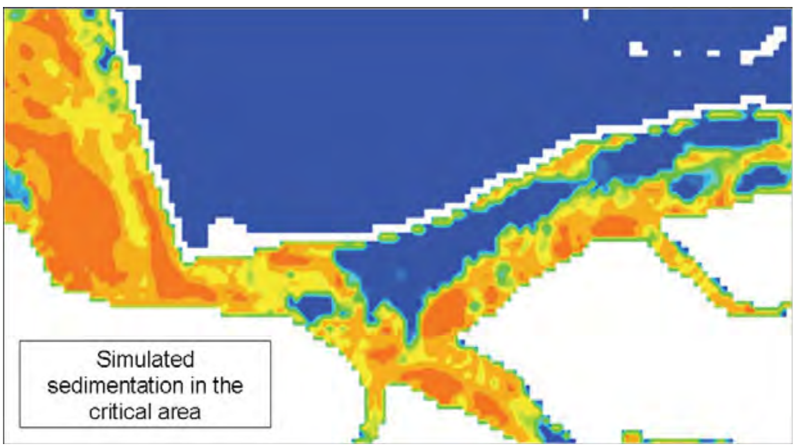

Figure 19. Simulated sedimentation in part of the Tan Chau model area. Blue areas erosion and red ones high sedimentation. Model is used to study impact of protection structures on bank erosion and river bed. Simulation and figure by the Vietnamese Modelling Team.

Figure 20 shows simulated oil accident in the Tieu River Mouth. The oil is released continuously from a point source for a week and dispersed mostly by the strong tidal currents. Simulation and figure are provided by the Vietnamese Team. The MRCS

Navigation Programme and the riparian countries have expressed interest in using of the model for contingency planning and emergency support in case of a real accident.

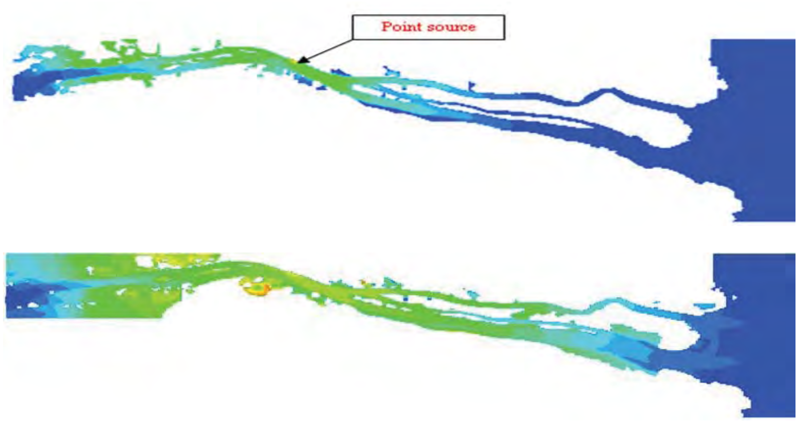

Figure 20. Simulated spread of oil from oil accident in Tieu River Mouth application. Above 1 day after accident and below one week. Simulation and figure by the Vietnamese Modelling Team.

Figure 21 presents results from two scenario simulations in Tieu River Mouth. The left time series shows impact of 25 cm sea level rise to the salinities in My Tho and the right one dredging impact. It is interesting to observe that dredging increases upstream salinities many times more than the sea level rise. The simulation is complex involving stratification (salinity versus fresh water inflow), tides and density and shear-stress dependent turbulence.

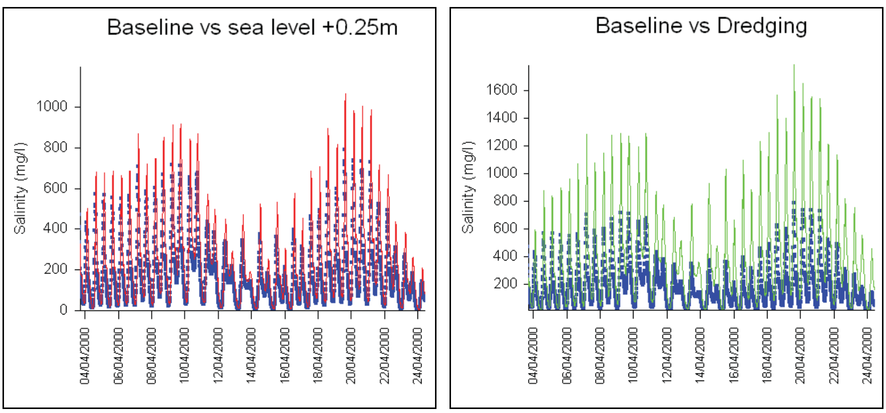

Figure 21. Salinity concentrations in My Tho, Baseline vs. sea level change (left) and dredging (right). Solid line is scenario and dots represent the baseline results.

Lower Mekong Basin model

Figure 22 shows flood depths simulated by the Lower Mekong Basin model. No control structures are included in the model. The model grid resolution is 1 km. The model runs rather fast and can be used as a basis for further developments. Necessary additions include coupling to a 1D model such as DSF ISIS and inclusion of control structures. After the additions model would be very comprehensive platform to support Delta Master Plan or other Delta developments.

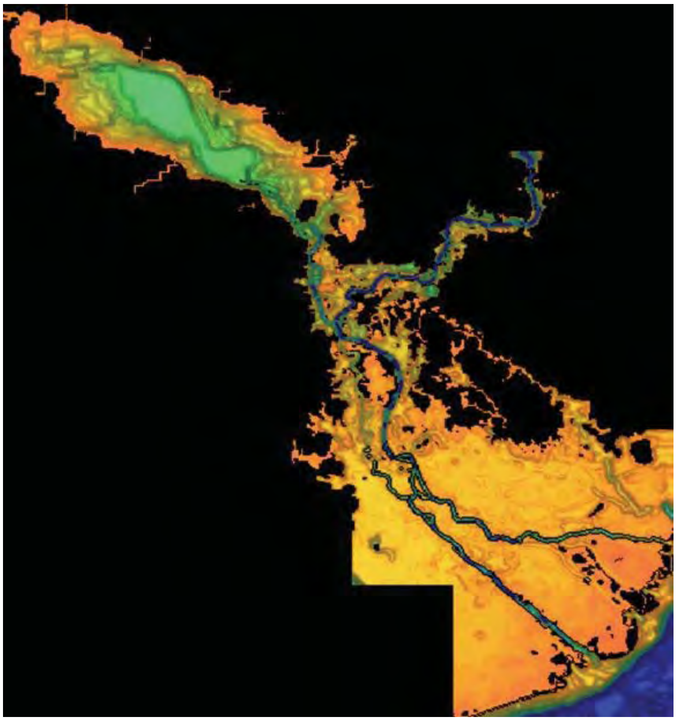

Figure 22. Lower Mekong Basin 2D/3D flood simulation. Colours signify water depths. No control structures included in the model.

Main findings

The Mekong Delta is an exceptional system both in terms of its complex hydrological characteristics and livelihoods structures with remarkable differences in different parts of the delta.

The success of the agricultural development of the delta has also severe environmental consequences such as worsening water quality and diminishing biodiversity as well as social impacts e.g. through loss of common pool resources that have lead to increased social differentiation.

While the extensive water control structures have decreased the problems with water quality (both floods and drought), new kind of problems and risks have emerged particularly related to water quality and diversification of livelihood sources. In addition, the embankments have also had negative transboundary impacts to Cambodian side.

While future social and economic development of the delta builds on diversification of livelihoods, it should also consider more strongly pro-poor approaches.

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2.5 BANK EROSION

The changes in river channel such as bank erosion and accretion are natural processes but often human activities can have a significant impact on those changes. During the WUP-FIN project, the bank erosion issue has been studied in Vientiane – Nong Khai section of the Mekong River, identified one of the hot spot areas by LNMC and TNMC.

> **Bank erosion:** River channel changes, such as bank erosion, downcut and bank accretion, are natural processes for an alluvial river. However, development like sand mining, infrastructure building on the river bank, artificial cutoff, bank revetment, construction of reservoirs and land use alterations have in many places changed the natural geomorphological dynamics of rivers.

Thus, this chapter aims to assess changes in river bank location in Vientiane – Nong Khai section of the Mekong River where the Mekong borders between Thailand and Lao PDR. The analysis of the river bank location is based on the aerial photos from the 1960s and early 1990s, and SPOT 5 satellite image acquired in 2005. The erosion and accretion rates on both sides of the Mekong were analysed between two time periods: 1960-1990 and 1990-2005. The EIA 3D hydrodynamic model was applied to the area to simulate fluvial hydraulic forces related to bank erosion. The observed bank erosion was compared to the model results and the model was also used to create scenarios of possible human impacts on potential hydraulic forces in the future.

This Chapter is partly based on the article of Kummu et al. (in press).

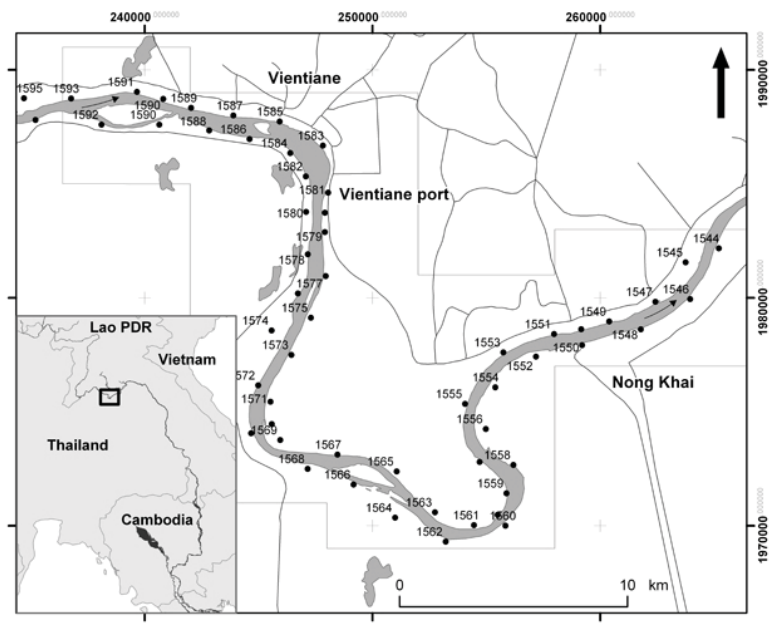

Figure 23. Map of the study area and its location in larger scale.

Livelihood linkages: The bank erosion can have severe social and economic consequences, particularly due to loss of agricultural and residential land, collapsing of buildings and the consequent costs and danger it causes for households. For example in Vientiane area, several villages have moved inland to protect their buildings. Also loss of human lives can occur when large areas of river bank collapse suddenly.

Bank erosion, sedimentation, island growth and attachment of islands to river banks is also a sensitive transboundary issue as the Mekong River forms most of the border between Laos and Thailand, and changes in the river channel have implications for the position and administration of the border (MRCS/WUP-FIN 2006e).

2.5.1 Research aims

This study therefore focuses on this part of the Mekong in order to assess the problems and provide information of the bank erosion rates. The study aims to

- assess how much the shape of the river in Vientiane-Nong Khai section has changed over time as a result of bank erosion and accretion by using data based on aerial photos from the 1960s and early 1990s and SPOT5 satellite image in 2005
- compare the EIA 3D model results of the simulated hydraulic forces related to the bank erosion, with the measured bank erosion
- present some simulation scenarios of possible human impacts on bank erosion caused by hydraulic forces
- discuss the possible causes of the changes in bank erosion rates in the study area between the two time periods

2.5.2 Methods

Remote sensing

Part of the required data sets was already in digital format and ready to be used for the analysis. The following processes needed to be done for the non-digital data and data which were not geo-referenced: geo-referencing satellite imageries and scanned hydrographical atlas, digitising or digitalising riverbank location of different years using scanned and satellite images as based maps. The processes used for each data set are defined below in more details.

In the analysis the riverbank location datasets of different years were compared. The comparison of riverbank location was carried out in three main phases as listed below:

- Comparison of riverbank location between Hydrographical atlases from 1960 and 1990
- Comparison of riverbank location between the new hydrographical atlas data in 1990 and SPOT5 12/2004 and 04/2005 images
- Comparison of islands shape during the two periods of 1960-1990 and 1990-2005

This analysis was made in order to measure the changes in river bank location that have occurred over time and identify the places where erosion and accretion occurred in each specific time period. The river bank erosion and accretion were calculated separately for each side of the Mekong, and islands, using the ESRI ArcMap programme, part of the ArcGIS 8.3 programme package.

Modelling

The mathematical model applied to the study area is the three dimensional (3D) EIA Model (Koponen et al., 2005) for the detailed hydrodynamic studies. The sediment transportation module is coupled with the model, including suspended sediment transportation, and bed aggradation and degradation calculations (MRC/WUP-FIN, 2006). The EIA 3D model system is fully three-dimensional model based on rectangular grid representation. The model system accommodates meteorological, hydrological, topographic, land use and infrastructure characteristics of any modelling area and produces 3D hydrodynamics and a few selected water quality parameters. The model is able to describe the 3D characteristics of the flooding, flow, water quality, erosion and sedimentation in the lakes, reservoirs, river channels and floodplains.

The model output parameters for Vientiane- Nong Khai application, as listed below, were selected to focus on how the hydrodynamics and sediment transportation and erosion of the river affect potentially on bank erosion:

1. flow related physical parameters (3D flow, water depth, flooding)
2. suspended solids concentration
3. bed degradation and aggradation
4. fluvial hydraulic forces related to bank erosion

2.5.3 Major findings + way forward

Remote sensing analysis

The bank erosion rates have changed over the study periods (1960-1990) and (1990-2005). The average annual erosion rate has dropped from 4.4 ha/a to 3.4 ha/a in the Thai side, but has increased from 3.4 ha/a to 4.9 ha/a in the Lao side. The locations of the bank erosion based on this study correspond rather well with the WAD erosion map which was produced based on the field visits and interviews of locals during the years 2004 and 2005. Like any GIS and remote sensing work, the errors of our results are inherited from both local and positional errors, as a result of employing maps obtained in various times and with various scales. Therefore, small changes can be treated as an error, instead of real change.

Table 3. Annual average bank erosion and accretion areas [ha] for periods 1960-1990 and 1990-2005. Erosion and accretion areas have been divided to Lao and Thai side of the rivers.

	Annual area [ha/a]			
	1960 -1990		1990 -2005	
	Lao	Thai	Lao	Thai
Erosion	3.4	4.4	4.9	3.4
Accretion	2.0	2.0	2.5	3.3

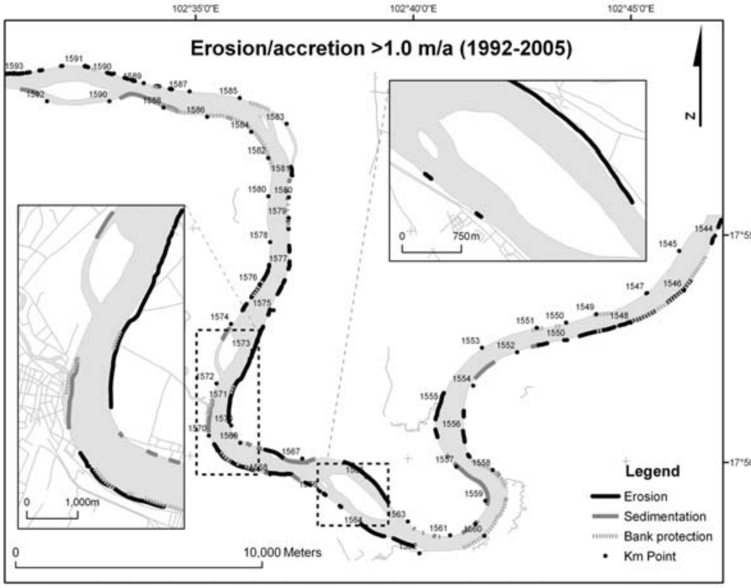

Figure 24. Map of the river bank location changes where the change in either direction has been more than 10m during the 1990-2005.

The results of the changes in islands are presented in Table 4. The annual erosion of the islands was 5.8 ha/a and 5.0 ha/a for periods 1960-90 and 1990-2005, respectively. Hence, the erosion rate has been rather stable over the studied periods. The accretion has increased from 1.4 ha/a during the 1960-90 period to 6.7 ha/a during the latter period. This is, however, partly due to the fact that one of the main islands joined to Lao side close to Vientiane.

Table 4. Annual average island erosion and accretion areas [ha] for periods 1960-1990 and 1990-2005.

	Annual area [ha/a]	
	1960 -1990	**1990 -2005**
Erosion	5.8	5.0
Accretion	1.4	6.7

Modelling results

The EIA 3D model has been be used for analysing the impacts of changes in the flows and sediment transport caused by natural or man-made reasons. The model can simulate well the water levels in all the water level stations in the study area. The vertical velocity profiles fit also well with the profiles measured by ADCP. The results are reported in more details in MRC/WUP-FIN (2006). Here we just briefly present the model validation results and a brief scenarios analysis for the southernmost part of the study area.

The model results, fluvial hydraulic forces, were compared to the actual bank erosion rates in the southern part of the model area (Figure 25). It can be seen that the areas with high horizontal and vertical flow velocities correspond well to the observed erosion areas. The observed data relates to bank erosion between 1990 and 2005. The information of the existing bank protection structures is produced by the WAD and is based on the field visits as stated earlier.

