6th Annual Mekong Flood Forum

Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin

Proceedings

27-28 May 2008

Phnom Penh, Cambodia

Contents

PREFACE

ADDRESSES OF THE INAUGURAL SESSION
- Welcome speech *by Mr. Jeremy Bird*
- Opening address *by H.E. Sin Niny*
- Statement *by Dr. Armand Evers*

PAPERS OF THE INAUGURAL SESSION
- Summary of the 5th Annual Mekong Flood Forum (AMFF-5) *by Hatda Pich An*
- Overview and expected outcomes of the 6th Annual Mekong Flood Forum (AMFF-6) *by Nico Bakker*

COUNTRY REPORTS ON LESSONS LEARNED FROM 2007 FLOODING AND NATIONAL AND MRC-RFMMC FLOOD FORECASTING AND WARNING EXPERIENCES
- Cambodia country flood report for 2007 *by Sok Bun Heng*
- Lao PDR country flood report for 2007 *by Virana Sonnasinh*
- Thailand's country flood report for 2007 *by Tosporn Suthijinda and Supapap Patsinghasanee*
- Viet Nam's country flood report for 2007 *by Trinh Hoang Ngan*
- Flood disasters and flood forecasting progress in China *by Guoqing Wang*
- Floods, forecasting system and management in Myanmar *by U Hla Myint Thein and U Sein Tun*

- 2007 Mekong flood report - flood hydrology of the Mekong tributaries *by Ms Janejira Tospornsampan and Peter Adamson*

TOWARDS AN IMPROVED MEDIUM-TERM FLOOD FORECASTING AND WARNING
- The Mekong River flood forecasting system at the Regional Flood Management and Mitigation Centre *by Bob Pengel, Janejira Tospornsampan, Terry Malone, Marco Hartman and Ms. Astrid Janssen*
- Hydro-meteorological information exchanges and communication improvements. Support for URBS model in medium-term flood forecasting over the Mekong River Basin *by Perapol Begkhuntod, Hatda Pich An and Katry Phung,*
- Identification and measurement of factors affecting flood vulnerability in the Lower Mekong River Basin *by Nguyen Huy Dzung and Chris Joy*
- The Mekong regional flash-flood guidance system - a technical overview *by Robert W. Jubach, Eylon Shamir, Christopher Spencer and Jason Sperfslage*

PLENARY PAPERS
- Achievements and lessons learnt. Component 4 of the MRC's Flood Management and Mitigation Program (FMMP): Flood Emergency Management Strengthening (FEMS) *by Loy Rego*
- Asia Flood Network: USAID/OFDA Flood Mitigation and Preparedness Program in Asia *by Ms. A. Sezin Tokar, Richard Paulson, Eric Wolvovsky, Angel Bennett, Kelly Sponberg, Robert Jubach, Saud Amer, Guleid Artan and Greg Husak*
- Enhancing cooperation between Mekong River Commission (MRC) member countries for addressing trans-boundary flood and related issues *by Huynh Minh Ngoc and Nicolaas Bakker*
- Integrated flood management in the context of regional to global integrated observing and information systems. Overview of current activities of the World Meteorological Organization *by Wolfgang Grabs*

PARALLEL PAPER PRESENTATIONS ON THE FOUR TOPICS

Topic I. New developments with respect to flood forecasting and early warning

I.1 Quality assessment of forecasts *by Erich J. Plate and Falk Lindenmaier*

I.2 Flood risk forecasting for poorly-gauged basins in the Mekong River Basin using a distributed hydrological model and a satellite derived precipitation dataset *by Jun Magome, Kazuhiko Fukami, Hironori Inomata and Kuniyoshi Takeuchi*

I.3 Improving the meteorological network in Cambodia *by Long Saravuth, Katry Phung and Bob Pengel*

I.4 Potential of satellite altimetry for flood model assessment *by R.J.J. Dost, G. Parodi, T. Rientjes, Le Thi Hanh*

I.5 Flood hazard in Savannakhet province, LAO PDR mapping using HEC-RAS, remote sensing and GIS *by M.K. Hazarika, A. Bormudoi, S. Phosalath, V. Sengtianthr, L. Samarakoon*

I.6 Mekong-HYCOS-Strengthening integrated hydrological management in the Mekong River Basin *by Liko Solangkoun and Daniel Jouve*

Topic II. Land use based requirements for flood forecasting and early warning systems

II.1 Outline of an approach to generate flood probability information and its possible use in land management *by Georg Käsler*

II.2 The lower Mekong Basin flood mapping service: development and delivery of near-real-time flood map products *by A.M. Dean, O.T. Tsui, A. Syed and T. Boivin*

Topic III. Costs and benefits of flood forecasting and early warning

III Workshop cost and benefit of flooding/flood forecasting *by Peter Adamson*

III.1 The role of flood forecasting and early warning in integrated flood risk management *by Guus Sutmuller*

III.2 Long Lead Climate Forecast Application to Benefit Society: Experiences of 2007 Bangladesh Floods *by A.R. Subbiah and S.H.M. Fakhruddin*

III.3 Economic valuation of flood damage for decision makers in the Netherlands and the Lower Mekong River Basin *by Jurjen Wagemaker, Ms. Jakolien Leenders and Jan Huizinga*

Topic IV. Lessons learned from past flood events

IV.1 August 2002 and 2005 floods in Danube River *by Kim Seanvirak*

IV.2 Lessons learned from application of new technologies for flood proofing residential clusters in the Lower Mekong River Basin *by Marshall L. Silver, Robert Barton and Pham van Le*