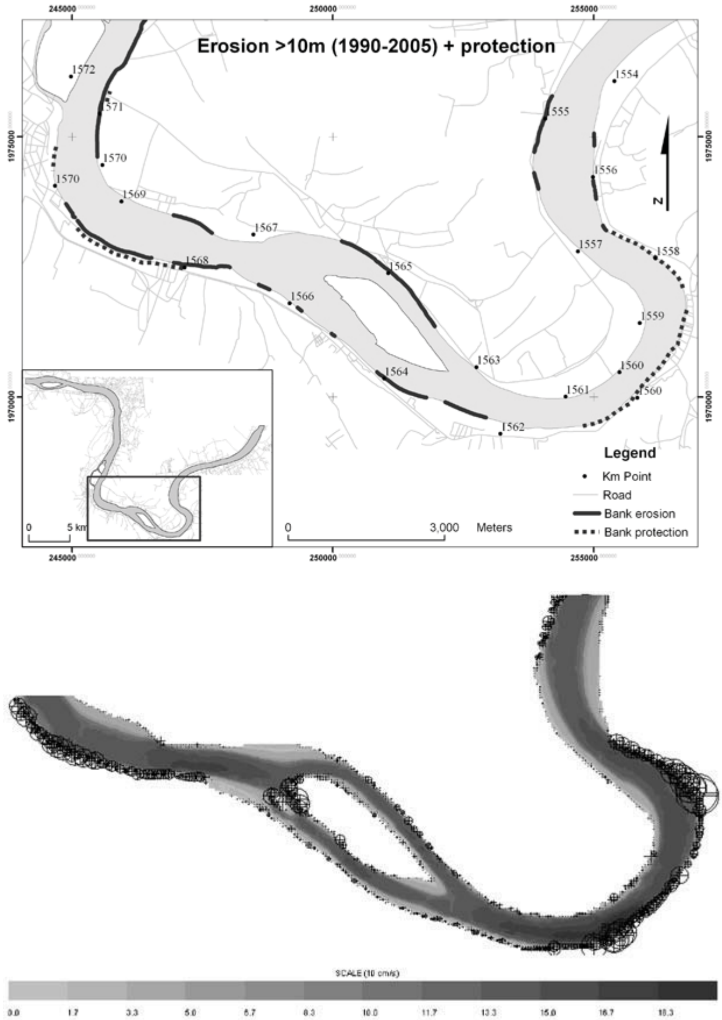

Figure 25. Up: Observed bank erosion >10m (1990-2005) and built bank protection. Down: Simulated horizontal (grey scale) and vertical velocities (crosses and circles). Discharge 12’000 m3/s. Highest vertical velocities 0.5-1m/s.

From the results we found also that there is practically no correlation between the observed bank erosion and near bottom velocities or shear stresses. Especially the formation of the high vertical velocities and to some extent also the horizontal distribution of flow depends on nonlinear momentum transfer. It causes upwelling and scouring on the banks in the river bends.

Four scenarios were run to analyze human impact on fluvial hydraulic forces related to bank erosion. The bank protection measures can increase those hydraulic forces very locally downstream of the bank protection structures as illustrated in Figure 26. The model doesn’t show increased velocities in further downstream. Sand mining causes generally decrease of flow velocities in the modified area, but may increase near bank flow velocities downstream from the sand mining (Figure 26). In any case the impact is relatively small. The larger impact can be seen from blocking parts of the river, for instance, by bridge or road construction to the islands, or major infrastructure work that would block part of the river and thus, decrease the size of the cross-section and increase significantly the hydraulic forces on bank on the other side.

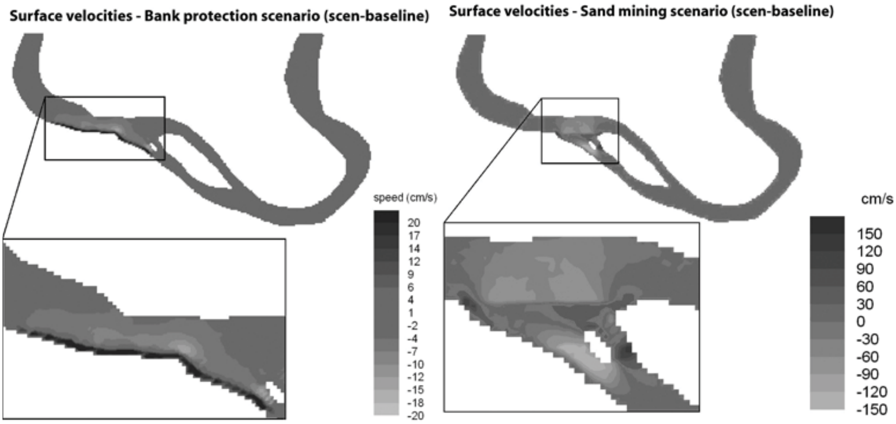

Figure 26. Changes in surface velocity in sand mining (left) and bank protection scenarios (right).

Further studies will be conducted to analyze impact of changing flow regimes. Moreover, the hydrodynamic model should be linked to the in bank erodability properties, i.e. bank failure under the influence of gravity, and obtain an overall picture of the magnitude of the expected bank erosion rates.

Conclusions

The bank erosion in the lower Mekong Basin has become a serious issue and its damages have been significant. There is an urgent need to understand the underlying mechanisms. The bank erosion and channel change can also cause the change in the thalweg line which is used as the border line between Thailand and Lao PDR. Therefore, it would be important to maintain the river channel stability through minimising the human impacts. Employing the historical maps and hydrodynamic modelling tools, our study provided preliminary evidences that the river banks might have been changing as influenced by the artificial construction as well as water flow and sediment concentration changes. Such changes could be further enhanced in the region with the increasing changes in hydrodynamics as a result of human activities like reservoirs construction, river channel improvement for navigation, river bank controls, bridge construction, and sand mining etc. Work is under processes to further examine some of these important impacts and to combine the modelled hydrodynamic and sediment transport processes with in-bank processes (Kummu et al., in press)

“Bank erosion in the lower Mekong Basin has become a serious issue and its impacts have been significant

Way forward - *modelling bank erosion in support of bank protection in the LMB countries*

Background -- The MRC member countries have identified several hot spot areas along the river. This has guided to set up hydrodynamic and sediment transport model applications by the MRCS/WUP-FIN project in Vientiane-Nong Khai area (Laos-Thailand border), Chaktomuk confluence (Cambodia) and Tan Chau (Vietnam). Much wider need exists for the model applications and erosion studies along the Mekong.

Justification -- River flow is causing a shear stress towards the river bank and causes bank erosion when the shears stress exceeds a critical value. The critical value varies along the river and depends on the stability properties of the river bank. The combination of hydraulic data and bank erodability data provides a tool for estimating the bank erosion rates and helps to evaluate the socio-economic risks and planning of bank protection measures. In some locations bank collapse may be an additional factor contributing to bank retreat, triggered by fluvial stress and/or bank saturation.

Objective - To develop a method to evaluate bank erosion along the Mekong River and provide support for planning bank protection measures.

Methodology -- Existing models and tools: WUP-FIN 3D hydrodynamic model, model applications set up for Vientiane- Nong Khai, Chaktomuk and Tan Chau areas, integrated flow (ADCP) and TSS databases, geomorphological and remote sensing data on channel changes, JICA study on bank protection in Vientiane, MIKE 21 application and database in Chaktomuk area, MIKE 21 application in Tan Chau.

To develop: Method for coupling hydrodynamic modelling and data with bank erodability data, taking into account bank saturation and its effect in bank collapse.

To measure: Continue river geomorphology, bank and bed changes as well as integrated flow and sediment transport measurements, study soil stability and bank erodability in erosion prone areas

Socio-economic analysis and risk assessments.

Counterparts -- NMCs, Line agencies, Universities, EP/IBFM, Lao-Thai Border Commission. University of Southampton (Paul Carling, Steve Darby) and National University of Singapore (NUS).

Expected outputs -- Tan Chau measurement programme carried out over an annual cycle (river morphology, integrated flow (ADCP) and TSS data), Vientiane-Nong Khai and Chaktomuk measurements continued.

Impact of development scenarios on river hydrodynamics (shear stress distribution) studied with the national teams

Information on socio-economic risks in hot spot, erosion prone areas.

Data on bank erodability and critical shear stress.

Hydrodynamic model (near bank stress data) coupled with bank erodability data, estimates on bank erosion rates.

Support to bank protection planning for national authorities and trans-boundary consultation.

High priority areas for further erosion model applications identified.

Main findings

- The average annual erosion rate has dropped from 4.4 ha/a to 3.4 ha/a in the Thai side, but has increased from 3.4 ha/a to 4.9 ha/a in the Lao side.
- The bank erosion in the low Mekong River has become a serious issue and its damages have been significant
- Though the model has not yet been linked with actual river channel changes, the 3 D model has created a very promising start to couple the fluvial shear stress data with bank erodability data for calculating erosion rate estimates along the river channel
- the model has proved to be a useful and user friendly tool in simulating the impacts of man made interventions in the river channel; the simulation results show very local changes in the flow pattern when no major changes in the river cross-section are made

Additional information:

Kummu, M. and Varis, O., 2007. Sediment-related impacts due to upstream reservoir trapping in the lower Mekong River. Geomorphology, 85: 275–293.

Kummu, M., Lu, X.X., Rasphone, A., Sarkkula, J. and Koponen, J., in press. Riverbank changes along the Mekong River: Remote sensing detection in the Vientiane-Nong Khai area. Quaternary International, in press.

MRC/WUP-FIN, 2006. Technical Paper No.7 – Remote sensing study of Mekong River bank erosion in Vientiane – Nong Khai area. WUP-FIN Phase II – Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR. 126 pp.

MRC/WUP-FIN, 2006. Working Paper No.4 - Vientiane - Nong Khai Bank erosion model application, WUP-FIN Phase II - Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR. 58 pp.

MRCS/WUP-FIN, 2006e. Vientiane Village Survey Report. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR. XXX pp. Available on-line at http://www.eia.fi/wup-fin/wup-fin2/publications.htm

2.6 CLIMATE CHANGE IN NAM SONGKHRAM

The Nam Songkhram watershed is part of the Mekong River basin and has an area of 13,138 km^2 (Figure 27). The Nam Songkhram River starts from the low mountains with elevation of 675 m and drains to Mekong in elevation of 135 m. The lower part of the catchment has extensive floodplains and the area is known from its rich fisheries. The high productivity of the floodplain depends on the flood pulse originated from the monsoon rains in the upper catchment and influence of the Mekong due to backwater impact and sometimes even reverse flow from the Mekong to the Nam Songkhram floodplains (Kummu et al., 2006b).

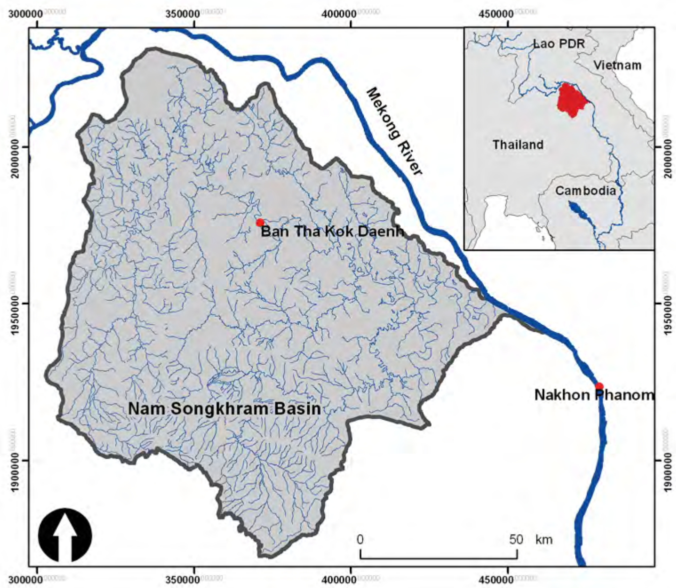

Figure 27. Location of the Songkhram River basin.

Livelihood linkages: The Nam Songkhram floodplains support a variety of different kinds of local livelihoods. As indicated by the Thai Baan research carried out in the area (MWBP, 2005), the rural livelihoods in Nam Songkhram are based on combined use of wide range of natural resources adapted to seasonal changes. The main livelihood sources in the basin include fisheries, rice cultivation and utilisation of diverse wetland products.

Nam Songkhram is one of the poorest areas in Thailand, and most of the development goals for the area set by the government are connected to the enhancement at agricultural and fisheries sectors (Kummu et al., 2006b). As is often the case, there seems to be great differences between the opinions of different people and organisations on what kind of activities would actually be the best to enhance sustainable development of the area. To facilitate also this discussion, it is important to understand how the possible climate change would impact on the hydrology and floods, and ultimately the livelihoods in the basin.

2.6.1 Research aims

The main aim of the study was to simulate the impacts of the climate change scenarios on the hydrology and flooding in the Songkhram River Basin. The results of the VMod hydrological model were used as boundary conditions for the EIA 3D model. The following parameters were simulated:

Impact of the climate changes on discharge (results of the VMod model)

Impact of the climate changes on flooding

- Flood arrival time
- Maximum flood extent
- Duration of inundation
- Water level in a few selected places in the floodplain

Impact of the climate change on the reverse flow from the Mekong main stream based on the scenario results from the Mekong basin wide hydrological model (VIC)

2.6.2 Methods

Climate scenario based on Conformal Cubic Atmospheric Global Change Model (CCAM) that is developed and run by Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), and modified for the Southeast Asia region by SEA START RC (Chinvanno and Snidvongs, 2005). The atmospheric model CCAM was used to simulate climate conditions with three different levels of Atmospheric Carbon content:

- **Scenario 1:** Baseline period on 1980 – 1989 (atmospheric carbon content 360 ppm)
- **Scenario 2:** Atmospheric carbon content 1.5 x compared to the baseline (540 ppm)
- **Scenario 3:** Atmospheric carbon content 2 x compared to the baseline (720 ppm)

The VIC (Variable Infiltration Capacity) model of was used to simulate the Mekong basin wide hydrological impacts of the three scenarios, and gave the boundary hydrological condition in the Mekong River for the local model application in the Nam Songkhram basin

The main tools used in this project to simulate the local hydrological impacts were

- VMod hydrological model
- EIA 3D hydrodynamic model

The VMod, distributed hydrological model application covered the entire Nam Songkhram watershed. Results of the climate scenarios in CCAM model have been used for the VMod hydrological input. The EIA 3D model application was applied to the Lower Songkhram river basin floodplains and the confluence of the Songkhram River and the Mekong River.

2.6.3 Major findings + way forward

Climate change impacts on basin wide hydrology

The Mekong Basin wide impact was calculated by the SEA-START RC team by using the VIC model. 10 years daily average discharges were computed for each scenario. The result of the Mekong discharge is presented in Figure 28.

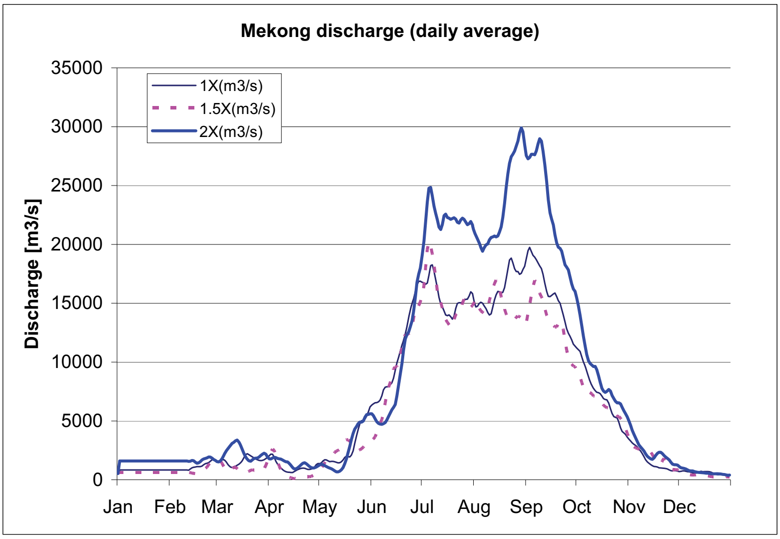

Figure 28. Climate change impact on Mekong discharge in the mouth of Songkhram River.

The scenario 2 (1.5X) gives smaller discharges during peak flow (September) than baseline scenario. However, the scenario 3 (2X) gives much higher discharges during the whole wet season compared to the baseline. The analysis of scenario 3 results and reason for the much higher discharge will be continued together with SEA-START RC and Chulalongkorn University teams.

Climate scenario impact on local hydrology

Table 5 presents the local hydrological characteristics for the Ban Tha Kok Daeng station. The average discharge would increase in scenario 2 8.4% and in scenario 3 23.1%. The increase in the discharge is 2-2.5 times larger than increase in precipitation for same climate scenarios. The local impacts differ in scenario 2 to the basin wide hydrological impacts as in Mekong mainstream the peak discharge decreased during that scenario. In scenario 3 the peak discharge increased in both, local and basin wide, simulations.

> **“ The increase in the discharge is 2-2.5 times larger than increase in precipitation for same climate scenarios**

The average dry season discharge increases in scenario 2 while it decreases in scenario 3. This might have something to do with the increased evaporation in scenario 3.