IV.3 Flood forecasting accuracy for the Mekong River Basin *by Willem Kanning, Sambo Pich and Bob Pengel*

IV.4 The role of government in flood management and the lessons from hurricane Katrina *by J. Ligh and M. Schnabel*

SPECIAL PRESENTATION

- Flood forecasting for best management of floodplains *by Prof. Kuniyoshi Takeuchi*

PRESENTATIONS DURING THE CONCLUDING SESSION

- Summary of proceedings and recommendations for follow-up of the 6th Annual Mekong Flood Forum (AMFF-6) *by Bart Schultz*
- Forum Statement
- Closing address *by Jeremy Bird*

GENERAL IFORMATION

- Characteristic data on the Mekong River Basin
- Programme 6th Annual Mekong Flood Forum (AMFF-6)
- Abbreviations and acronyms
- Glossary
- List of participants of the 6th Annual Mekong Flood Forum

Preface

On behalf of the Mekong River Commission (MRC) I am delighted to present to you the proceedings of the 6th Annual Mekong Flood Forum that was held in Phnom Penh, Cambodia, 27 – 28 May 2007. This year the theme of the Forum was *Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin.* Discussions were focused on the importance of availability of flood-related tools, data and knowledge. Without this there cannot be a reliable and authoritative flood forecasting system, which is one of the prime objectives of MRCs Flood Management and Mitigation Programme (FMMP).

Reports of the MRC Member States - Cambodia, Lao PDR, Thailand and Viet Nam - and Dialogue Partners - China and Myanmar, MRC papers and presentations from other participants have been prepared within the framework of the forum theme and fall under four defined topics:

I. new developments with respect to flood forecasting and early warning;
II. land use based requirements for flood forecasting and early warning systems;
III. costs and benefits of flood forecasting and early warning;
IV. lessons learned from past flood events.

The 6th Annual Mekong Flood Forum has also provided the opportunity to discuss the third Annual Mekong Flood Report 2007 produced by the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC). This report examined not only the flood impacts from the four countries' perspectives, but it also puts the floods into a historical context by explaining the hydrological cycle of the Mekong River.

The 6th Annual Mekong Flood Forum was result-oriented in order to assure that its outcomes can be applied by the MRC-RFMMC and the MRC Member States in their pursuit of improving data collection and sharing, which is the prerequisite for the attainment of reliable and dependable medium-term flood forecasting and early warning. Based on the outcomes of the 6th Annual Mekong Flood Forum, it is expected the MRC-RFMMC and the MRC Member States will be able to improve their flood forecasting services, and further develop integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin. The broader goal is that the MRC Member States will use the Annual Mekong Flood Forums as a mechanism to review and improve their own flood policies, strategies, plans and projects.

I would like to take this opportunity to thank the country report authors from Cambodia, Lao PDR, Thailand and Viet Nam and from our Dialogue Partners, China and Myanmar, and all the other authors for the submission of their high quality reports and papers. I also like to thank all participants that actively participated in the Forum and contributed to the discussions.

Last but not least I extend our gratitude to the Governments of Denmark, France, Germany, Japan, the Netherlands and the United States of America, as well to as the Asian Development Bank and the European Commission for their support of the MRCs Flood Management and Mitigation Programme.

I am confident participants and other readers will find much interesting information in these proceedings and that this will benefit both day-to-day practices and contribute to the improvement of our work with respect to integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin.

Jeremy Bird
Chief Executive Officer
Mekong River Commission Secretariat
30 May 2008

WELCOME REMARKS

JEREMY BIRD

CEO Mekong River Commission Secretariat (MRCS), Vientiane, Lao PDR

Excellencies, Members of the MRC Joint Committee, Representatives of Development Partners, Representatives of International and Regional Organisations and Institutes, Distinguished Delegates;

It is a great pleasure for me to return to Phnom Penh to present this address at the start of the 6th Annual Mekong Flood Forum, just weeks after participating in the opening of the Regional Flood Management and Mitigation Centre of the Mekong River Commission (MRC). I am pleased also to note the broad interest in this event and to see the number of participants continues to grow steadily since the first Flood Forum in 2001. At that Forum, the MRCs role in the Flood Management and Mitigation Programme was just being conceived. Here, we see it moving from infancy to maturity.

For the MRC, this meeting provides an important chance to share experiences of last year's flood season in the Mekong River Basin, and add to our understanding of the positive and negative impacts of floods. It allows us to follow and support interventions of MRCs Member States to reduce the loss of lives as well as damage to infrastructure and loss of production. Also, to support their efforts to enhance levels of preparedness and response among people living in the basin and the capacity of responsible authorities, especially the disaster management organisations.

Floods remain an essential part of the natural life cycle in the basin, but at the same time a threat to human life and dignity. The recent cyclone and consequent floods in Myanmar have demonstrated again that meteorological conditions may turn a peaceful landscape into total chaos, resulting in casualties and destruction of houses, communities, roads and communications. Sitting here in the comfort of this pleasant setting, it is hard for us to imagine the hardships and misery that the affected people are facing. Our thoughts go out to those that have lost their loved ones and are struggling to survive, as well as to those working hard to help them. It is the mitigation of such impacts on peoples' lives that is driving us in our work here and it would be helpful to keep those images in our minds as we work together over the next two days and beyond.

Turning back to the Lower Mekong River Basin, there already seems to be a relationship developing between the heavy rainfall recorded in many areas over recent weeks, so early in the year, and the fact that 2008 is a year in which the *El Niño* and *El Niña* phenomena are active.

Even though climate change, with its associated extremes and variability, will further complicate weather prediction, being able to provide longer term or seasonal flood forecasting has become more relevant than ever before. It is our duty to help our partners enhance awareness of flood events and the preparedness to cope with them; strengthen search and rescue capabilities; design and build intelligent flood resistant irrigation, road and dyke infrastructure; adopt appropriate management systems; and instigate a number of other measures and interventions to minimise the negative impacts of floods while retaining their natural benefits. This is no small task.

The Flood Management and Mitigation Programme, with the support of our development partners including the Netherlands, Germany, the United States, Japan, Denmark, the Asian Development Bank and the European Commission, has provided our Member States with a well structured programme of regional cooperation and information exchange in dealing with floods.

The opening earlier this year of the new building of the Regional Flood Management and Mitigation Centre here in Phnom Penh is a clear sign of the countries' interest in applying a joint concept and of MRCs role in delivering on development needs.

This flood season, the Centre will introduce a new hydrological flood forecasting system, to be tested alongside the existing forecasting system for the mainstream of the Mekong in the Lower Basin. Further improvements will be made to incorporate a hydrodynamic forecasting model, thereby allowing more specific forecasting capabilities over the entire floodplain in Cambodia and Viet Nam.

A basin-wide Flash Flood Guidance System will be operational by the end of this year, while a basin-wide assessment of 'Integrated Flood Risk Management' based on a combination of soft and hard measures is ongoing.

A capacity building programme to enhance the ability to address issues, differences and disputes on transboundary flood matters will be implemented within weeks. National systems and processes have been strengthened in the fields of emergency management and disaster preparedness, and in land management, but more is clearly necessary. Thanks to the additional funding that has been received, these activities can continue throughout the first phase of our programme, up to the end of 2010.

The coordinated support of our development partners not only enables us to achieve effective internal coordination of all flood mitigation and management activities, but in doing so promotes the quality and pace of their implementation.

Excellencies and Distinguished Delegates;

Implementation of this programme has now passed the halfway mark of six years. It is time to review and evaluate the progress made so far, and to identify those steps required to complete and sustain the systems already established. Also to assess the steps needed to support dissemination and replication of good practices into new provinces, districts, communes and villages. In addition, analysis should be conducted to determine how we can help Member States enhance their flood management guidelines and procedures.

Flood management and flood mitigation remains a vital issue in the Lower Mekong River Basin. Although upstream dams may reduce the flood risk in certain areas, they will not eliminate the threat. Heavy rainfall from recurrent typhoons, and the effects of climate change, mean that inundation will remain extremely variable. In this context, the MRCs Annual Flood Report will continue to be a valuable instrument for documenting hydrological hazards and reporting the effects of floods across the basin.

In partnership with other MRC programmes such as the Basin Development Plan, Navigation, Environment, and Information and Knowledge Management Programmes, the Flood Management and Mitigation Programme is investing in and contributing to research, training, and technological development. This is an essential part of our work, but is not the end of it. I firmly believe that the focus of our efforts should equally be on generating and delivering results to our clients - the line agencies, research and training institutes, and other organisations of the Member States - in a form that materially assists them to help rural and urban communities at a time of heightened risk.

This we cannot do without the full support of each country, the continued contributions of our development partners, and the cooperation of the numerous international and regional institutes and organisations represented here today.

Excellencies and Distinguished Delegates;

I look forward to hearing the exchanges of experiences and recommendations at this 6th Annual Mekong Flood Forum, in what is one more step along the path of developing an effective regional management capability for flood events and so providing a more secure future for vulnerable people in the basin.

Before we move on I would like, on behalf of the MRC, to extend my sincere appreciation to staff of the FMMP and the Cambodian Government who have put in so much hard work to organise this Forum. Also to thank all of you who have contributed to the proceedings and given your time to be with us here today.

I wish you all a productive and enjoyable time here in Phnom Penh.

Jeremy Bird
Chief Executive Officer,
Mekong River Commission Secretariat
Vientiane, Lao PDR

OPENING ADDRESS

H.E MR. SIN NINY

Vice Chairman of Cambodia National Mekong Committee, Member of the MRC Joint Committee for Cambodia, Phnom Penh, Cambodia

Dr. Armand Evers, First Secretary, Integrated Water Resources Management, Royal Netherlands Embassy, Hanoi-Vietnam;
Mr Jeremy Bird, Chief Executive Officer of the MRCS;
Excellencies;

Donors, Partners and International Organisations Representatives;
Distinguished Delegates;
Ladies and Gentlemen

It is my great pleasure and privilege to attend this important 6th Annual Mekong Flood Forum, organised by the Regional Flood Management and Mitigation Centre of the Mekong River Commission (MRC), and marking another key advancement in the Centre's operation.

On this auspicious occasion I would like to extend a warm welcome to all distinguished delegates, donor representatives, international organisations, MRC Member States and our Dialogue Partners from the upstream countries, China and Myanmar, who will present their own experiences of the 2007 flood season later today.

Let me also take this opportunity to extend a warm welcome to Mr Bird, who started as the new Chief Executive Officer of the MRC Secretariat in April of this year on the occasion of the celebration of the twelfth anniversary of the MRC during the inauguration ceremony of the Regional Flood Management and Mitigation Centre's building.

Today's Forum is the sixth such event to discuss progress made and the state of flood forecasting and warning systems at national and regional levels in the Lower Mekong River Basin. We are gathered here today to learn from each other and from international adopted integrated approaches and applicable systems used in the improvement of medium-term flood forecasting and warning services.