The average wet season discharge increases 7.9% and 23.6% in scenario 2 and 3, respectively.

Table 5. The hydrological characteristics for the baseline and the two climate scenarios in Ban Tha Kok Daeng during the 1980-1989.

		Ban Tha Kok Daeng				
		Scen1 m3/s	Scen2 m3/s	Scen3 m3/s	Scen2 %	Scen3 %
MQ	average discharge	114.54	124.14	140.96	8.4%	23.1%
MHQ	average max discharge	533.26	571.46	589.82	7.2%	10.6%
MNQ	average min discharge	0.05	0.03	0.04	-31.0%	-3.4%
MQdry	average dry season discharge	2.30	3.56	1.56	54.7%	-32.4%
MHQdry	average dry season max discharge	25.17	58.53	45.64	132.5%	81.3%
MNQdry	average dry season min discharge	0.05	0.03	0.05	-31.0%	1.3%
MQwet	average wet season discharge	226.09	243.98	279.52	7.9%	23.6%
MHQwet	average wet season max discharge	533.26	571.46	589.82	7.2%	10.6%
MNQwet	average wet season min discharge	0.76	1.62	1.63	113.9%	114.8%
HQ	maximum discharge	607.10	712.40	668.60	17.3%	10.1%
NQ	minimum discharge	0.02	0.03	0.02	11.6%	-4.1%
HQdry	maximum dry season discharge	151.20	317.70	288.90	110.1%	91.1%
NQdry	minimum dry season discharge	0.02	0.03	0.03	7.9%	4.6%
HQwet	maximum wet season discharge	607.10	712.40	668.60	17.3%	10.1%
NQwet	minimum wet season discharge	0.02	0.03	0.02	11.7%	-4.1%

Water levels

The water levels in the floodplain, especially the peak water level, decreased in scenario 2 some tens of centimetres while the water level increases even by 2 m in the scenario 3. These changes are due to the impact of climate scenario in Mekong mainstream water level. The water level in the floodplain is dominated by the water level in the Mekong mainstream as shown in Figure 29 where water level in the Mekong mainstream plotted against water level in TS Point3 situated in the floodplain.

“The water level in the floodplain is dominated by the water level in the Mekong mainstream

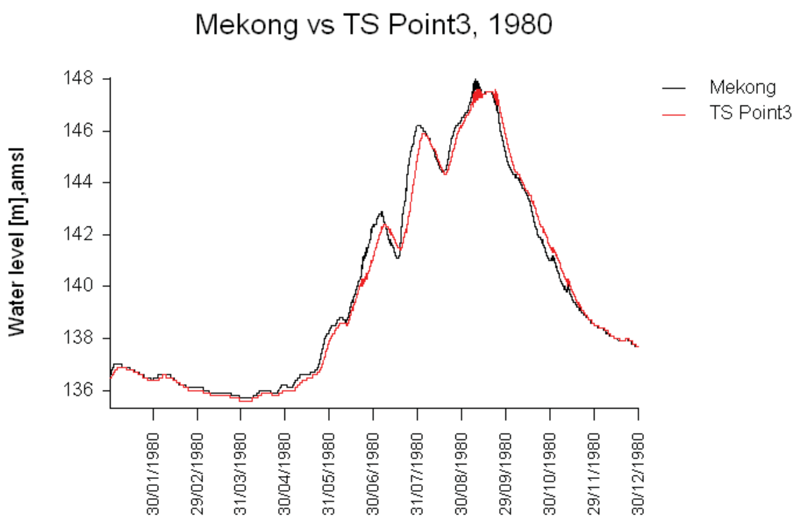

Figure 29. Water level in the Mekong mainstream plotted against water level in TS Point3 at the floodplain.

The impact of climate scenario on flooded area, flood duration and flood arrival time were also simulated during the project. The impact on flooding depends on the year, whether it is wet, average, or dry. The most significant changes in flood characteristics occurred during the wet year. However, the overall patterns of the changes were similar in all the years: the floods were smaller during the Scenario 2 and larger during the scenario 3.

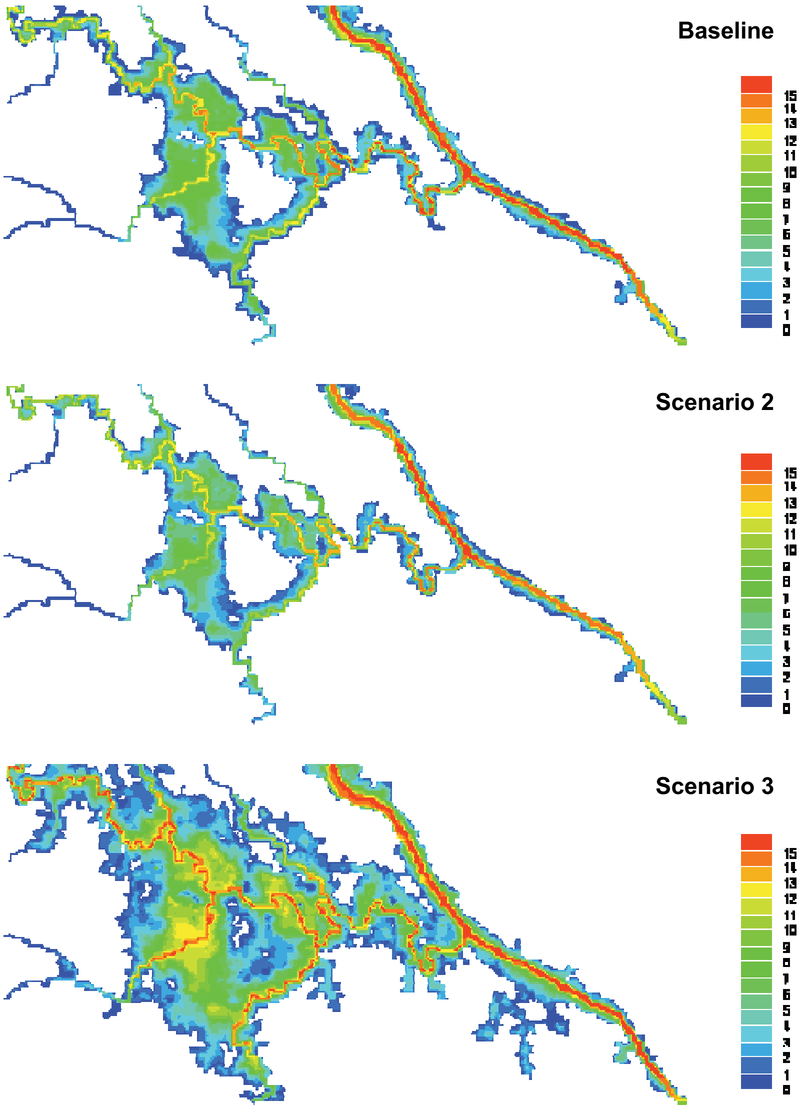

Figure 30. Maximum water level in the floodplain during year 1980. Scenario 1 (up), scenario 2 (middle), and scenario 3 (down).

Way forward in providing modelling support for Nam Songkhram IWRM/E-Flows work

Water-related development plans in Nam Songkhram basin have dealt with e.g. developing irrigation by utilizing reservoirs, and improving flood control using upstream reservoirs and regulator at the mouth of the Nam Songkhram. There seems to be a wide variety of opinions on what kind of developments would support the area's livelihoods and sustainability of its ecosystem, e.g. the floodplain and its fisheries. The modelling tools are essential to help analyzing the impacts of various development scenarios and give the necessary information for the planning work and stakeholder dialogue that has been progressing well.

There exists a good basis for continuing cooperation based on the work done within the Mekong Wetlands Biodiversity Programme, Thai Baan socio-economic studies, WUP-FIN models for basin hydrology and floodplain hydrodynamics. Scenario impact simulations done for local and basin wide developments (flood regulation, land use, climate change etc. in Nam Songkhram basin, main stream flow regimes impacts). Stakeholder cooperation and dialogue group has been established and functioning for successful realization of the E-Flows/IBFM case study. Cooperation covers a wide range of partners: TNMC, Thai national modelling team, provincial departments, IUCN, climate change group of Chulalongkorn University (START-project), MRCS/WUP, EP and FP, Khon Kaen University.

Te next proposed steps are to

- initiate water quality measurement programme in the tributaries and the floodplain
- continue scenario modelling on basin developments, flooding, irrigation and climate change scenarios with the BFM/E-flows/dialogue collaborators
- provide modelling support to analyze impacts of flow conditions on floodplain fisheries productivity (work on-going at Thai Department of Fisheries)

Main findings

- The water level in the floodplain is controlled by the water level in the Mekong mainstream.

  ➔ regulation of the Nam Songkram River and its tributaries has no effect on flooding in the Nam Songkhram floodplain

- Based on the simulations the flooded area, flood height, and flood duration, would increase in Scenario 3 but decrease in Scenario 2
- it is crucially important to understand the impact of climate scenarios on Mekong mainstream water levels in order to be able to predict the impacts of the climate change on the flooding in the Nam Songkhram floodplains
- The high productivity of the floodplains and rich fisheries in the Nam Songkhram floodplain is based on the flood pulse

Additional information:

Chinvanno, S. and Snidvongs, A. (eds.) 2005. The Study of Future Climate Changes Impact on Water Resource and Rain-fed Agriculture Production. Proceedings of the APN CAPaBLE CB-01 Synthesis Workshop, Vientiane, Lao PDR, 29 - 30 July 2004. SEA START RC Technical Report No. 13, 92 pp.

Kummu, M., Koponen, J., Veijalainen, N., Sarkkula, J. and Keskinen, M. 2006. Modelling Interconnected Mekong River and Nam Songkhram watershed system, Thailand. APHW Conference in Bangkok, October 2006.

MRCS/WUP-FIN, 2006. Technical Paper No.1 - EIA 3D model manual, WUP-FIN Phase II - Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR, 261 pp.

MRCS/WUP-FIN, 2006. Technical Paper No.2 - VMod hydrological model manual, WUP-FIN Phase II - Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment. Mekong River Commission and Finnish Environment Institute Consultancy Consortium, Vientiane, Lao PDR, 118 pp.

MWBP, 2005(?). Thai Baan Research on the Ecology and Local History of the Seasonally-Flooded Forest in the Lower Songkhram River Basin, IUCN and Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme (MWBP).

USAID, 2007. Impact of Climate Change on hydrology in Nam Songkhram, Thailand. Prepared for USAID by Finnish Environment Institute in collaboration with Environmental Impact Assessment Centre of Finland. The report is part of the USAID and IRG project on Climate Change Scenarios in the Lower Songkhram River Basin. 46 pages.

2.7 LIVELIHOODS IMPACTS

This chapter aims to provide a summary of the work carried out and results achieved by WUP-FIN socio-economic and policy analysis component. Although this kind of research theme is extremely broad and multifaceted, we hope that by presenting the summary in one single chapter we are able to show more easily the most relevant similarities –and differences– between the case studies, and also to draw conclusions on larger, basin-wide scale.

As the methods and results from the socio-economic analyses and policy analyses are already presented elsewhere, this research theme does not describe in detail the approaches used in the socio-economic and policy analyses and social impact assessment, neither does it present detailed results from those[10]. Rather, the aim of this theme is to summarise the lessons learnt related to livelihoods and governance in more overall terms. By doing this, we also aim to provide our insights and recommendations on social impact assessment (particularly in basin-wide level) as well as our thoughts about integration and interaction between different project components. The discussion on basin-wide social impact assessment is naturally closely linked to the analysis of broader social and economic trends in the basin (see next chapter).

2.7.1 Methods – socio-economic and policy analyses

The research theme on governance and livelihoods builds on two broad, interlinked approaches; WUP-FIN socio-economic analysis and WUP-FIN policy analysis. The latter is mainly based on so-called policy models and related expert consultations, while the methods used in the former range from participatory village surveys and interviews to literature reviews and socio-economic database analyses (for more information see e.g. MRCS/WUP-FIN, 2006). The idea in the WUP-FIN Project has been to apply these different kinds of methods flexibly in each case study area, based on their specific situation and needs. In some areas there was more urgent need for consultative village surveys (e.g. in Vientiane area), while in others for example socio-economic database analysis was needed to complement other existing information and/or to support the overall objectives of the project in that specific area (e.g. in Tonle Sap and Mekong Delta).

Overall, the socio-economic and policy analyses carried out within the WUP-FIN aimed to increase understanding of social, economic and political issues related to water resources and their management particularly in the local level, and to use this increased understanding to support other project components (most importantly modelling) as well as to facilitate social impact assessment both locally and more broadly in basin-wide scale. As both analyses build on participatory research methods, their aim was also to compare –and contest– our interpretations related to water resources and their management with those of other actors and stakeholders, particularly from the local level.

> **“Socio-economic and policy analyses improved our understanding of social, economic and political aspects of water and its management**

When compared to most of the other approaches used for social impact assessment within the MRC, the WUP-FIN approach can be seen to be more practically and locally orientated. While the socio-economic and policy analyses aimed ultimately to address

[10] For more information on those, see e.g. the list of WUP-FIN2 socio-economic reports in the third page of this report as well as the references mentioned in this chapter.

also regional, basin-wide challenges, this was done by studying first the challenges in the local level, and then putting them into larger, regional context. Thus, instead of applying same thematic analysis and impact assessment approach to all case study areas, we aimed to apply different, tailor-made approaches to each of the study areas, based on local needs. The results from these analyses were then used –under common framework and together with broader basin-wide analysis– to facilitate basin-wide impact assessment.

2.7.2 *Major findings*

There would naturally be a diverse set of different kinds of findings and recommendations to be presented from the topic as broad as livelihoods impacts[11]. In this chapter, however, we want to summarise only few main findings that, we believe, are of great importance in local, national and regional level[12]. The findings presented are hopefully also beneficial for other similar kind of processes within the MRC, such as IBFM and BDP. To make the findings more concrete and practical, we also give examples from case study areas related to different findings[13].

In order to make the findings easier to understand, we have grouped them under two broad and interlinked headings: one on findings related to methodological issues, and the other on the actual 'substance' of the research theme on livelihoods impacts. Consequently, following eight key findings are presented in this chapter:

FINDINGS RELATED TO METHODOLOGY:

- Socio-economic and policy analyses can contribute significantly for the modelling and impact assessment, making it more focused and balanced
- Applying multiple methods for socio-economic analysis in multiple levels is needed to overcome the weaknesses of individual research methods
- Estimating the actual value of resource use and its contribution to people's well-being is challenging – and currently most probably underestimated
- Cooperation and dialogue with other actors provides clear benefits for analysis and impact assessment process

FINDINGS RELATED TO LIVELIHOODS IMPACTS:

- Livelihoods and governance contexts are extremely diverse both within and between case study areas
- The poorest groups are deeply dependent on aquatic resources, and are therefore particularly vulnerable to the changes in river flow and availability of aquatic resources
- Already existing small-scale utilisation of Mekong's resources forms more sustainable basis for water management aiming at poverty reduction – and should be used as starting point for discussion about trade-offs

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[11] For specific findings in different case study areas, please refer to the specific socio-economic reports listed in the third page of this report + the references given in this chapter.

[12] Summarising the findings from socio-economic and policy analyses work carried out in five different case study areas is naturally not an easy task, and requires inevitably some generalisations. We would like to emphasise, however, that these findings are result of discussions within the WUP-FIN Team and counterparts and we believe that they therefore truly summarise in a concise but yet not over-simplifying way the key findings of our work.

[13] Many of the examples are from the Tonle Sap as we have longest and broadest experience from there, and the area also represents a particularly important and vulnerable area within the Mekong Basin.

- Balanced water management requires better understanding of governance context –including access to and control over water-related resources– as well as recognition of highly political nature of water management

Socio-economic and policy analyses contributing for impact assessment

The WUP-FIN socio-economic analyses and policy analyses were used to gain better understanding of the interconnections between water resources and social and economic issues as well as of broader institutional and political context. At the same time it also enabled the project to address the multi- and inter-disciplinary needs set by the Mekong Agreement and Integrated Water Resources Management (IWRM).

The socio-economic analysis consisted of two main phases: analysis phase, and assessment phase. The former was carried out in the beginning of the project work, and it aimed to analyse the most important water-related social and economic issues in the study area as well as to enhance the participation of and linkages to local level. The assessment phase was implemented at the latter half of the project, and it aimed to link the model results with results of socio-economic and policy analyses, and therefore to assist the actual social impact assessment. Results from the policy analysis also contributed for this latter phase.

> “ **Socio-economic analysis helps to frame and focus the modelling work**

The experiences from different WUP-FIN case study areas indicate that the results from socio-economic analysis can contribute significantly for framing the modelling and impact assessment work. For example, in the Tonle Sap, the findings of socio-economic analysis –highlighting the poorest groups' dependency on fish and other aquatic resources– helped to focus the project work on the lake's aquatic production and its possible changes. Based on the challenges we faced in linking the different disciplines or themes (and consequently project components) together, we want to highlight the importance of common agreement on continuous interaction and discussion between different components, starting already from the formulation of the research questions and establishing the project approach[14].

Applying multiple methods to overcome the weaknesses in individual methods

Based on our experiences from the case study areas[15], we see that a successful socio-economic analysis requires an approach that analyses the situation at different levels and with a set of different methods that complement each other; relying only on one method is not enough to provide a proper picture about the diverse social, economic and political reality in the study areas.