The theme of this year's forum *'Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin'* reflects the current needs and great joint efforts made by the governments of the MRC Member States - Cambodia, Lao PDR, Thailand and Viet Nam - in managing and mitigating floods in the Lower Mekong River Basin. This theme is chosen in close consultation with the MRC Member States, based on their requirements with respect to flood forecasting and early warning by the MRC Regional Flood Management and Mitigation Centre.

The rapid population growth in the region, urbanisation, intensification of agriculture, changes in land use and river morphology, and rapid technology development require present day flood forecasting to be improved. More accuracy and longer lead time are needed, and these must be based on better data inputs and modern technology and tools. Flood forecasting and warning is a complex task and significant damage reduction can only be achieved if the whole range of necessary flood forecasting and warning activities is implemented and well coordinated, starting from a high-quality database and information, competent and qualified human resources, state-of-the-art supporting tools and models, and appropriate communication technologies for warning dissemination.

The MRC Regional Flood Management and Mitigation Centre, aware of the strong desire among the MRC Member States for improved operational flood forecasting, has been taking on the challenge of increasing forecast accuracy and timing. Real progress has been made over the past year, and steps are already in place to continue this advance over the forthcoming flood season.

Excellencies, Distinguished Delegates, Ladies and Gentlemen,

Over the next two days, we will hear both plenary and parallel topic presentations and discussions on the current state of upgrading and improvement of flood forecasting and warning systems at both national and regional levels. It is my sincere hope that the results of this Forum will be used and applied by the MRC Regional Flood Management and Mitigation Centre and the member countries in their pursuit of reliable and dependable medium-term flood forecasting and early warning.

Based upon outcomes of this Forum, the MRC and the Member States, line agencies, and national, international and civil society organisations, will gain a better understanding of and insight into the progress of data collection and sharing. We will learn about the new Mekong River Flood Forecasting System, which will enable operational flood forecasting six to ten days in advance of events on the mainstream of the Mekong River, and will allow us to better address the flood aspects of human security.

During the Forum you will also be able to learn from the experience and best practices of international organisations, academic institutions, and civil society organisations on data collection and exchange for flood forecasting, and the database hardware and software used for data storage and processing. Gatherings such as this strengthen and enhance cooperation among the international community.

Excellencies, Distinguished Delegates, Ladies and Gentlemen,

I am confident that this Forum will produce solid conclusions and set recommendations for further action to attain our common goals. I would like to express my profound gratitude and sincere thanks to the governments of the Netherlands, Germany, Denmark, Japan and the United States, and to the Asian Development Bank and the European Commission for their continuing support for the MRCs Flood Management and Mitigation Programme.

To conclude my opening address, I would like to declare the 6th Annual Mekong Flood Forum open. I hope that every participant has the opportunity to make a fruitful and productive contribution, and that all of you enjoy a pleasant stay in Phnom Penh, here at the heart of the Mekong River Basin.

Thank you.

H.E Mr. Sin Niny
Vice Chairman of Cambodia National Mekong Committee
Member of the MRC Joint Committee for Cambodia
Phnom Penh, Cambodia

STATEMENT

DR. ARMAND EVERS

First Secretary, Royal Netherlands Embassy, Hanoi, Viet Nam

H.E. Mr. Sin Niny, Vice-Chairman of the Cambodian National Mekong Committee
Mr. Jeremy Bird, Chief Executive Officer, Mekong River Commission Secretariat

Dear Excellencies, distinguished delegates, representatives of the donor community, regional and international organizations and institutes, Ladies and Gentlemen,

In the first place I am happy to see again so many participants at this 6th Annual Mekong Flood Forum. Secondly, this is the 6th Annual Mekong Flood Forum after the Lower Mekong River Basin was hit by the major floods of 2000 and 2001.

Certainly these Annual Mekong Flood Forums have contributed to raise flood awareness in the region and to enhance the understanding of the character and impacts of floods in the Member States of the Mekong River Commission (MRC).

The Flood Management and Mitigation Programme (FMMP) has certainly been instrumental in providing support to the MRC Member States in the understanding of floods and to enhance and strengthen the ways in which the Member States and all other stakeholders deal with the negative impacts of floods, particularly the loss of lives and the direct and indirect damages. The cyclone Nargis, which hit Myanmar a few weeks ago, has once again proven that flood emergency preparedness and disaster management remain 'key' to reduce the loss of lives, the destruction of livelihoods, and the damage and loss of properties. At the same time sensible structural measures should also be explored to further reduce the flood risks.

Floods are results of meteorological and hydrological hazards and a statistical approach is to be applied in order to develop proper flood management and flood reduction- and protection systems.

We will all agree that mitigating and managing the negative impacts of flood and flood protection are in the first place the cooperative responsibility of government authorities, but also of non-government organizations and of the organizational capacity and talent of communes and villages, of the frequently affected people. It are these affected people who should be targeted with the MRC strategy for flood management and flood mitigation.

I would like to suggest that we assess the outcomes of the 6th AMFF in terms of contribution to the further reduction of the negative impacts of floods for this target group.

The Royal Netherlands Embassy is happy with the progress made by the Flood Management and Mitigation Programme in the recent months, particularly with regards to the building up of implementation momentum, as all components are currently operational.

We expect from the MRC Secretariat that this implementation momentum will be maintained, as it will enhance the spin-off and synergy between the various components under FMMP, but also with other MRC-, and other government- and donor programmes in the region.

The Royal Netherlands Embassy appreciates the cooperation, coordination and contribution of the MRC Member States to the success of FMMP. Also, we believe that the knowledge/experiences gained from these forums has been and will be useful for all participants for their careers. We, as Embassy certainly support these developments in general terms, and we are particularly interested in the outcomes of the identification of core functions of the MRC, as this is being reviewed under the MRCs institutional review.

However, I also would like to emphasize that this is closely related to future operations of the Regional Flood Management and Mitigation Centre (MRC-RFMMC), requiring support to the core functions of this centre. Therefore in our view a strong commitment by the MRC Member States is absolutely necessary as a prerequisite before any donor will consider any financial contribution.

To put it very clear …….. International financiers will not come forward for further financing of the centre, if the MRC Member States do not produce a solid conceptual and financial commitment to this centre. Realising that only 2.5 years of the current FMMP project duration is available, urgent action is required!

So, the Royal Netherlands Embassy will look with optimism into the future of the MRC-RFMMC, while we would like to invite also other donors to assess the options and to join us.

Last year during the 5th Forum, I explicitly mentioned in my speech that I would like to see more international financiers to join the establishment of this Centre, as well as running the Annual Flood Forum. I would like to repeat that call again.

On another note, I would like to mention that Royal Netherlands Embassy together with the Asian Development Bank (ADB) will organise a review of the FMMP in the second half of 2008 and we hope that this will provide the MRC and the FMMP with solid conclusions and recommendations for present and future operations.

Excellencies, distinguished delegates, Ladies and Gentlemen, let me wish you, participants, presenters and organizers, two useful, fruitful days, and a successful 6th Annual Mekong Flood Forum.

Thank you.

Dr. Armand Evers
First Secretary
Royal Netherlands Embassy
Hanoi, Viet Nam

SUMMARY OF THE 5TH ANNUAL MEKONG FLOOD FORUM (AMFF-5)

HATDA PICH AN

Operations Manager, MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC)
Phnom Penh, Cambodia

ABSTRACT

The MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) convened the 5th Annual Mekong Flood Forum (AMFF-5) in Ho Chi Minh City, Viet Nam on 17 - 18 May 2007, with the theme of *Improving Inputs towards Medium-term Flood Forecasting and Warning in the Mekong Basin*. Hosted by the MRC-RFMMC, the meeting was attended by approximately 140 representatives from the Mekong River Commission (MRC) Member States and Dialogue Partners, organisations working in the Mekong River Basin (MRB), International organisations, institutions and companies.

There were 40 presentations in the plenary and parallel sessions and 6 booths in the exhibition. Participants were briefed on flood-related conditions in the Basin in 2006 and human and technical capacities of the MRC Member States and the MRC-RFMMC. Presentations also were provided by participants from outside the Lower Mekong River Basin (LMB) by Dialogue Partners Myanmar and China, technical organizations that have capacities for implementing advanced forecasting and warning systems, and organizations that focus on providing flood-related forecasts and information to communities at flood risk.

Based on outcome of AMMF-5, the MRC-RFMMC and the MRC Member States will be able to improve their flood forecasting services, and strengthen their capability and collaboration mechanisms for real and near real-time data collection and transmission, among others, to enable the MRC-RFMMC to produce medium-term 6 to 10 days flood forecasts as needed by the MRC Member States.

Within the framework of the theme of AMFF-5 four topics were selected in such a way that the various relevant aspects of the theme could be covered. The four topics were:

I. Meteorology and weather forecast with respect to medium-term flood forecasting and warning;
II. Medium-term flood and water level forecasting;
III. Data and information requirement for effective early warning and flood preparedness measures;
IV. Data and information requirement for emergency management, relief and reconstruction.

At the end of the Forum the participants adopted the Forum Statement. This Statement clearly reflects the importance of flood forecasting, flood warning, and in fact of integrated flood management. The issue is not typical for the Mekong River Basin, but is globally of increasing importance due to the impacts of population growth and the increase in the value of agriculture, buildings and infrastructure in flood prone areas, as well as due to the possible impacts of climate change. On the other hand there is an increasing competition for water, especially during dry periods. In light of all these factors, sustainable development will require integrated approaches of the riparian countries in a river basin. It is hoped that the present Forum, as well as future Fora may deliver a substantial contribution towards such approaches in the Mekong River Basin.

INTRODUCTION

The MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) convened the Fifth Annual Mekong Flood Forum (AMFF-5) in Ho Chi Minh City, Viet Nam on 17 - 18 May 2007, with the theme of *Improving Inputs towards Medium-term Flood Forecasting and Warning in the Mekong Basin*. Hosted by the MRC-RFMMC, the meeting was attended by approximately 140 representatives from the Mekong River Commission (MRC) Member States and Dialogue Partners, organisations working in the Mekong River Basin (MRB), International organisations, institutions and companies.

The Mekong River Commission Secretariat (MRCS) Chief Executive Officer (CEO) Dr. Olivier Cogels formally welcomed meeting participants and was joined on the dais by Mr. Nguyen Hong Toan, Secretary General of Viet Nam National Mekong Committee (VNMC) and Member of the MRC Joint Committee for Viet Nam, who formally convened AMFF-5. They were joined by Dr Armand Evers, First Secretary, Water Management, of the Royal Netherlands Embassy in Hanoi, Vietnam, who made remarks on behalf of his government.

There were 40 presentations in the plenary and parallel sessions and 6 booths in the exhibition. Participants were briefed on flood-related conditions in the Basin in 2006 and human and technical capacities of the MRC countries and the MRC-RFMMC. Presentations also were provided by participants from outside the Lower Mekong River Basin (LMB) by Dialogue Partners Myanmar and China, technical organizations that have capacities for implementing advanced forecasting and warning systems, and organizations that focus on providing flood-related forecasts and information to communities at flood risk.