> “ **Socio-economic databases are often too static to capture the real changes happening on the ground**

While our experience shows that socio-economic databases and statistics can provide a relatively sound baseline for the current socio-economic situation in the area, it is also clear that the picture painted by the databases is often overly simplified and presents far too homogenous image of the reality. The databases proved also to be too static to be able to really capture the changes happening on the ground, and sometimes the data derived from the statistics can even be completely misleading[16]. Consequently, the participatory village surveys carried out in the local level complemented –and contradicted– the information provided by the

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[14] Something as simple as regular team meetings and internal newsletter on the proceedings of project work can assist this interaction remarkably.

[15] Particularly from the Tonle Sap and the Mekong Delta where both participatory village surveys and database analysis were applied.

[16] For more information on this, see Keskinen, 2003; MRCS/WUP-FIN, 2006d; and Käkönen, 2007.

databases and statistics and improved enormously the understanding of local level dynamics and complexities.

Couple of examples: The comparison of the results from databases analysis and villager surveys in the Tonle Sap revealed that the socio-economic databases are not presenting correctly the seasonal migration in the study area; e.g. Population Census 1998 considers many seasonal migrants as permanent inhabitants in floating villages, and as a result provides biased distribution of livelihood sources in those villages, with agricultural activities being over-presented (Keskinen, 2003). With the help of village surveys and literature review, we were able to notice and overcome this bias. In the Mekong Delta of Vietnam, on the other hand, the key-informant interviews and village surveys in lower administrative levels (commune and hamlet) indicated that water quality was among the main concerns for local people, showing clear differences to the higher level discussion about the major water-related challenges in the delta (MRCS/WUP-FIN, 2006d; Käkönen, 2008).

Challenge of estimating the real value of resource use

This key finding addresses the challenge in measuring the poverty and the value of resources in the diverse conditions such as those present in the Mekong Basin[17]. The findings from our case studies in Tonle Sap and Nam Songkhram indicate that both of these areas are simultaneously considered to be poor in monetary terms but rich in natural resources, with local people relying on a variety of different natural resources that are providing both food and income (although not necessarily in cash)[18]. This kind of contradiction raises questions about the validity of current poverty measures, and suggests that macro-economic analyses measuring the poverty in pure monetary terms are not able to measure properly the wide and diverse use of natural resources. We believe that these kinds of problems have most likely lead to underestimation of the real values of different natural resources for the people living in the case study areas, and indeed in entire Mekong Basin[19].

> “ **Macro-economic analyses are often not able to measure the real value of wide and diverse use of natural resources**

Consequently, the close linkage between the viability of river ecosystem and people's livelihoods seems usually not to be taken properly into account in regional level social and –particularly– economic analyses. While everyone agrees that the health of the river ecosystem feeds directly back as welfare of basin's inhabitants (particularly to those among the poorest sections of society), the importance of maintaining the river ecosystems –and consequently the diverse set of resources and services they provide for people– seems still not to be appropriately considered in the discussion about the development in the basin. Hence, we think that there is an urgent need for new methods looking more comprehensively the different ways of utilising the water-related resources and estimating their actual value (also other than monetary) for the local people. The framework suggested for social assessment of IBFM Phase 3 for looking at resource dependency, use and value through combination of quantitative and qualitative studies offers one promising example on this kind of methods (MRCS/IBFM, 2006).

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[17] The finding is therefore closely linked to the next chapter on poverty reduction and economic growth, and also similar to the conclusions of the MRC's IBFM Social Assessment Team (WUP-FIN socio-economist was part of the team in 2006). For more information on IBFM Social Assessment, see MRCS/IBFM 2006.

[18] For example during the dialogue process in Nam Songkhram it became clear that the area's wetlands are considered to be the 'nature's supermarket' where you need no money to 'shop' the large variety of different resources they provide.

[19] See also section below on small-scale utilisation of Mekong's resources as well as next chapter on the dilemma of poverty reduction and economic growth.

The benefits of cooperation and dialogue

All our case studies demonstrated that an analysis of water-related livelihoods and/or water governance is a time- and resource-consuming task. Yet at the same time there is a variety of actors that are working and/or doing research on same themes, often with far better understanding of the local context and firmer linkages to different actors in different levels. Consequently, one major finding from the case studies is related to the obvious benefits that cooperation and dialogue can bring to analysis and impact assessment work.

Our experience shows that while cooperation and dialogue with different actors naturally requires time and resources –and naturally also information sharing and transparency in our approaches–, its benefits clearly outweigh the efforts used in it. The cooperation related to socio-economic and policy analyses has helped us to frame the research questions and methods, to analyse the survey results and has also resulted in fewer overlaps and formation of new research collaborations.

> “Cooperation and dialogue with a variety of actors have improved significantly the quality of our work

The cooperation has naturally taken different forms: for example in the Tonle Sap the collaboration with WUP-FIN counterparts from different ministries and provincial line agencies was fundamental for both socio-economic database analysis and participatory village surveys. In addition, consultations with a variety of different experts were the key for the formulation of WUP-FIN Policy Model for the Tonle Sap. At the same time, the publication of research findings –in different forms and in both English and Khmer– resulted in feedback that helped to improve the understanding of the issues in the local level. In Nam Songkhram, on the other hand, the entire socio-economic analysis was after series of meetings with different actors decided to be based on the work carried out Mekong Wetlands Biodiversity Programme plus provincial actors and universities, thus avoiding overlaps and allowing WUP-FIN Project to focus on modelling work to form the basis for joint impact assessment and scenario work.

Diversity of livelihoods and governance contexts

The comparison of findings from different case study areas emphasise the diversity of water-related livelihoods and the broader governance contexts both between and within different study areas (and between and within the countries). Consequently, in this first key finding on ‘substance’ of the research theme, we see that detailed understanding of local level and its realities is an absolute prerequisite for successful analysis and impact assessment in higher levels. Even though this sounds almost too obvious, in reality the two –regional and local analyses– seem usually to be far too apart from each other, and analyses and assessments usually focus either on local or on regional level, not both.

Following examples shed light on the diversity between as well as within the study areas. While the findings from the Cambodian floodplains[20] emphasised people’s adaptation to annual flood pulse, the importance of understanding the diverse interconnection between livelihoods, water and related resources as well as challenges with the governance of those resources, the findings from the Mekong Delta of Vietnam[21] –just few dozens of kilometres downstream– were related to very different kinds of issues, such as on high level of control over water resources, increasing water quality problems as well as relatively rapid changes in livelihoods sources. In the Vientiane-Nong Khai Area, on the other hand, there seem to be clear differences

[20] For more information, see MRCS/WUP-FIN 2006b & 2006c

[21] For more information, see MRCS/WUP-FIN 2006d

between the two countries (Laos and Thailand) on their preparedness to address bank erosion issues as well as to provide alternative livelihood sources in cases where original livelihood sources were threatened[22]. Finally, the results from the Tonle Sap Area[23], one of the study areas, showed the diversity of different livelihood sources within the study area, and also indicated apparent differences in the management of different natural resources that those livelihood sources are dependent on (Keskinen, 2003; Keskinen et al. 2007b).

The poor's dependency on aquatic resources

The findings from our case study areas indicate that the poorest villagers[24] are commonly most directly dependent on water-related natural resources –particularly so-called open access resources, particularly fish[25]– for their livelihoods, and have usually also fewer alternative livelihood sources. At the same time the poorest have usually less capabilities and resources to adapt and make use of the changes that take place in the availability of these resources due to changes in water flows following e.g. irrigation development or dam construction (be it local or regional). Thus, those who are better-off tend also to benefit more, or at least more easily, from the changes occurring due water resources development. This, in turn, is likely to lead to growing disparities between villagers: while those who are better off are likely to gain, those who are already poorer will lose.

" **The poorest are most dependent on water-related resources, particularly fish**

This kind of finding was particularly evident from the results of the participatory village surveys in the Tonle Sap Area (see MRCS/WUP-FIN 2003, Keskinen 2006) that concluded that the people living in the villages closest to the lake were in many ways most vulnerable to the changes in the natural resources. In addition, there seemed to emerge clear differences within the villages between the poor's and the better-off's capabilities to respond to the changes in natural resources[26]. Similar kind of findings were apparent also in the Cambodian floodplains (MRCS/WUP-FIN 2006b; 2006c), in Nam Songkhram (MWBP, 2005; MRCS/WUP-FIN, 2007) as well as in the Mekong Delta where livelihoods development seems not to take properly account the poor's dependence on so-called open access resources such as wild capture fisheries (MRCS/WUP-FIN 2006d).

[22] This finding is naturally closely linked with the broader governance context and also supported by the results of IBFM Phase 3 Social Assessment (MRCS/IBFM, 2006)

[23] For more information, see MRCS/WUP-FIN 2005 & Keskinen, 2006.

[24] Landless people in particular.

[25] In reality these so-called "open access resources" such as fish are often under different kinds of informal management agreements.

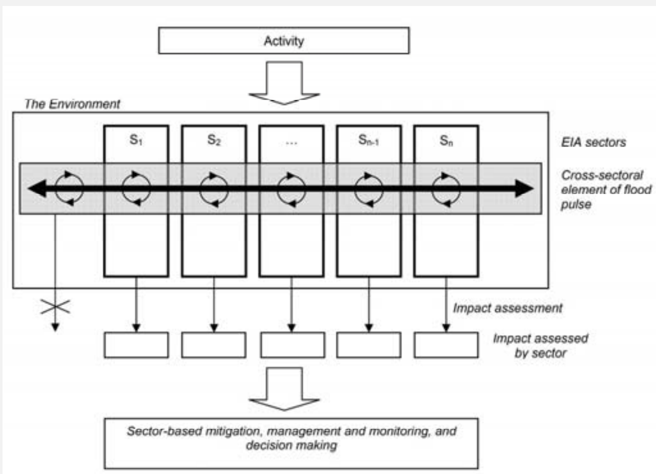
[26] This conclusion is also supported by the findings of ADB-supported Built Structures Project (CNMC & World Fish Center 2007).

Major governance issues concerning floodplain ecosystems

Floodplains are integral elements of river and lake ecosystems. Most of the floodplains in the Mekong Region experience a natural pattern of regular flooding, or a flood pulse. The ecological paradigm of flood pulse refers not only to the hydrological event of flooding, but to all associated processes of exchange between the terrestrial and aquatic elements of the ecosystem, effectively and inseparably integrating them. Flood-pulsed systems are highly productive and rich in biodiversity, and form typically the rich foundation for local livelihoods.

Flood-pulsed systems are very resilient to natural inter-annual variation in the floods. In fact, this variation is a key driver of their productivity and biodiversity development. At the same time, they are highly vulnerable to man-made alterations to the flood pulse as the result of changes made in the flow in the main water body. Such changes are usually the result of development activities and affect those characteristics of the flood pulse that are the most important in determining ecosystem productivity. They also affect the natural productivity assets of the ecosystem such as flooded forest or sediment inflow.

There are three major issues that are specific for floodplain ecosystems governance in the Mekong Basin. First, floodplains and flood pulse and their importance are generally unknown or ignored, leading to the belief that they can be excluded from water resources management decision-making. Second issue is related to the assessment of the impact of flood pulse alterations. Currently used best-practice impact assessment approaches are flawed and not suited to the evaluation of the impacts of flow alterations on the flood pulse and its processes. This leads to an underestimation of the consequences and the belief that its loss can be mitigated and replaced by aquaculture or agriculture. Finally, research and dissemination of new knowledge need improving to better inform the water resources management process.



Small-scale utilisation of Mekong's resources offering sustainable basis for poverty reduction – and for discussion about trade-offs

As discussed above, we believe that many of the current economic assessments in the Mekong Basin are underestimating the actual value of natural resources for the local people. Following from this, although Mekong is –through subsistence fishing, farming, use of wetland and floodplain resources etc.– already utilised in a variety of ways at the local level, the common justification for water development is the "underutilisation" and "underdevelopment" of the basin's resources. Consequently, most future development options in the basin are focusing on the development of modern sectors such as irrigated agriculture, while a majority the population in the basin actually depends on more traditional livelihood sources (Keskinen et al. 2007a; MRCS/IBFM, 2006). As noted by Phillips et al. (2006):

> *"The key development paradox of the region is that economic growth is necessary to bring many of the populations out of poverty, but the 'classical' route involving the subsidised construction of massive infrastructure is most unlikely to provide the optimal result in this respect for the poorer sections of the populations".*

Indeed, based on the findings from the WUP-FIN case studies as well literature review, we see that 'classical', large-scale development interventions such as irrigation and hydropower projects are –despite their objectives on poverty reduction– often actually undermining the foundations of the livelihoods of the poorest groups by impacting negatively the availability of and access to common pool resources, most importantly fish.

Consequently, we see that the management and development of Mekong's water resources –if aiming on poverty reduction– should be based much more on already existing, "decentralised" utilisation of the Mekong's resources taking place at the subsistence level. In addition to the actual value of this decentralised utilisation, also its distributional benefits should be considered: compared e.g. to the distribution of the benefits from hydropower dams, the subsistence use allows usually more equal distribution of the benefits derived from the Mekong's resources, reaching more easily also the poorest[27]. Hence, if for example development of hydropower dam and sustaining river fisheries would offer approximately the same monetary value, we see that in terms of poverty reduction fisheries provides clearly more favourable basis due to its more equal –and already existing– distribution of benefits.

> **"Large-scale infrastructure projects are often undermining the foundations of the livelihoods of the poorest**

It is important to emphasise that this findings does not mean that infrastructure should not be build, as it is definitely needed for countries' economic development. What we are highlighting, however, is that in terms of poverty reduction, we believe that much more emphasis should be put on sustaining and developing existing subsistence livelihoods sources, rather than trying to replace them with more modern approaches. Related to this, we see that construction of small-scale infrastructure offers more sustainable option where the risks of unintended impacts is less, the involvement of local people is more fluent, and distribution of benefits –and costs– from the project is easier than in larger-scale projects. This finding is also supported e.g. by the results from the ADB-funded Built Structures Project for the Tonle Sap Lake (CNMC & World Fish Center, 2007).

We also believe that the recognition of the actual value of the traditional livelihood sources and their distributional benefits leads to more balanced discussion about the possible trade-offs required in developing the Mekong's resources. Indeed, when

[27] As is discussed in the later chapters, distribution of the benefits from different resources (such as fish) is naturally not without problems, either; particularly the poorest groups have often problems getting equal access to these resources.

considering the huge amount of different plans for Mekong's development, it is extremely worrying to notice a complete absence of well-informed and transparent discussion about the different trade-offs that are unavoidably required –both within and between the riparian countries– due to changes caused by water development. We see that there is an urgent need to acknowledge that development requires trade-offs, and that the discussion about trade-offs is always highly political. Related to this we believe that achieving best possible compromises on different trade-offs requires open discussion, access to relevant information to all concerned parties as well as research that is focused on those themes –such as subsistence fisheries– that are likely to see most radical changes.

Importance of governance contexts and political structures

Our last key finding is related to the importance of broader governance context – including formal and informal power structures– related to water and natural resource use. Based on the findings from our case studies, we have concluded that governance context matters much more than what is usually recognised in technically-orientated projects such as WUP-FIN. Yet, only through thorough understanding of broader governance context of water and related resources we are able to properly address the different aspects of water management – and to place the changes in physical availability of water and related resources in their actual context.

An example supporting this finding can be found from the Tonle Sap Area, where the case studies and reviewed literature indicate that the governance context of resource use and access seem often to be at least as important factors as the physical availability of the resource in contributing for (or limiting) people's livelihoods[28]. Thus, when discussing about the people's livelihoods and their trends, the discussion should not be only about the availability of water and related resources, but also about the access to and control over these resources. The broader governance context is naturally highly country- and even area-specific, and also varies between the different resources; for example governance structures related to fishing are likely to be very different to those of agricultural land.

This finding also emphasises the highly political nature of water management and development –particularly in transboundary contexts such as Mekong– that seems often to be forgotten and/or ignored in technically-orientated water projects and processes such as WUP-FIN[29]. However, for linking the research in a meaningful way to decision-making processes, we see that it is important to acknowledge the political nature of water development. This includes being also prepared to the possible implications it may have, such as differing views on the research results and even potential conflicts in their interpretation. In larger, basin-wide impact assessment processes we see that this preparedness should also mean some kind of capacity for conflict resolution.

> **“Water management and related impact assessment processes are highly political**

[28] For more information, see e.g. Keskinen, 2003; CNMC & World Fish Center, 2007; Keskinen et al., 2007b.

[29] Conventional technical water projects can actually be seen to depoliticise the water development as they look water resources just as quantities and numbers, detaching water from its social and cultural context.

Main findings

Based on the work carried out by WUP-FIN socio-economic and policy analysis components, this chapter highlighted eight key findings related to livelihoods impacts:

FINDINGS RELATED TO METHODOLOGY:

- Socio-economic and policy analyses can contribute significantly for the modelling and impact assessment, making it more focused and balanced
- Applying multiple methods for socio-economic analysis in multiple levels is needed to overcome the weaknesses of individual research methods
- Estimating the actual value of resource use and its contribution to people's well-being is challenging – and currently most probably underestimated
- Cooperation and dialogue with other actors provides clear benefits for analysis and impact assessment process

FINDINGS RELATED TO LIVELIHOODS IMPACTS:

- Livelihoods and governance contexts are extremely diverse both within and between case study areas
- The poorest groups are deeply dependent on aquatic resources, and are therefore particularly vulnerable to the changes in river flow and availability of aquatic resources
- Already existing small-scale utilisation of Mekong's resources forms more sustainable basis for water management aiming at poverty reduction – and should be used as starting point for discussion about trade-offs
- Balanced water management requires better understanding of governance context –including access to and control over water-related resources– as well as recognition of highly political nature of water management

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2.8 THE DILEMMA OF POVERTY REDUCTION AND ECONOMIC DEVELOPMENT

Should the water resources policy of the Lower Mekong River basin have its priority in environmental conservation, in maximizing economic growth, or in reducing poverty as much as possible? The needs are huge in all of these aspects. Cautious scrutiny and compromise-building is needed, because these three inter-linked facets of development very easily collide in conditions such as those of the Mekong Basin.

This research theme draws together selected conclusions related the basin-wide socio-economic development, with focus on the dilemma of poverty reduction and economic growth. We scrutinise the relation between economic growth and poverty reduction in the Mekong context, by elaborating different concepts and definitions of poverty and comparing them to the conditions in the Mekong countries.

The chapter is thus closely related to the previous chapter on livelihoods impacts, and also builds on the same methods, namely socio-economic analysis and policy analysis with specific focus on basin-wide policy analysis. At the same time it must be noted that the structure of this chapter differs somewhat from those of other research themes, with more focus on thematic background and findings.

2.8.1 Poverty and wealth

In macroeconomics, the basic ground to allow poverty alleviation is economic growth. Without growth, there is not more to distribute to the poor than before. Whereas this is basically right, it tells only a part of the story. In too many low-income countries, the growth of the Gross National Income (GNI) means widening income gap and polarization of the society as well as uprooting of uneducated people to urban shantytowns.

Poverty reduction has found its way onto almost all national and international political development agendas, including the key agendas related to the development of the Lower Mekong Basin (cf. Rowcroft & Ward, 2005). Roughly one-fifth of mankind is typically classified as being poor. But what actually is meant by poverty? Intuitively, within a familiar context to an individual, the concept of poverty should not be very unclear. In reality, however, the issue is far more many-sided and complicated. Accordingly, the contemporary poverty-related literature is rich –and highly inconsistent– in approaches to its analysis, alleviation, and definition. The concept varies across scientific disciplines as well as cultures, and has changed markedly over time (Nafziger, 1997; Maxwell, 1999).

> **“The definition of poverty is far more many-sided and complicated than what is usually thought of**

Is wealth relative or absolute? Are some groups of people rich because some others are poor? At least the former ones have much power over the latter ones. As the question of poverty is very difficult and many-sided, the answer is not as easy as the somewhat provocative statement above. It is true partly, but poverty has definitely a dimension, which is more absolute, related to the capability of an individual or community to meet their basic personal needs, and to make their life better.

There is not a single country, where all people are equally wealthy. There have been several attempts to reach such a society, but so far all failed. The uneven wealth distribution is a reality everywhere, both inside and among countries. One generation ago, the richest 20% of the mankind were around 30 times richer than the poorest 20%, but now they are over 50 times richer (World Bank, 2003). This fact has many reasons, which raise fundamental moral questions, particularly at the global level.

In many Asian countries, the celebrated Kuznets (1955; 1963) theory seems to be valid. It says that the income disparities grow with economic development, until a middle-income level is reached, and decreases thereafter (Figure 31). The Mekong basin countries have a wider gap between the rich and the poor, but not as wide as in many other Southeast Asian countries. Cambodia's inequality is somewhat higher than in the other countries within a comparable GNI level. If the theory of Kuznets will be correct in Southeast Asia case in coming decades, there is a considerable risk that the social inequalities will grow in countries such as Laos, Cambodia and Vietnam.

Cornia et al. (2005) analysed the development of inequality in 73 nations throughout the world and concluded that in two-thirds of the nations, inequalities are growing, and going down in only one out of six countries. As a positive result of this analysis it is possible to conclude that given the stable and strong economic progress in China, South Asia and Southeast Asia, and the fairly modestly growing inequalities, these regions have a reasonable capacity to reduce their poverty. They are in this respect perhaps better off than almost all other developing parts of the world.

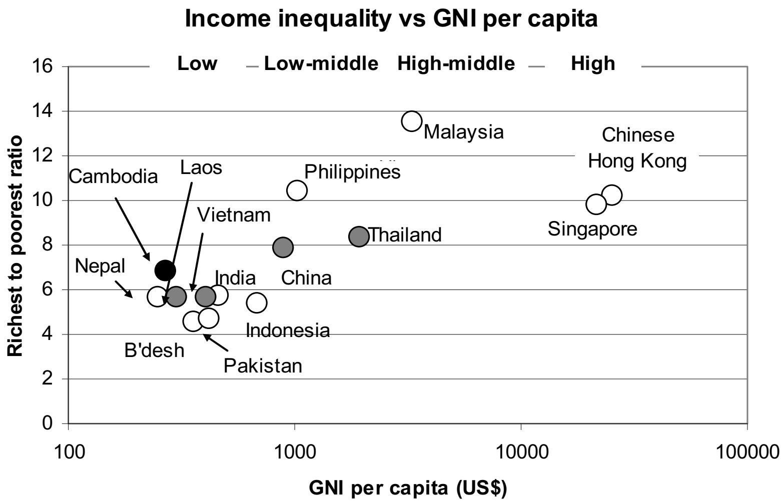

Figure 31. Richest to poorest ratios: Ratios of the income levels of the richest 20% and the poorest 20% in selected Asian countries. These ratios are also related to the GNI per capita. Source: World Bank (2003).

In economic terms, the practical prerequisite to poverty alleviation is economic growth (Figure 31). Without growth, there is not more to distribute to the poor than before. The hot perennial theme for discussion is the dilemma between economic growth and income distribution within an economy.

The liberalistic "trickle-down" argument postulates that economic growth is the most efficient way to reduce poverty since the increasing wealth trickles down through the whole society and benefits also the poor. Redistribution of wealth and income distorts the economy and growth declines. Growth is typically assumed to be distribution-neutral, meaning that growth benefits all equally.

The others claim that this is a far too slow approach to poverty eradication. This view has a strong support from the Kuznets theory and innumerable other empirical analyses since (cf. Figure 31 and Figure 32). Wealth and income should be redistributed to the poorer echelons of the society for many reasons. Political, social, and economic stability are increased, fertility rate tends to go down along with better schooling possibilities and other social conditions that follow from redistributive policies.

The Mekong Region has seen a sharp split between communist, centrally planned societies and market oriented economies in the past few decades. Thailand has followed the latter one while the other countries have had at least periods in which the former one has been dominant. China has loosened its communist policies already at the early 1980s with Deng Xiaoping's famous policy that "allowed people to become rich". In Cambodia, the end of the communist era came in early 1990s with the re-establishment of the Kingdom of Cambodia. Vietnam's Doi Moi policy has been somewhat equivalent to the Chinese approach, but it was initiated one decade later. In Vietnam, the recent times have witnessed a strong liberalisation of markets and the private sector. At the same time, the social services have not totally been able to keep in tact with the economic development, and the income gaps have been growing steadily. Yet, the rapid economic development, particularly in Thailand, Vietnam and China has allowed the rapid reduction of income poverty (e.g. World Bank, 2004; Rowcroft & Ward, 2005).

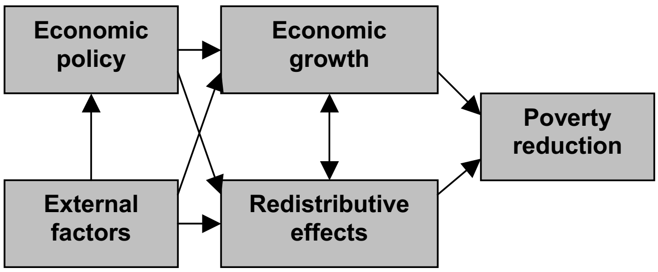

Figure 32. Macroeconomic view to poverty reduction: Macroeconomists emphasize economic growth and redistributive effects in poverty reduction, but tend to forget the crucial role people's local activities and empowerment.

Redistributive policies were taken as self-evident in the west over decades, yet the boom of liberalistic thoughts in the 1990s, and particularly in the early 2000s, has vitalized the myth of income and wealth distribution neutral growth (cf. Cornia, 2005; Shorrocks & van der Hoeven, 2005).

Many are convinced that too high economic disparities within a country are harmful to development, both in social and economic terms. Equally, many arguments against too even wealth distribution appear convincing. The latter ones say that some level of disparity is necessary for rational economic behaviour, and accelerates thus economic development.

Accordingly, it seems that there is a place for finding a compromise between too low and too high disparities in order to create a good economic growth environment so that the process of growth would benefit the whole society and stabilize the economy and political system. These both legs are necessary for sustainable economic growth and, consecutively, to poverty alleviation that has possibilities to sustain in the long term.

There are various means to redistribute wealth (cf. Dagdeviren et al., 2005). It is important to note that for the poorest countries almost all what remains possible is to invest in education and health of the population as well as on governance. Infrastructure and public works construction are usually considered as another major possibility for improving the livelihood of the poor.

2.8.2 Poverty: definitions

Since poverty has both an absolute and a relative dimension, its definitions include both these concepts. Another axis to the diverging definitions comes from the tradition of economics as science: the split to macro and micro oriented views and weightings is evident in many analytical approaches and definitions throughout economics.

Many development agencies are in favour of using income indices such as one or two dollars a day. If an individual has a daily income less than such a threshold, he is classified as poor. The power and – at the same time – the weakness of this indicator is its extreme simplicity. It is a straightforward tool in comparative studies, but provides only very limited information about the individual's ability and preferences to access the basic goods and needs. Varis (2008) provides a comprehensive summary of commonly used poverty indicators and analyses their suitability within the context of the Lower Mekong Basin. He concludes that the most suitable approach is the approach of Amartya Sen, Nobel Laureate of Economics of 1998. Sen has extensively studied the interconnections of welfare, poverty and famines. He has developed approaches to study the poverty question with a higher resolution than frequently used poverty indices. His concept of poverty (Sen, 2000) is:

> *"There are good reasons for seeing poverty as a deprivation of basic capabilities, rather than merely as low income. Deprivation of elementary capabilities can be reflected in premature mortality (especially of children), persistent morbidity, widespread illiteracy and other failures."*

Deprivation leads typically to social exclusion and marginalization. Such groups are particularly weak in finding themselves out of poverty by "self-help", and economic growth does not trickle down to these people.

In the water sector, we also need far more elaborate and tailored analytical tools than what exist today in order to tackle with policies related to poverty reduction. The poverty issue should be encompassed more profoundly than is done in most contemporary analyses that tend to equate economic growth to poverty reduction. The policy analyses based on so-called WUP-FIN Policy Models and developed for the Tonle Sap Area and the Mekong Delta of Vietnam offer one possible approach for this kind of more profound analysis[30]. In addition, some additional aspects to consider specifically in the Mekong Region were discussed above (see previous chapter on livelihoods and governance).

> **"We need far more elaborated analytical tools to study the policies related to poverty reduction**

2.8.3 Poverty, traditional and modern sectors, and the environment

Poverty is a part of many facets of the society, including:

Informal and formal institutions. Social exclusion due to poverty leads easily to erosion of the loyalty of individuals to formal institutions. The results are the more negative the less the person respects the "positive", informal institutions such as good habits, traditions, culture, religions, etc. Then, an individual easily loses the feeling of ownership to development efforts within a community and society. Poverty is strongly associated with the informal sector, although some people are getting fairly rich in the informal sector. Rapid changes in a society such as wars, massive urbanization, environmental changes, etc., tend to uproot people from traditions without providing them a proper new institutional "home". This leads easily to marginalization and poverty.

[30] For more information see e.g. Varis (1998; 2003), Keskinen & Varis (2004), Varis & Keskinen (2006) and MRCS/WUP-FIN 2006d.

Population growth and poverty are closely interlinked in both directions. The fertility of the poor tends to be far above the average within a country. Also if population grows very fast, the poverty problem is at high risk of worsening (see e.g. Keskinen, 2008).

Urbanization. If urban poverty rates are much lower than rural ones, cities—their informal sectors in particular—are prone to grow faster than in the opposite situation.

Gender, education and health. The poverty and low status of women are the key components in the multigenerational vicious circle of fertility, gender, poverty, and education. Most of the poor are illiterate. Poverty is also an empowerment-related issue.

Ethnic issues. Poverty is often very unevenly distributed among different ethnic groups within a country. 40% of the world's countries have more than five sizable ethnic populations, one or more of which suffers from severe economic, social, and political discrimination.

Environment. Poverty has been recognized widely as an important factor in the degradation of the nature and the environment. The share of the poor in causing water quality problems, uncontrolled deforestation, etc., is grand in the global scale, and investing to poverty reduction is an important policy measure in working against degradation of natural resources and the environment.

An important but largely neglected distinction must be made between people who live in more or less traditional manner, often on subsistence farming; fishery etc. and such marginalized people as the landless and urban slum dwellers even though economic indicators (such as $1-2 a day) make not much difference between them.

In the case of the Mekong Basin, it is striking indeed to realize how strong the contrasts are between the traditional livelihoods relying mainly on subsistence livelihood activities and the emerging modern economic sector that most development projects tend to focus on. Table below summarises some of the key features of these two sectors.

Table 6. Subsistence and modern sectors: some basic attributes.

Subsistence (traditional sector)	Modern sector
Uses no or very little money	Is driven by money
People supply themselves with basic commodities such as food, water and fuelwood	Nature is used as a resource of tradable goods that are primarily valued after their trade value
Institutions are primarily customary and religious	Institutions are primarily set up by government
People are living within the nature	People are using nature as a resource base and are living out of the nature
Example activities: family farms/fishery/forestry for village-level supply	Example activities: cash-crop farming, commercial fishery, fish farming, industry, hydropower generation, urban water supply plants

The subsistence sector is often called traditional sector. However, even when we use this term, we also include in it the urban informal sector that includes illegal dwellers, shantytown inhabitants and so forth, who in a way are living at the borders of the formal economy on subsistence level.

In many cases, the expansion of modern sector has introduced massive changes to more traditional livelihoods. Related to this the challenge is how to ensure that the increased aspirations for modern sector do not lead to marginalization and exclusion of the people from more traditional sectors. In Sen's (2000) philosophy, the local economic activities should be developed so as to allow the people the control and ownership over the productive resources and the local markets as well as other institutions should function well. These local markets should be connected to the urban markets so that the growing urban wealth would benefit rural population.

"How to ensure that the expansion of modern sector does not lead to marginalisation?

In Cambodia, for instance, there is still a long way to go to reach such a situation. The country has violent recent history, its economy is still exceptionally dependent on foreign aid[31] and rural land tenure and other governance systems remain unclear and discontinuous. Although the economy has been growing, also the disparities are increasing, particularly between rural and urban areas.

In term of Tonle Sap and its management, natural reserves are one way to conserve lake ecosystems and the nature of the lake basin as a whole. In this context, an interesting question arises on the relation of traditional sector and natural reserves: Should we see the traditional sector as a part of the ecosystem to be conserved? Do we encounter human rights questions? How should we handle the poverty reduction issue in such situations?

If conservation efforts hinder economic activities of the local population, the counter-effect may be the erosion of loyalty of those and related groups and subsequent expansion of illegal exploitation activities, at least in cases in which the governance system is weak as for instance in Cambodia. The contrast between economic development and environmental degradation tends to be seen very one-sidedly; it is too often disregarded that the negative impact of social deprivation on environment is a massive problem in most parts of the world (see e.g. Palo & Mery, 1996), and it can be tackled by social and economic policies rather than solely with environmental policies.

2.8.4 Conclusions

Poverty reduction is one of the key development goals within the Lower Mekong Basin. In economic terms, poverty is most often measured with an income indicator such as $1 a day: people below such an income level are classified as poor and those above it are not considered as poor. It is astonishing how widely this concept is still being used by leading aid agencies despite of its well-recognised problems as well as the affluence of more elaborate alternatives, one of which was discussed in this chapter.

An income indicator applies well to people within the modern sector but not at all to people who are living in the traditional sector (Table 6). Such an indicator may give an increased income value to an absolutely impoverished individual who was before a respected and prosperous farmer or fisher but was not using much money, but is now living in a shantytown of a big city because his livelihood was destroyed by the modern sector that took over or destroyed that part of the lake basin that traditionally (customarily if not legally) belonged to his tribe or family or village. How we should understand and develop the poverty concept to be more valid in coping with the

[31] For instance the official development aid to Cambodia was in 2004 10 percent of GDP, exceeding domestic tax revenues (World Bank, 2006).

differences between the traditional and the modern sector? Sen (2000), among several others, provide plausible alternatives but their way to policy level would require further operationalization of the concepts as well as the appreciation of the complex character of the poverty issue—it is not only an income issue but an outcome of social deprivation.

Economic growth is a prerequisite of poverty reduction— there is little doubt about it. China and Vietnam were among many countries that promoted socialist policies which did not allow much spread for the income distribution, but both recognised some decades ago that this policy did not lead to economic or social development.