MAIN EXPECTED OUTCOME

Based on outcome of AMMF-5, the MRC-RFMMC and the MRC Member States will be able to improve their flood forecasting services, and strengthen their capability and collaboration mechanisms for real and near real-time data collection and transmission, among others, to enable the MRC-RFMMC to produce medium-term 6 to 10 days flood forecasts as needed by the MRC Member States.

TOPICS

Within the framework of the theme of the Forum four topics were selected in such a way that the various relevant aspects could be covered. The four topics were:

I. Meteorology and weather forecast with respect to medium-term flood forecasting and warning;
II. Medium-term flood and water level forecasting;
III. Data and information requirement for effective early warning and flood preparedness measures;
IV. Data and information requirement for emergency management, relief and reconstruction.

OBJECTIVES

The objectives of the AMFF-5 were formulated as follows:

- discuss short-term flood forecasting and the development of medium-term (6 - 10 days) forecasts for the Lower Mekong River Basin (LMB);
- presentation of lessons learned on 2006 floods by MRC Member States and Dialogue

Partners;

- presentation and discussion of especially water level and rainfall data collection and transmission, database software, tools for dissemination of flood forecasting and early warning products of MRC-RFMMC and line agencies of the MRC Member States;
- formulation of recommendations for actions on data collection and transmission for medium-term flood forecasting by MRC-RFMMC;
- to inform MRC Member States and Dialogue Partners on the database system of MRC-RFMMC for medium-term flood forecasting for the mainstream of the Mekong River;
- exchange experience and best practices with international organizations, academic institutions, and Civil Society Organisations (CSO);
- recommendations for actions to enhance database system establishment and data sharing among MRC Member States, Dialogue Partners and MRC-RFMMC, and for strengthening the cooperation and information exchange among the international community and civil society organisations (CSO).

RESULTS OF THE AMFF-5

Country reports and presentations of Dialogue Partners

During the Forum the four MRC Member States presented their country reports. In addition there were presentations by the Dialogue Partners China and Myanmar. Some key points that came out of the presentations and discussions were:

- as far as flooding is concerned 2006 was a moderate year. There were three damaging typhoons, the worst was Xangsane, with locally 250 - 500 mm rainfall;
- floods can be a benefit or a threat. An important and very substantial benefit is obtained by the use of floodwater for fisheries and recession agriculture in the Tonle Sap Great Lake area in Cambodia. In fact for these purposes large floods are more appreciated than small floods. Flood forecasting is also of importance for these purposes;
- it is considered to be very important to develop a good quality digital elevation model (DEM) of the MRB, while it is in fact the basis for all model simulations and forecasts. The presently available scarce topographic data often result in inadequate decisions;
- it was generally felt that substantial improvement of data collection and storage is needed. This will first of all require good measuring stations, but also a good database, that facilitates easy exchange of data between the MRC Member States, Dialogue Partners and the MRC-RFMMC;
- in the set-up of the database and simulation models a modular structure is very important to enable adding of new models and procedures by users in an easy way. This will also facilitate keeping up with technological changes.

MRC-RFMMC approach towards an improved medium-term flood forecasting and warning

The MRC-RFMMC is developing its new short and medium-term forecasting system for the mainstream of the Mekong River. Important components at present are the Hydrological Modelling System (HYMOS) database and the URBS flood routing model. In several papers as presented during the Forum the general set-up and details of the new approach was shown. The coming months will be used to make this approach ready for operation in close interaction with the MRC Member States and the Dialogue Partners. Practical experience is being obtained with flood early warning to flood-vulnerable communities in Cambodia. Among others it is of major importance that for local communities' information has to be submitted in the local language.

In addition, based on contributions from organisations active in the region, as well as at a

global scale there was a presentation of three papers during one of the plenary sessions and various papers under each of the topics during the parallel sessions. All papers are included in the proceedings.

Results of the plenary and parallel sessions

The content and summarised results of the parallel sessions on the four topics are as shown underneath. Based on the presentations and discussions more detailed recommendations were made on each topic. These will be used by the MRC-RFMMC during the further development of the new approach.

General items

There were four plenary presentations on respectively the International Centre for Water Hazard and Risk Management (ICHARM) in Japan, the Asia Flood Network (AFN), the flood forecasting system of the Yangtze River in China, and a global overview of developments and experiences. Especially the last presentation was of interest, because of the high accuracy of the flood forecasts that was presented. Based on these presentations the following recommendations were formulated:

- it is time that science, policy and the practice work closely together;
- take good note of global developments, interact with them and make use of them;
- the importance of the application of risk based approaches;
- man induced changes have significantly more impact than climate change, especially in case of densely populated and rapidly growing urban areas. This aspect deserves much more attention in design, operation and maintenance of flood protection schemes and in flood forecasting, warning and emergency relief approaches.