However, economic growth is by far not a sufficient condition for poverty reduction. In fact, the relative poverty (i.e. income disparity) tends to grow in low-income countries as their economy develops, as was detected by Kuznets (1955; 1963) decades ago. But the growth of poverty must not take place—investment in education, in empowerment of people's small-scale entrepreneurship and other means of microeconomic environment, in good governance, infrastructure and so forth, together with income distribution, can make the economic growth include also the poorer echelons of the society. In fact, we strongly believe that such a society can boost and create growth in a more sustainable and broad manner than economically more polarized society. Additional social policies are needed to work against the exclusion of the rural landless and underemployed people as well as the urban slum dwellers.

"Economic growth is not sufficient condition for poverty reduction

We see that these are the key entry points in developing the Lower Mekong Basin into a prosperous region which still would enjoy a rich nature. The opposite scenario—a deprived, overly polarized and poverty-driven society with degraded natural resources—is also a real possibility.

Main findings

The concept of poverty is far more many-sided and complicated than what is usually considered; economic growth alone is not sufficient condition for poverty reduction.

Since the income indicators used in economics (such as $1 a day) are not able to capture this complexity properly, more elaborate alternatives should be used instead. We propose that the concept of 'deprivation' (Sen, 2000) is perfectly suitable definition of poverty also in the Mekong Region.

Deprivation leads typically to social exclusion and marginalization and such groups are particularly weak in finding themselves out of poverty by "self-help", and economic growth does not trickle down to these people.

When looking at the connections between poverty reduction and economic growth, special emphasis should be put on the differences between modern and more traditional sectors: development of modern sector should not marginalize and exclude those dependent on more traditional livelihoods.

Investment in education, in empowerment of people's small-scale entrepreneurship and other means of microeconomic environment, in good governance and infrastructure can together with income distribution make the economic growth include also the poorer echelons of the society.

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2.9 CAPACITY BUILDING

During the WUP-FIN Project, a large number of experts from MRCS, NMCs, national agencies, provincial departments and universities have been trained for sustainable use and maintenance of the modelling and impact assessment tools. The objective has been to bring about the models and impact assessment tools to serve as everyday tools for the MRCS and national teams.

The main training target groups have been:

1. The MRCS Modelling Team (Key Modellers and Associated Modellers) as the core beneficiaries in the training programme. This training has included an introductory course as well as training and communication on the new model developments as well as on environmental, socio-economic and policy analyses. One of the key tasks in the WUP-FIN Phase 2 has been the complementation of the DSF by the WUP-FIN tools on hydrological, environmental and socio-economic impact assessment, as closely as possible with the MRCS Modelling Team.
2. National Training has targeted national model users selected from the riparian NMCs, line agencies and universities. Training has been implemented by an introductory course and follow-up National Training Workshops in each country. The objectives has been to
   a. demonstrate the theoretical background of the models, socio-economic and policy analyses methods and impact assessment tools, the validation of the models with monitoring and survey data, the application of the models in target areas and to train the trainees to use the models through their User Interface
   b. share and elaborate with the trainees the findings derived from model applications and data analysis as well as the conclusions for providing support to the MRC programmes and activities, especially IBFM and BDP
   c. demonstrate model use in support of water resources, environmental and socio-economic planning for managers and decision-makers. In several occasions the training workshops have been linked with national consultations, where the scenario results and case study conclusions have been presented and discussed.
3. University training has targeted interdisciplinary groups of university teachers and students. Training has included lectures with practical exercises in model use and application as well as on socio-economic and policy analyses and impact assessment approaches. Curriculum material has been provided to encourage on-going use of the models. An integral part of the training has to advise the trainees in research problems, help them drafting research programmes, and carry out research for academic theses, particularly by using the modelling tools.

Training at the MRCS, NMCs, line agencies and universities has contained the following elements:

1. progress in model applications, data collection and analysis, and model development
2. presentations on tools and approaches for applications, socio-economic and policy analyses, impact assessments and modelling
3. in-depth hands-on use of the WUP-FIN modelling tools

4. collecting feed back from the users for further development of the application
5. running scenario simulations and analyzing the results

Introductory workshops on utilizing the WUP-FIN modelling and impact assessment tools were carried out as follows:

1. Vietnam national institutes/ Southern Institute for Water Resources Research, HCM City, 11-14 October 2004
2. Vietnam, Can Tho University/ Can Tho, 18-20 October 2004
3. Cambodia national institutes/ Inland Fisheries Research Institute, Phnom Penh 17-18 November 2004
4. Lao PDR national institutes/ MRCS, Vientiane, 8-9 February 2005
5. Thailand national institutes/ Ministry of Natural Resources and Environment, Bangkok, 10-11 February 2005
6. MRCS Modelling Group/ MRCS, Vientiane, February 23 2005
7. Vietnam, HCM City Universities/ University of Water Resources, HCM City, March 2005, followed by practical training sessions at Water Resources University (2 March), University of Technology (3 March) and University of Natural Sciences (4 March)
8. Khon Kaen University, Thailand, June 2005

The total number of trainees in the above events was about 150 persons with typically 15-20 persons per event. The general outcome of the training events was very positive. The participants showed a great interest in gaining the knowledge on numerical modelling and to learn the practical use of the WUP-FIN tools. However, the trainee groups have not been very homogenous in terms of their preparedness in adopting the given training, including differing linguistic levels. This has naturally brought some extra challenges that have been mostly overcome through increased personal guidance during the training.

Moreover, there have been different opinions among the trainees about the right balance between theoretical and practical aspects addressed in the training. It is evident that some of the trainees need a firm knowledge of the scientific background of the models and their application, on top of the skills of managing the model system by its Graphical User Interface. From the feed back of the trainees one can conclude that personal guidance and instruction given during the workshops has been much appreciated, as well as the experiences shared on how to use the model in practical, every day environmental problem solving work.

After the introductory steps the trainees have been sub-divided in different groups with different emphasis and intensity of using the model system: core teams for in depth model development and data work, and end users dealing with practical problems, using models for monitoring and research support etc.

> “ **The general outcome of the training events was very positive**

As mentioned above, the introductory training cycle has been followed by forming national core teams for detailed data, survey and modelling work. The intention has been to involve the core teams closely in the project work by regular follow-up meetings and internet communication and exercises through the project web-site. Due to other obligations and time limitations this opportunity has been used only in a rather limited extent.

Very encouraging element in the national capacity building has been the active participation of university students in using the modelling tools in their academic dissertation work. The Institute of Technology (ITC) of Cambodia has sent annually 2-3 students to do their practical 3 month training for BA degree at the WUP-FIN office in Phnom Penh. Main part of day-to-day instruction in running the model applications have been given by two Cambodian WUP-FIN team members. Cooperation with Vietnamese and Lao universities has led to the promotion of four students to join the three year MSc courses on hydroinformatics and modelling at European universities network, within the framework of EU Euroaquae capacity building programme. Two of the students graduate this year.

2.9.1 www.eia.fi/wup-fin

Project web-site in address ***www.eia.fi/wup-fin*** has been updated during the second phase of WUP-FIN Project (Figure 33). At the moment the web-pages consists of three sub-sections:

1. Tonle Sap Modelling Project (WUP-FIN first phase)
2. Lower Mekong Modelling Project (WUP-FIN second phase)
3. Training portfolio

In "Training portfolio" -pages the training material as model manuals, training presentations, exercises, etc. are available for the trainees and other interested fellows (Figure 34).

In project's sections the published documents are downloadable as a pdf-document, the contact information for the project staff is listed and general information of the project is displayed.

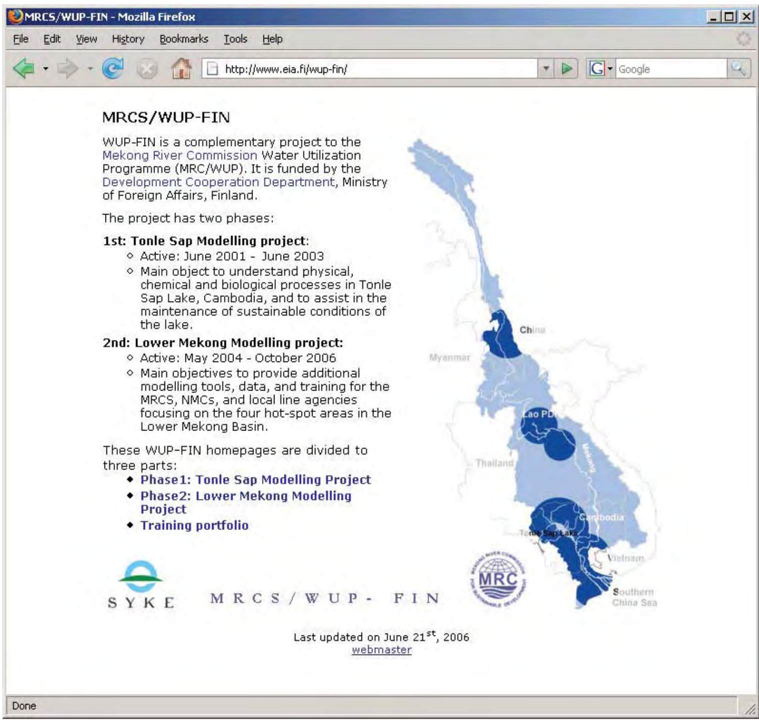

Figure 33. WUP-FIN web-pages: starting page.

Proper and updated **model manuals** are essential for the training progress for users in different levels. The updating of manuals for both, 3D EIA Model and VMod watershed models is on-going task and is following the model development. The most updated version is are available online on the project's website and distributed to the countries as a softcopy during the training sessions.

Figure 34. WUP-FIN web-pages: training portfolio.

2.9.2 *Model software policy and agreements*

The modelling done within the WUP-FIN Project is based on the software developed by one of the WUP-FIN consortium members, the EIA Centre of Finland Ltd. The software is non-commercial in the sense that it has no licence fee. However, for the reception of the software, an agreement has to be made between the software owner and the recipient organisation. The agreement includes the following articles:

> **The software is non-commercial in the sense that it has no licence fee**

1. No restriction for the recipient organisation for:
    - institute internal use
    - training and related personal use
    - academic use
2. Written approval needed for:
    - model use for consulting and other commercial activities
3. Distribution of the model is prohibited without a permission by the software owner
4. The recipient institution must nominate a responsible person for further delivery of model package within the institution. This person must make the users aware of the above model software policy and new users must confirm this by adding their name and signature in the agreement document

2.9.3 Challenges in training and capacity building

Training and capacity building activities have taken more work amount and effort than originally foreseen. To make the training process more effective and practically oriented, teams working on contractual basis on modelling, GIS and data processing have been established step by step in Vietnam, Cambodia and Laos. This has increased the ownership of the modelling tools by the trainees and helped the WUP-FIN team to share the workload with the riparian colleagues. Actually, there exists much larger demand and need to proceed in this kind of training and collaboration mode that has been possible with the existing project resources.

Integration of the activities with the MRCS Modelling Team has not been realized as planned because the Modelling Team has been assigned to a number of other activities. The original idea of the in-depth involvement of the MRCS and NMCs' modelling teams has to be realized in the coming work within the IKMP. This would integrate the consultancy with the modelling teams by working on real-world scenarios and problem solving case study applications.

The way forward:

Building riparian capacity for modelling, impact assessment and IWRM

Background Building of riparian capacity to apply and develop mathematical models and tools for water resources planning and management has been a priority task of the MRCS and the NMCs in the past few years. Modelling teams composed of trainees mainly from the NMCs and line agencies have been working with the international consultants developing a set of models, tools and applications.

Capacity building task has proven to be more challenging and time consuming than originally expected. One constrain has been the continuous development of the modelling tools, leaving limited time and resource for the training itself. Partly limited basic skills of the teams and from time to time changing team composition have posed additional concern of the desired level and sustainability of the training result. One of the conclusions from the past experience is to extend the coverage of the trainee staff to academic institutions and wider set of disciplines in the field of IWRM. A more solid connection between the international teams and the riparian teams, e.g. through contract arrangements is needed to improve the efficiency of the training and increase the teams' abilities for independent modelling and impact assessment work.

Justification The MRCS and the countries need capable and sustainable expert teams as precondition for the maintenance and future use of the developed model system and for carrying out impact assessment work supporting MRCS programmes and the member countries' IWRM needs.

Methodology The key for any successful modelling and impact assessment is development of analytical capabilities to understand the processes in the nature, functioning of the modelling tools and analyze the data produced from monitoring and modelling tools. In addition, the modeller must be able to describe the results in a useful way for the managers and decision makers. The capacity building needs to be realized through project work where the teams of international and riparian experts work together on full time basis.

Involving riparian Universities and Research Institutes in the modelling and impact assessment teams is an important part of the project, aiming at facilitating long-term capacity building in riparian countries and linking project activities better with other, national research activities. The academic institutions are expected to provide an expert resource for the national and MRCS teams and projects and for the maintenance and development of the tools

The three layers of experts (1) at the MRCS, (2) the riparian teams and (3) the academic institutions will provide a pool of expertise that is not too vulnerable for changes for any one individual.

The modelling and IA teams need to comprise of wide enough diversity of expertise (numerical modelling, IT, GIS, EIA, socio-economy) in order to be able to take care of development and maintenance of the model system, run the applications and integrated, problem solving case studies. The national teams should preferably work in networking mode and act as focal points at their institutions, promote further cooperation and capacity building in the countries.

Main findings

- general experience on the training has been very positive
- trainees have shown great interest to gain the knowledge on modelling and skills to use the model in their every day practice
- national case study applications have been designed largely based on the feedback and needs expressed by the country teams
- preparedness of the team members to advance in model applications is still diverse, requiring efforts in personal guidance
- linking model training and application to academic studies and thesis work has produced good results in long term capacity building
- modelling and impact assessment work should be increasingly based on cooperating with multidisciplinary country teams, based on solid contracts

Additional information:

www.eia.fi/wup-fin

PART 3: CONCLUSIONS & WAY FORWARD

This chapter introduces the overall conclusions, reflecting main points from the presented research themes and adding more general conclusions from the WUP-FIN project. The way forward will open up some of the future challenges the Mekong is facing in the near future and recommendations related to those.

3.1 CONCLUSIONS

This report has presented results from the different research themes of WUP-FIN Project. One of the main technical tasks within WUP-FIN Phase 2 has been to complement the MRCS Decision Support Framework (DSF) with advanced analytical models and tools for interdisciplinary and integrated modelling and assessment. These include water quality and ecosystem models, socio-economic and policy analysis tools as well as methods to assess environmental and social impacts under various flow regimes and development scenarios.

In order to succeed in responding to this demanding objective in the complex context of Lower Mekong River Basin, it has been necessary to apply state-of-the-art methodology in hydrodynamic and integrated modelling, and even beyond that to develop novel solutions and tools to create technical means to satisfy the project objectives. As described in this report as well as in the preceding technical reports submitted earlier during the project, the development has led to a number of tools that can be considered to be forerunners in this field of science. These include:

- hybrid 1/2/3-dimensional model for the LMB channel and river network coupled with the floodplains; the challenge in the developments has been in the complexity of the hydrodynamic processes, the presence of very different types and scales of infrastructures and environmental processes as well as plain computational difficulty to handle and control this entity in practice
- flood pulse model for simulating floodplain processes and shifting of the system between aquatic and terrestrial phases, combined with an aquatic and terrestrial primary production module (aimed at being ultimately linked with a fisheries model)
- 3-dimensional river channel model for calculating the distribution of fluvial shear stress along the river reaches, ready to be coupled with bank stability and erodibility data for estimating actual erosion rates in various flow conditions

The model development has been tightly linked to the requests and needs of the MRC member countries, as expressed in numerous national consultations and training events, and has been done in cooperation with the MRCS and national modelling teams whenever possible. Despite the good progresses made in capacity building, the capabilities of the riparian experts to use, maintain and develop the model system is still a serious challenge. This has been strongly addressed in the preparations of the IKMP, the programme where the main bulk of the MRCS and countries future modelling activities and case study work will be carried out. This report proposes to pay considerable attention in setting up the riparian modelling and impact assessment teams in each member country in a way that responds to this multidisciplinary and difficult task ahead.

This Final Report has presented the results and findings of the various research themes and case studies in Chapter 2, and they will not be repeated here. The following chapters will study and propose how the results and information can be brought into conclusions and recommendation on the three crosscutting themes. These were introduced already in the first chapter of this report and they are related to all selected research themes:

- **Poverty reduction** – ultimate objective
- **Critical natural resources, particularly fisheries & floodplains** – thematic focus
- **Impact assessment processes** – methodological focus

3.1.1 Conclusions & recommendations on poverty reduction

In terms of poverty reduction, the different research themes of the report indicated strongly that there is a need to change fundamentally the way we consider the linkages between poverty reduction and economic growth as well as the linkages between poverty and natural resources.

The case studies from different parts of the basin show clearly that the linkages between economic growth and poverty reduction are far more multifaceted than is often thought of, and in many cases the development projects focusing on economic growth are actually undermining the living conditions of the poor. Thus, we believe that there is an urgent need to revise the current approaches in water development and management with particular focus on the poorest groups of society in order to really aim at poverty reduction.

At the same time, and closely related to above, the case studies point out that there seem to be considerable challenges to measure the real value (monetary and other) of different natural resources to the basin's inhabitants, and particularly to the poorest. In fact, we believe that many of the current macro-economic analyses focusing on monetary measures underestimate the real value of natural resources in the basin, and as a result consider many basin inhabitants to be poorer that what they actually are. This has, on the other hand, lead to situation where most water development plans are focusing on modern, large-scale infrastructure that are believed to help to 'lift the poor out of poverty' by changing fundamentally the basis of their livelihood sources.

However, the case studies presented in the chapters above challenge this approach. The large-scale development interventions such as irrigation and hydropower projects are often benefiting only those who are already better-off (and thus able to make better use of changed situation), and at the same time undermine the foundations of the livelihoods of the poorest groups by impacting negatively the availability of and access to common pool resources, most importantly fish. Consequently, we see that the biggest and clearly the most efficient way towards poverty reduction would be to shift the subsistence use of Mekong's diverse resources –fishing, farming, utilisation of wetland resources– to the core of water development and management plans, and use infrastructure and other projects to support and enhance this use, rather than just replace it.

> **"Subsistence use of Mekong's resources should form the basis for poverty reduction**

In addition, the research themes also highlight the importance of broader governance context in poverty reduction: good governance is ultimately the key for equal water management and distribution of resources and benefits, and therefore for poverty reduction. With the existing governance challenges –due to limitations of human and other resources as well as other reasons– in different riparian countries, we see that it is important to encourage open dialogue about the development in the basin, including different options for water development and the trade-offs these development are likely to cause. Facilitating this kind of dialogue is a long-term process that requires easy access to information in all riparian languages as well as increased capacity in different levels –including local level– about the development plans and the impacts, both positive and negative, they are likely to cause. At the same time, the role of well informed and transparent decision-making process cannot be overemphasized as an integral part of good governance.

3.1.2 Conclusions & recommendations on critical natural resources

The thematic crosscutting theme of this report was critical natural resources, particularly fish and floodplains. Both of these were dealt with in one way or another in most of the research themes in Chapter 2. The chapters demonstrated that both fish and floodplains –that can be considered as common pool resources and are closely linked together– are socially and economically extremely important for the entire basin, and particularly for the poorest groups that often lack access e.g. to agricultural land. What makes these resources particularly critical is the fact that they are, as pointed out in many chapters and case studies, exceptionally vulnerable to the flow changes likely to occur in the basin due to basin development. Consequently, we see that much more emphasis should be put on assessing the potential impacts of the basin development on these two resources –and their social consequences particularly to the poorest.

“Fish & floodplains; socially significant, vulnerable to flow changes – and still missing from regional discussions?

In more specific manner, we see that basin-wide impact assessment processes should focus more clearly on the impacts to fish. Related to this, there is an urgent need to collect baseline data for fish and fisheries in order to estimate the actual social and economic importance of fisheries as well as to increase our understanding of the diverse impacts that are likely to occur due to on-going development –particularly hydropower dam construction– in the Mekong River and its tributaries.

As it is nearly impossible or at least very time-consuming to collect comprehensive baseline data for entire basin, we see that instead of detailed fish guilds or superficial groups of fish (such as white, black and grey fish), it would be important to focus the research on socially important fish species i.e. to those species that the fish catches of different groups of people mainly consist of – and again with specific focus on the poorest groups of people.

On the entirely other end of the spectrum, the basis created by WUP-FIN hydrological, hydrodynamic and productivity models offers one promising start to look at the actual limiting factors –and possible flow changes' impacts– to primary production, and ultimately to fish production. This work has, however, only started and lot remains to be done; a collaborative research effort is thus needed.

In terms of floodplains, we see that we have to find ways to estimate –rather than underestimate as is usually done– the real value of the diverse resources and services they produce both directly and indirectly. In order to do this, we need to better understand and acknowledge the complexities involved in the floodplain processes, and consequently, the limitations that the usual impact assessment processes have in addressing possible impacts to the floodplain resources. Again, the work done by WUP-FIN particularly in the Tonle Sap offers one possible start to increase this understanding, but more research is definitely required.

3.1.3 Conclusions & recommendations on impact assessment

This chapter present some of our conclusions and recommendations on assessment of diverse impacts –hydrological, environmental, social– of basin development, with specific focus on basin-wide impact assessment processes. As this is the major methodological issue for entire Mekong Basin and also the foundation of the WUP-FIN Project, this chapter covers a relatively wide range of different issues related to impact assessment, ranging from its limitations to way forward.

Redefining integration to facilitate impact assessment

One of the more methodological findings on impact assessment is related to the linkages between different themes, and consequently between different project components. Although one of the aims of the WUP-FIN project was to develop an approach for integration of socio-economic data with hydrological and environmental datasets, it is now evident that a single integration framework linking all these three broad themes –water, environment and livelihoods– together is too simplifying and uncertain to be really meaningful. The linkages between water, environment and livelihoods are so multifaceted and changes within all these three issues linked with so many other issues, we see it now more sensible to fully acknowledge the diversity of those linkages and changes and not to force ourselves to link them through a pre-defined framework.

Consequently, instead of focusing on straight-forward integration –be it quantitative or more descriptive[32]– between hydrology, environment and socio-economic issues, we see that it is more fruitful to address each of these themes on their own, and find the most relevant linkages between them with the help of facilitated interaction between the themes. Following from this, we see that it is more feasible to shift the actual impact assessment process from linear "impact assessment tables" (IA tables)[33] towards more flexible approach that better reflects the multidimensionality of the linkages between water, environment and livelihoods[34]. This shift also reduces the problems of 'piling up' of uncertainties that was apparent with impact assessment tables due to their linear structure[35].

"The linkages between water, environment and society are too many-sided to be simplified in a single impact assessment frame

This larger impact assessment process should then be more qualitative and interdisciplinary (not just multidisciplinary) by its nature, and focus on finding the most meaningful linkages between the different themes. These linkages do not have to follow some pre-defined structure, but the most relevant linkages should be searched in interdisciplinary and flexible manner. As finding the linkages between environment and livelihoods is particularly challenging, one important theme connecting the two are different water-related natural resources –particularly fish– that should be taken as starting point to find those linkages. The figure below seeks to illustrate this idea visually.

[32] For more information on different integration methods developed and tested within WUP-FIN Project, see MRCS/WUP-FIN 2006a and MRCS/WUP-FIN 2005.

[33] We introduced these tables in WUP-FIN Impact Assessment Report (MRCS/WUP-FIN, 2006a). The basic idea of such tables is to look at the causal linkages between hydrological changes, ecosystem, natural resources and livelihoods and to do this in one single table where all these connections are linked to each another into a single 'link chain'.

[34] While we still think that impact assessment tables can be a useful tool to facilitate impact assessment, the IA tables should not be regarded as end results, but rather as kind of by-product facilitating larger impact assessment process and helping to find knowledge gaps.

[35] If for example the linkage between livelihoods and fish was rather certain but the linkage from flow changes to fish very uncertain, in the impact assessment tables this resulted in high uncertainty also in livelihoods linkages due to the table's linear structure that combined the uncertainties.

FROM STIFF IA TABLES: TO MORE FLEXIBLE INTEGRATION:

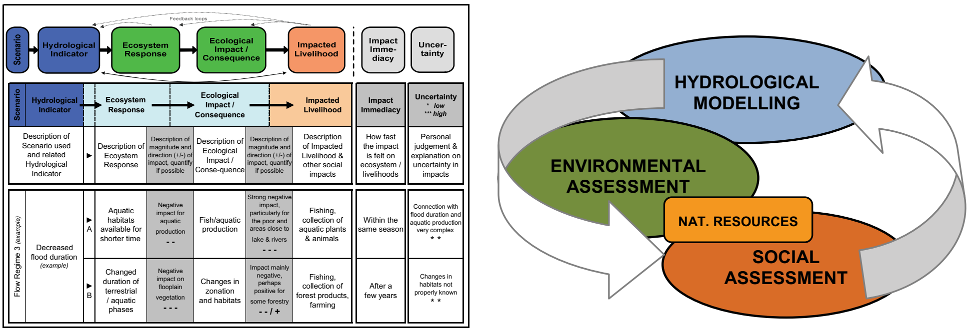

Figure 35. Visual illustration showing the basic differences between the impact assessment tables (left) and more flexible integration based on loose interaction between different themes (right).

One example of the possible approach for this kind of more multifaceted integration is Sustainable Livelihoods Framework (SLF) that has also been applied in the Mekong Region e.g. by the Asian Development Bank (ADB, 2004). This development- and people-orientated framework aims to understand how households interact with natural environment as well as with broader policy and institutional context. To do this, the SLF takes as a starting point the livelihoods strategies as well as different 'livelihood assets' that households have, and then look at different transforming structures and processes that shape the outcomes of households livelihoods.

The basic Sustainable Livelihoods Framework is, however, relatively simplified (see e.g. DFID, 2001; ADB, 2004), and is therefore not necessarily well suitable to provide framework for integration of water, ecosystem and livelihoods. But there exist also more applied versions of the framework that can potentially help to understand the larger context where to study the water-ecosystem-livelihoods –linkages. Some of them can also help to look at the enabling and disabling processes of livelihood development, and how different natural resources and infrastructure contribute to this process. An example for such modified Sustainable Livelihoods Framework is the one presented in Carloni & Crowley (2005): figure below shows a diagram from the report.

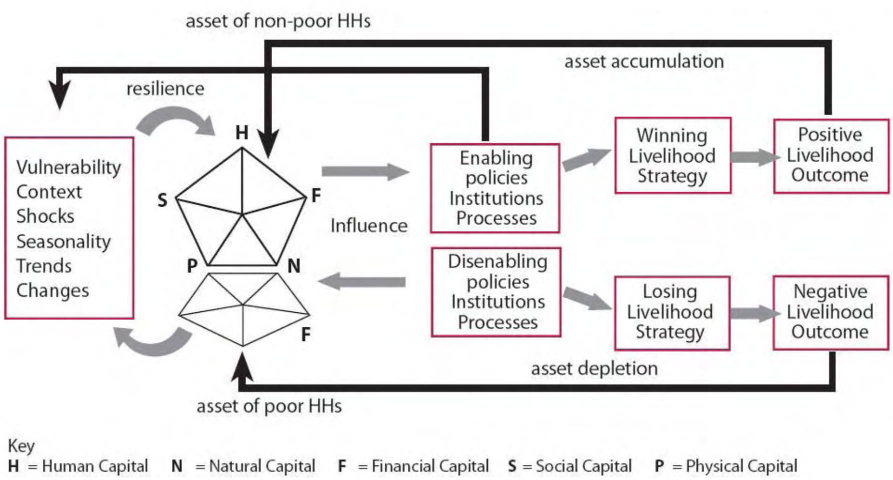

Figure 36. The modified Sustainable Livelihoods Framework with enabling and disenabling processes for livelihood development (Carloni & Crowley, 2005).

Challenges of basin-wide impact assessments

In this section we discuss more specifically about the basin-wide impact assessments, their common challenges and our approach and recommendations related to them. This will also hopefully provide support for other basin-wide assessment processes within the MRC, including Basin Development Plan (BDP), Integrated Basin Flow Management (IBFM) process, DSF as well as the upcoming impact assessment processes within new Information & Knowledge Management Programme (IKMP).

The WUP-FIN project's approach to impact assessment (IA) can be seen to be more practically and locally orientated than most other IA approaches studied and applied e.g. within the MRC. We have taken this kind of approach for IA as we believe that it is essential to study the central aspects of impact assessment *first* in the local level, and only then combine this local level understanding with broader, regional social, economic and political analysis to facilitate basin-wide social impact assessment.

In order to keep its focus, this kind of multi-level impact assessment approach applied within WUP-FIN also requires use of so-called bridging factors, or themes, that help to find the most critical linkages between different levels. One example of such theme is the annual flood pulse that is so concretely present in the Mekong Basin. The flood pulse itself is a mechanism that brings and carries along the impacts of basin wide measures and interventions (dams, diversions, land use etc.) in changes of numerous properties, such as flood characteristics, sediments and water quality to the downstream ecosystem, biodiversity, fisheries and agriculture. Another example of such bridging factor –that is closely linked to flood pulse– is fish that is one of the crosscutting themes of this report, and was discussed in more detail above.

> **"Flood pulse is one possible bridging theme to link different levels together**

The decision to rely on this kind of more locally based IA approach was based on our experiences from existing impact assessment processes[36] as well as on our review of different impact assessment methods and approaches[37]. Based on these, we have concluded that there are at least three major challenges in standardised basin-wide impact assessment approaches: one related to the reliability of available information, the second to the addressing complexities in local level, and the third to the issue of scales and orders of magnitude. These three are discussed in more detail below, after which we present our recommendations for basin-wide impact assessment process that seeks to overcome these challenges.

Challenges with data reliability

Based on the experience from different impact assessment processes, we see that the challenge with the reliability of information used in the regional impact assessments calls for local level case studies, where relevant information is collected and defined also bottom-up and not only top-down.

Many of the regional analyses build –quite naturally– on available macro-scale social and economic data from the region, and these statistics are used mainly in national and/or provincial level[38]. However, as discussed in the chapter about Livelihoods impacts above, the comparison of this macro-scale data with information available from local level indicates that there are clear biases and even errors in it; both due to misrepresentations and

> **"Regional-scale social and economic data is often seriously biased**

[36] Most importantly WUP-FIN, IBFM and BDP.

[37] Such as Strategic Environmental Assessment (SEA), Social Impact Assessment (SIA) and Social Development Approach (for more information on these, see MRCS/WUP-FIN 2006a)

[38] For an example see the MRC's Social Atlas of the Lower Mekong Basin.

simplifications that scaling up of the data causes and due to biases in the actual enumeration methods. We believe that local level analyses –building on both quantitative and qualitative information– helps to reduce significantly the risk for misinterpretations of this data, and also enables recognition of possible missing indicators and links in the available regional data.

Challenge of local level diversity

Related to above, we believe that most of the current, 'top-down' impact assessments building on one, standardised and pre-defined impact assessment approach fail to capture properly the complexity and huge regional differences of social, economic, political, environmental and hydrological issues and their interconnections. The simple fact that the Mekong Region is both geographically and culturally such an enormous area with great regional differences –both between and within the countries– indicates that assessment relying only on one top-down approach is likely to present overly simplified and 'standardised' picture of the entire area. The major reason for this, we believe, is that this kind of regional approaches offer usually almost no flexibility in their indicators and methods, but they force –in the name of comparability and understandability– different areas into the same format with standardised and pre-decided indicators and methods.

This challenge is closely related to the issues of scale between different levels. When reading the different impact assessment reports, the abstract numbers, indicators and proportions presented seem often to hinder the fact that ultimately the assessment is about the people and their livelihoods. We see that for successful basin-wide impact assessment it is essential to recognise that 'regional level' is always a simplified representation of the realities in lower levels – and that these levels are again simplified representations of lower levels all the way to the households and single people living within the basin. Combining regional assessment with more local level analyses helps to bridge the gap between different levels, and therefore to make the abstract numbers and indicators bit more real and better linked to the actual challenges on the ground.

> **"Combining regional assessment with local level analyses helps to bridge the gap between different levels**

At the same time we do understand that due to diversity and complexities in the local level, the assessments in higher levels require focusing on selected key issues. But for this kind of focusing to be meaningful, we believe that we need *first* to understand the actual complexities in the local level, and only then to focus our assessment on the selected key issues – and at the same time make it clear that the assessment covers only some key issues and does therefore not capture all possible aspects and impacts. We could thus talk about 'deliberate' generalisation that is based on understanding –at least partial– of local complexities, instead of kind of 'subconscious' generalisation that happens because we do not really realise the actual complexities in the local level.

Challenge of realising the orders of magnitude

In order to be able to focus your basin-wide impact assessment to regional key issues, it is clear that we have to first understand what these key issues actually are. To do this, we have to combine our understanding of the local level with understanding of the scales and orders of magnitude. And in order to understand the orders of magnitude in regional level, we have to know, among other things, where most of the people (particularly the poor) in the basin live, what are their livelihood sources and possible alternative livelihood sources, and to what extent and how their livelihoods are linked to water and different natural resources.

Although this may sound to be even too obvious, we have noted that for many basin-wide impact assessment processes acknowledging and really understanding the orders of magnitude poses a real challenge; often there is not even information available where most of the people dependent on water-related resources actually live in the basin. As a result, the basin-wide impact assessments seem often to be missing their main point and instead focus on secondary or even tertiary issues. In other words, lot of time and resources –both of which are usually very limited– is put on research in areas and themes that are actually not the most relevant ones for the majority of the people (particularly the poorest) in the basin.

"To be able to focus on key issues, we have to have firm understanding of local contexts and orders of magnitude

To summarise, we see that focusing required for impact assessment at the basin-wide level –for example in terms of selecting most important research themes or most appropriate level for analysis– asks for broader social and economic analyses that help to capture the most critical, regional trends and increase our understanding of the orders of magnitude. However, in order not to oversimplify things and/or to focus on wrong issues, these broader analyses must be combined with the understanding of the situation in the local level. The local level case studies can thus be used to support regional impact assessment framework by linking it to the real issues on the ground.

Way forward: multi-level, interdisciplinary approach for impact assessment

Due to the challenges presented above, we see that for meaningful basin-wide social impact assessment it is essential to combine regional, top-down impact assessment approaches with more local level analyses and assessments that utilise both quantitative and qualitative research methods. We see that neither of these approaches will work alone for regional impact assessment, and particularly challenging would be to scale up the experiences from local level to regional level. Thus, we see that a common framework –flexible enough to accommodate the regional differences between the case studies– is needed for basin-wide impact assessment to support local level analyses.