Topic I. Meteorology and weather forecast with respect to medium-term flood forecasting and warning

The meteorology, the weather forecast and the conditions in the river basin create the basis for an adequate flood forecasting and flood warning. Therefore an efficient data collection, processing and retrieval system for real or near-real time meteorological and weather forecast data will be of utmost importance to enable an adequate input to the river flow modelling and finally the issuing of forecasts. In case of the Mekong River Basin most of the data are collected by the agencies in the riparian states, while forecasts for the mainstream of the Mekong River are prepared by the MRC-RFMMC as well as by most of the riparian states. This will require a good compatibility of the data, based on agreed accuracy and protocols. The formulation of the requirements for such interrelated database systems in the conditions of the Mekong River Basin was an important aspect of Topic I. In addition to the plenary presentations there were five interesting presentations on new developments with respect to data collection and analysis. The presentations and discussion on this Topic resulted in the following summarized recommendations:

- make clear what means forecast, while this may have different meanings. For example meteorology and weather forecast, or medium-term water level forecast;
- update the network of data collection;
- improve information sharing/coordination between the MRC-RFMMC and the national forecast centres;
- reach agreement on forecast methodologies.

Topic II. Medium-term flood and water level forecasting

From the MRC-RFMMC, in addition to the existing short-term forecasts, reliable medium-term forecasts (6 - 10 days) are expected. These forecasts need to be based on up to date technology for data collection, processing, retrieval and subsequent river modelling, with a focus on flood forecasting, related to the risks in the flood prone areas. The output of these activities will be the forecasts. However, in order to prepare these medium-term forecasts an effective database and modelling software will be of utmost importance. The possibilities and requirements for exchange of input data to such a database and the required software under the present day and possible future conditions was the focus of Topic II. In addition to the plenary presentations there were six interesting presentations on new developments with models. The presentations and discussion on this Topic resulted in the following summarized recommendations:

- for medium and long term forecasts improvement is needed;
- a model gives only an approximation, the real forecast is made by the forecaster;
- it is desirable to have integrated forecast and warning systems. This is technically possible, however, it is politically difficult;
- develop criteria for model selection by the MRC Member States;
- with respect to observed rainfall: improve data collection, storage and retrieval;
- with respect to rainfall forecasts: make accurate estimations, both spatial and in time.

Topic III. Data and information requirement for effective early warning and flood preparedness measures

The responsible agencies in the MRC Member States are in charge of the early flood warning and the organisation of the flood preparedness measures. This requires an effective interaction between the MRC-RFMMC and the concerned agencies. In addition there is the requirement of the issuing of the flood forecasts to land and property owners, organisations in charge of public facilities and infrastructure provisions in the flood prone areas that potentially may suffer from a flooding. Therefore the focus of this Topic III was on what information is really needed by these institutions or individuals to enable them to take the best possible measures. In addition the Topic paid attention to the best modes to transfer the required information. In addition to the plenary presentations there were four papers with interesting approaches. The presentations and discussion on this Topic resulted in the following summarized recommendations:

- *data and information requirement for effective early warning*: correlation between rainfall data and floods, water levels at upstream stations and information on the correlation between stations, local models, local wisdom and flood marks;
- *data and information requirement for flood preparedness*: flood risk maps, location of high grounds, emergency plans, boundary and duration of floods and flood depth, plan for rapid removal and drainage of floodwater, density and composition of the population.

Topic IV. Data and information requirement for emergency management, relief and reconstruction

At the occasion of a flooding emergency management may require its own specific information and effective channels to transfer this information under generally complicated conditions. After the flooding when the flood water recedes, or even later on, may be again another type of forecast, or information will be required to enable effective relief and reconstruction measures, that often may include temporal solutions. Such aspects and experiences with these aspects were the focus of Topic IV. In addition to the plenary presentations there were four papers with interesting approaches. The presentations and discussion on this Topic resulted in the following summarized recommendations:

- *need for good technical data and information:* short-term, medium-term and long-term

water level forecasts; messages: easy to understand, local language, gender issues, tools and methods (e.g. flood proofing); risk and vulnerability;

- *capacity building:* of stakeholder/users: on understanding and the use of products, of national scientists: on replication of technology/models;
- *outreach:* awareness raising among the community and partners, partnerships for information sharing on good practices and lessons learned.

FOLLOW-UP

Three types of follow-up actions were formulated, being: follow-up directly after the Forum, recommendations for the 6th Annual Mekong Flood Forum (AMFF-6), more comprehensive follow-up actions. The more comprehensive follow-up actions concerned:

- continue with annual flood fora, based on actual topics of joint interest of the MRC Member States and the Dialogue Partners;
- develop the new robust short and medium-term flood forecasting system in close cooperation with MRC Member States and Dialogue Partners, based on state-of-the-art international experience;
- improve accessibility and exchange of data among MRC Member States and Dialogue Partners;
- develop a more integrated focus on flood forecasting, taking into account not only reduction/prevention of damage and casualties due to floods, but also the possibilities to increase the benefits of floods;
- improve the insight in economic impacts of improved flood forecasting and early warning (by MRC Member States).

FORUM CONCLUDING

The concluding session started with presentations of the summary of the proceedings of the 5th Annual Mekong Flood Forum by the forum facilitator. At the end of the Forum the participants adopted the Forum Statement. This Statement clearly reflects the importance of flood forecasting, flood warning, and in fact of integrated flood management. The issue is not typical for the Mekong River Basin, but is globally of increasing importance due to the impacts of population growth and the increase in the value of agriculture, buildings and infrastructure in flood prone areas, as well as due to the possible impacts of climate change. On the other hand there is an increasing competition for water, especially during dry periods. In light of all these factors, sustainable development will require integrated approaches of the riparian countries in a river basin. It is hoped that the present Forum, as well as future Fora may deliver a substantial contribution towards such approaches in the Mekong River Basin.

Finally, the concluding session ended with a vote of thanks to the organising staff of the MRC-RFMMC and Viet Nam National Mekong Committee (VNMC) by the Chief Technical Advisor (CTA) of the Flood Management and Mitigation Programme (FMMP) and the concluding speech of the Assistant MRCS-CEO.