Consequently, we strongly recommend that basin-wide impact assessment should be based on flexible multi-level process, instead of standardised 'top-down' approaches that are currently the most commonly used. Combining results and experiences from different levels make it possible to compare –and contest– different conclusions which, we hope, can improve our understanding of the diversity of impacts as well as their linkages.

Additional challenge for basin-wide impact assessment processes is the assessment of cumulative impacts of different development plans. In fact, we believe that most current IA processes fail to properly assess these kinds of cumulative impacts due to their sectoral approach and focus on selected plans and projects only. In order to address complexities between different levels and to assess cumulative impacts in any meaningful way, we believe that the impact assessment processes must shift from multidisciplinary approach towards greater interdisciplinarity[39].While

"Most current IA processes fail to properly assess the cumulative impacts

[39] There is no exact definition for multi- and interdisciplinarity, and some of the definitions are actually contradicting each other (see e.g. van der Besselaar & Heimericks, 2001). In this context we consider multidisciplinarity to be the simpler form of these approaches, as it indicates viewing the topic from a variety of disciplinary perspectives and producing 'pure' disciplinary knowledge on it using the common methods for each discipline. Thus, no new approaches or methods are really used, but the topic is analysed jointly from different disciplines' point of view. Also WUP-FIN project approach has been closer to this approach.

Interdisciplinary approach, on the other hand, is more application-orientated and tries also to address the underlying assumptions of different disciplines. It thus seeks to integrate knowledge from different disciplines into a novel interpretation to develop a greater understanding of a problem that is too multidisciplinary approaches are getting more and more common and they are already a major step forward, we wee that they are not going to challenge the main problems in Mekong's water management, namely the dominance of sectoral approaches and lack of truly holistically views. Consequently, while multidisciplinarity presents a promising start, we see that impact assessment needs to move towards more interdisciplinary approaches.

Among the main challenges in truly interdisciplinary approaches seem to be the lack of understanding what the approach actually means, and how much time and effort it requires, starting already at the planning stages of the impact assessment process. Combining information and methods from the varying set of disciplines and professions is naturally not an easy task, and requires therefore a clearly defined but flexible framework that allocates enough time to the actual interdisciplinary process, including facilitated interaction between different components/disciplines. At the same time the different experts involved in the project must be ready to give up some of their 'disciplinary sovereignty' and to modify the common methods and approaches they have used to apply within their own disciplines.

Finally, we see that successful impact assessment requires the recognition of the highly political nature of water development and impact assessment. The impact assessment is thus not only about neutral numbers and estimates, but the results are likely to be contested and interpreted differently by different actors – and due to omnipresent issue of uncertainty their reliability is likely to be questioned. This means that all impact assessment processes should build on transparent processes, and they should have enough capacity and courage to get involved in open dialogue about the methods used, uncertainties included and results achieved in the impact assessment. Consequently, there is need for increased capacity to publish and communicate the assessment principles and results as well as to facilitate discussion –and even prevent conflicts– related to impact assessment process.

How could this kind of multi-level and interdisciplinary impact assessment approach be achieved within the MRC? Although it is unquestionably long process, we see that it is definitely possible and that its implementation is dependent mainly on good coordination between different programmes and already existing impact assessment processes.

It is indeed very promising that there already exist several regional impact assessment processes within the MRC, such as the Social Impact Monitoring (SIM) Process within EP as well as the IBFM process that is looking in comprehensive manner at hydrological, bio-physical and social impacts. At the same time different programmes and projects within the MRCS and NMCs are carrying out local level analyses and assessments in different parts of the basin[40]. Increasing coordination between the regional impact assessment processes –and ultimately combining them under one process– as well as between regional processes and local assessments would already make several important steps forward. In addition, increased cooperation and dialogue with other organisations and institutes working on regional impact assessment –such as IUCN– would help to

> **“ Improved coordination between different IA processes provides easy way forward**

complex or wide-ranging to be properly understood with methods and viewpoints of just one discipline. Interdisciplinary approach usually creates its own theoretical and conceptual identity and may apply completely new kind of methodologies in its research.

Also term crossdisciplinarity is often used, and it refers to approach where a topic is viewed from different disciplinary angle and analysed with different methods than what is usually done within that discipline.

[40] In addition to national case studies within the NMCs, there are for example WUP-FIN case studies as well as the different sites within the Mekong Wetlands Biodiversity Programme (MWBP).

better coordinate the different research efforts and share experiences (both positive and negative) about the impact assessment process.

In more long term, we see that it would be extremely important to bring the regional level impact assessment processes from the MRCS more towards the NMCs and national line agencies and universities, and test and develop them more actively in the national and sub-national levels. This could be done e.g. by the multidisciplinary riparian teams that could be coordinated by the NMCs and would consist of experts from line agencies, universities and research institutes and civil society organisations.

3.2 WAY FORWARD

3.2.1 Urgent research topics

Improvement of basin wide hydrological modelling and analysis

The MRCS Model and Knowledge Base (DSF) was developed under the contract with Halcrow Consultants during the period 2001 – 2003. The contract outputs consist of a basin knowledge base, hydrological and hydrodynamic models and impact assessment tools. The DSF was applied to estimate basin wide hydrological changes under three different levels of water resources and infrastructure developments in the basin. The high development scenario included the assessment of the hydropower expansion on the regional hydrological regimes in the Mekong Basin, definitely an issue of greatest importance and concern presently in the basin.

The flow change estimates are of primary importance for assessing the impacts of upstream developments, particularly hydropower storages, and determine greatly the results of hydrological, environmental and socio-economic impact assessment in the Lower Mekong Basin. Their accuracy and reliability deserves special attention by evaluating the DSF results and by comparing them with results of other available tools.

Due to shortcomings in the DSF to simulate cumulative impacts of the hydropower storages and their operational aspects, a need has been identified at the MRCS to further evaluate the scenario results and compare them with results of other available basin wide models.

Proposed next steps

- Evaluation of DSF an its Development Scenario results
- Applying other basin wide models (VIC, IWMI?)
- Further hydrological analysis
- Targeted measurement campaigns
- Active cooperation with relevant Chinese institutions

Role and fate of Mekong sediments

Sediments are a key factor in many Mekong processes. Navigation, bank erosion, filling up reservoirs, fisheries and agricultural production are all directly dependent on sediment processes. The changes in sediment regime that will results from basin developments, especially the hydropower plants, will affect the processes in the downstream river channels and the connected floodplains, lakes, the delta and the coastal areas. The varying conditions and processes along the Mekong set high demands for sediment monitoring methodology and modelling to respond to the complexity of the system.

Data and knowledge on sediments is still very limited in Mekong Basin, but there are already a number of tools and datasets to support the future work. There is an urgent need to develop sediment monitoring programmes and carry out research along the main stream and in major tributaries as well as to develop basin wide sediment model for assessing the changes in sediment transport resulting from planned basin developments.

Proposed next steps

- Integration and analysis of the existing data, identification of the critical data gaps.
- Measurement plan for measuring TSS flux and grain size distribution, bed load and bed material grain size distribution, sediment chemistry and biological productivity potential.
- Measurement campaigns carried out along the main stream, major tributaries and in the floodplains (supported by satellite image analyses).
- Basin wide sediment model developed and calibrated Reservoir sedimentation and trapping efficiency modelled
- Basin wide sediment transport changes under development scenarios simulated.

Tonle Sap floodplain productivity

The Tonle Sap Lake and floodplains in the heart of Cambodia contain the largest continuous areas of natural wetland habitats remaining in the Mekong system, while being the largest permanent freshwater body in Southeast Asia. Tonle Sap is a crucially important source of food security and rural livelihoods in Cambodia. More than one million people live in the immediate surroundings of the Tonle Sap Lake and wetlands, being the poorest ones in Cambodia, and highly dependent on its productivity. Tonle Sap fisheries provide 60 % of the animal protein of the diet of Cambodian people. Tonle Sap is a flood pulsed ecosystem, that combines aquatic and terrestrial production phases. The annual variation and interaction between these two phases is the basis of its high productivity.

Flow alterations, especially resulting from hydropower developments in the basin, will affect the hydrological characteristics of the flood pulse. A question of paramount importance is what the impact of theses changes will be for the productivity of the Tonle Sap ecosystem and hence the livelihoods it supports. Due to the rapidly proceeding developments in the basin, there is an urgent need to develop the means to assess the quantity of these changes.

Existing models and tools: MRCS/DSF based flow scenarios for the Mekong main stream, WUP-FIN models for Tonle Sap system (3D EIA), WUP-JICA flow model for Cambodian floodplains, WUP-FIN Tonle Sap database, project data from ADB-funded Built Structures Project on different built structures impacts on Tonle Sap fisheries, pilot productivity module for aquatic and terrestrial primary production, based on main groups of primary producers (phytoplankton, periphyton, rooted macrophytes and floating vegetation) linked with the 3D Tonle Sap model

Tools to develop: further parameterization and validation of the productivity model, feasibility study of linking a fisheries model to the primary productivity model

Data to collect: measurements on production rates of primary producers, complemented by literature data (e.g. from Amazon floodplain studies), surface area index and transferable biomass for main vegetation types in floodplain, distribution of main vegetation types in the floodplain in function of flood/drought duration, measurement of the organic matter input in the Tonle Sap ecosystem from the Mekong and the tributaries.

Expected outputs:

- Productivity model further parametrised and developed.
- Floodplain primary production rates, vegetation surface area index and biomass measured, distribution of floodplain vegetation linked to flood/drought duration, importance of allochthonous organic matter for ecosystem productivity assessed.
- Scenario runs on the impacts of flow alterations on primary productivity.

- Estimates on the impact of primary productivity changes on secondary (fisheries) productivity of the Tonle Sap system

Support to Vietnam Delta IWRM

The Mekong Delta has been the most challenging area for model developments in the WUP-FIN Phase 2. This is due to the complexity the delta environment sets for modelling its hydrodynamic, flooding, salinity intrusion and water quality processes. In addition, most important socio-economic trends, particularly the intensification of agriculture and the boom in aquaculture, are closely related to the water resources and water management decisions.

The modelling tools developed for the delta within WUP-FIN Project Phase 2 include the entire Lower Mekong floodplain model and sub-models for the Tan Chau area, the Plain of Reeds and the Tieu River mouth.

The development work done in the Plain of Reeds provides expanded perspectives for model application. The final aim is to arrive to a comprehensive modelling system for the whole Lower Mekong Basin. This system would take into account all of the complexities of the area and would provide more reliable guidance for planning and management than is currently available.

The complex system of Lower Mekong Floodplains includes rivers, channels, dykes, embankments and large areas of floodplains. In order to be able to simulate this system comprehensively a hybrid 1/2/3 D model system is needed. To this end the WUP-FIN 3D EIA Flow Model for floodplains has been coupled with 1/2/3D channel model, as pilot version. The advantages and necessity of using a hybrid 1D/2D/3D river channel model are very pronounced in the Vietnamese Delta.

On top of the complexity comes the interplay of large scale influences such as upstream discharges, tidal forcing and local scale phenomena. The LMB floodplain model is needed for simulation of flow and water quality over the floodplains and in the river channels and to give boundary values for the fine resolution target area applications.

Objectives:

- To provide modelling tool for simulating the complex and interlinked hydrological and environmental processes in the Mekong Delta as part of the Lower Mekong
- Basin and support hydrological, hydrodynamic and environmental impact assessment and socio-economic planning

Existing models: DSF/ISIS 1D model, 1D models developed by Vietnamese institutes, WUP-FIN models (pilot version of the 1/2/3 D hybrid model for the LMB and Plain of Reeds, sub area models for Tan Chau and Tieu River mouth)

To be done:

- Further development and validation of WUP-FIN hybrid 1/2/3 D channel-floodplain model.
- Field measurements on flooding, sediment transport and water quality for providing data for continued validation of the models and developing water quality applications.
- Providing boundary values for Delta sub-models (Tan Chau, Plain of Reeds, Tieu River mouth) by the LMB model. Scenario simulation and impact assessment based on local and basin wide development plans.
- Support for planning process in the Delta, e.g. the Delta Master Plan

Support to flood forecasting and flood protection by advanced modelling tools

Present knowledge on the flooding process in the floodplains is insufficient. Infrastructure development and land use changes cause changes in flooding pattern, unexpected water levels and risks for the communities. Hydrodynamic modelling provides a tool to increase understanding of the 2-dimensional flood propagation and the causes of exceptional water levels and to mitigate the related risks and damages.

Objectives:

- Provide advanced modelling tools to increase the understanding of LMB flooding
- process and to assist the FMMP to improve the accuracy of Mekong flood forecasting
- in space and time and to support flood management and flood protection

Existing models and tools: DSF/ISIS 1D model, JICA/MIKE 11 1D model for Cambodia, WUP-FIN hybrid 1/2/3 dimensional LMB model (pilot version) for river-channel network and connected floodplains, Cambodian floodplain water level and discharge data (TSLV data).

To be done:

- Further development of the hybrid model, e.g. by improving the description of the detailed infrastructure and further model calibration and validation.
- Data collection on floodplain water levels for validation of the hybrid model.
- Close cooperation with FMMP in hydrodynamic modelling and data collection.

3.2.2 Way forward for modelling in water management & impact assessment

Successful implementation of water management policies requires thorough understanding of water regime, environment and their linkages with the surrounding society. Due to the complex nature of these issues and their interconnections, various kinds of mathematical models have been developed to support water management, development and governance. Models are used to improve understanding of cumulative and aggregate effects, to provide forecasts, and to help to quantify scenarios, which in turn are helpful for long-term planning[41].

However, the role of models in water management is rather controversial, and models and their results are often mistrusted, under-utilised or misused in management and decision-making. There appears to be two totally different schools of thought regarding the use of models. While some managers and scientists look at the models as basically mathematical toys of over-enthusiastic engineers with only weak connection to real problems, others value models above anything else trusting almost blindly their results. As a consequence, models and their results are often either poorly integrated in the decision-making, or the management is based completely on their results without proper consideration of the limitations and uncertainties of the models and their results.

However obvious the needs for an integrated and cooperative approach for impact assessment in transboundary water basins are, there seems still to be a long way to go. Some progress in integration of teams from natural and engineering sciences has been made, but integration with the social sciences is still only dawning. To date, the approach adapted by modellers to address these more multidisciplinary connections has typically been just “to add some social stuff” to their models (Nancarrow, 2005). This may have been predominantly just to satisfy the demands of the donors and/or decision-makers, but it doesn’t really change the fundamental problems with modelling.

[41] This section is based on Sarkkula et al. (2007).

The real change may come through establishment of teams for integrated assessment and modelling with balanced and equal participation by modellers, social scientists, policy experts and other non-modellers. This may help to formulate the right questions to guide model development and impact assessments, and to end up with relevant answers and solutions from society's point of view. This may also help to bring new information and recommendations to the decision-makers.

Improving the connection with decision-makers is not without barriers and obstacles, either. Neither political attitudes and interests nor financial constraints are easy to overcome. We see that the responsibility to rise above these barriers rests mainly on modellers, who need to develop models and present the model results in such a clear way that they are acceptable and understandable by planners, managers and decision-makers.

This evident barrier makes one to think that a great deal of the effort put in modelling and its technical development should actually be released for collaboration and communication with planners, decision-makers and other 'non-modellers' to ensure that the results achieved by modelling projects (that are typically not cheap) are really utilised in planning and decision-making. For this communication to be truly successful and the results trustworthy, the communication should include the publication –in English and in riparian languages– of model results, but also transparent communication of methods and data used in the modelling and assessments. The necessary resources for this kind of research communication could be easily released from scattered model developments, if only the decisions for more collaborative and concerted modelling work can be taken and implemented.

The challenges described above lead one inevitably to think that the 'spiritual side' of the long discussed and awaited –and still largely pending– integrated approaches for water management has been mostly ignored. Reaching new milestones in the cumbersome road of integrated approaches thus necessitates identification of the mental and social barriers preventing true integration of the people involved. This does concern the research teams as well as the institutions and organisations, and also their governance methods and practices.

We believe that the solution rests very much in better mutual appreciation and listening between the involved individuals, teams, stakeholders and interest groups. The importance of multi- and interdisciplinary research for natural resources management is indeed obvious. As pointed out by Janssen and Goldsworthy (1996), to really achieve this, the most important attributes are attitude, communication skills, education and experience.

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This report presents the main thematic outputs of so-called WUP-FIN Project. The outputs are presented through nine specific research themes:

- Flooded forest and flood pulse: Future of the Tonle Sap Lake?
- Sediment issues
- Tonle Sap ecosystem productivity
- The complex dynamics of Mekong Delta
- Bank erosion
- Climate change in Nam Songkhram
- Livelihood impacts
- The dilemma of poverty reduction and economic development
- Capacity building

In addition to these specific topics, three crosscutting themes are discussed in the report; Poverty reduction; Critical natural resources, particularly fisheries & floodplains; and Impact assessment processes. The report finishes with a concluding chapter that draws together main findings and achievements of the WUP-FIN Project and provides recommendations for way forward.

WUP-FIN was a complementary project to the Mekong River Commission Water Utilization Programme (MRC/WUP). The project was funded by the Finnish Ministry for Foreign Affairs. The project had two phases: Phase 1 (2001-2004): Modelling of the Flow Regime and Water Quality of the Tonle Sap, and Phase 2 (2004-2006): Hydrological, Environmental and Socio-Economic Modelling Tools for the Lower Mekong Basin Impact Assessment

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