OVERVIEW AND EXPECTED OUTCOMES OF THE 6TH ANNUAL MEKONG FLOOD FORUM (AMFF-6)

NICO BAKKER

Chief Technical Advisor, Flood Management and Mitigation Programme (FMMP), Mekong River Commission (MRC), Phnom Penh, Cambodia

ABSTRACT

This years' Annual Mekong Flood Forum is another unique opportunity to be a platform for presenting and discussing issues, which are considered functional to effectively reduce the negative impacts of floods.

Government representatives, line agencies, international and regional knowledge institutes, international and national non governmental organizations (NGO) and other stakeholders will bring their experiences, good practices, solutions and concerns to the Forum.

The nowadays challenge is to find added value and effectiveness in the combination of a variety of systems and sub-systems, which all contribute pieces to the solution of the complicated puzzle, called 'flood management and mitigation'.

The 6th Annual Mekong Flood Forum has a broad set of sub-themes but will give focus to medium-term flood forecasting and early warning and it is expected that the event will look into opportunities to improve the collection and sharing of data and information from the Mekong River Commission (MRC) Member States, regional and international sources, to improve the processing of the information and particularly the presentation of forecasting and early warning information in clear terms, suitable for practical purposes and applications.

The two days event will exchange the experiences and the lessons learnt about:

- character and impact of the floods in 2007;
- collection, transfer and exchange of weather information and data, real-time and near real-time hydrologic and rainfall data and information, especially from national and regional centres to the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC);
- ways to strengthen the ongoing process of cooperation further between line agencies and national centres of the MRC Member States, international and national organizations, institutes, NGOs and most importantly the target groups, the vulnerable communities living in the Lower Mekong River Basin (LMB);
- exchange and optimisation of good practices.

In line with recent forums the gradual orientation towards practical technical and practical issues may stimulate discussion and exchange of views. It is expected that this Forum will add to the success of earlier forums.

INTRODUCTION

Excellencies, Distinguished Delegates, Ladies and Gentlemen,

Allow me at the beginning of the Annual Mekong Flood Forum 2008 to shortly present:

1. the Annual Flood Forum Concept;
2. the Forum Objective;
3. specific expectations of the AMFF-6.

THE ANNUAL FLOOD FORUM CONCEPT

The MRC Regional Flood Management and Mitigation Centre in Phnom Penh (MRC-RFMMC), funded through the Flood Management and Mitigation Programme (FMMP) under the umbrella of the Mekong River Commission (MRC) annually organises the Annual Mekong Flood Forum.

The Annual Mekong Flood Forum envisages active participatory cooperation between the National Mekong Committees (NMC), national line agencies, national disaster management committees and agencies, concerned international and civil society organizations (CSO). It is envisaged also to build and maintain a professional network of Flood Management and Mitigation (FMM) practitioners and scientists in the Lower Mekong River Basin (LMB), from NMCs, line agencies, the scientific community, international organizations and non governmental organisations (NGO).

The forums will facilitate and foster FMM-related knowledge sharing, flood forecasting technology and routines, flood damage assessment and damage prediction, and socio-economic impacts of floods.

Since 2002 the MRC has successfully organised five Annual Flood Forums with respectively the following themes:

1. '*Flood Preparedness*';
2. '*Information Flow, Networking and Partnerships*';
3. '*Flood Management and Flood Mitigation in the Mekong Basin*';
4. '*Improving Flood Forecasting and Early Warning Systems for Flood Management and Mitigation in the Lower Mekong River Basin (LMB);*
5. '*Improved Inputs Towards Medium-Term Flood Forecasting and Early Warning in the Mekong River Basin*'

THE FORUM'S OBJECTIVE

Floods in the LMB are a basin-wide problem. Regional cooperation is therefore necessary to solve transboundary and regional issues related to floods and to share lessons learned on successful concepts and practices for coping with floods from the region and other parts of the Globe.

The MRC as an Intergovernmental River Basin Organization is the appropriate institution to foster such cooperative and coordinating activities among its Member States. Based on the 1995 Agreement, it has been assigned '*to promote, support, cooperate and coordinate in the development of the full potential of sustainable benefits to all riparian States*.'

In addition, MRC has committed itself to play a strong role in regional flood management and mitigation. In November 2001 the MRC Council has approved the MRC Strategy for FMM. To implement the Strategy a comprehensive Flood Management and Mitigation Programme (FMMP) was formulated in 2002. The FMMP started up its operations in the period 2002-2004, and is now in full swing.

The Annual Mekong Flood Forum will provide a platform to exchange experiences, to inform on new technologies and based on this to secure commitment as well as to strengthen cooperation for regional flood management. As this Forum is an annual event it provides a suitable framework for improvement and the development of a sustainable network among participants and participating organizations.

Each year the Forum provides the floor to present past activities, to discuss emerging needs and to review the progress each country has made towards a holistic and balanced flood management plan. Sharing knowledge and experiences has helped to strengthen regional cooperation and finally helped to promote a regional approach for flood management and mitigation in the Mekong River Basin (MRB).

SPECIFIC EXPECTATIONS OF THE 6th ANNUAL MEKONG FLOOD FORUM

The 6th Annual Mekong Flood Forum (AMFF-6) will focus on the theme and be 'result-oriented' in order to assure that the results can be applied by the MRC-RFMMC and the MRC Member States in their pursuit of improving data collection and sharing, which is the prerequisite for the attainment of reliable and dependable short-term and medium-term flood forecasting and early warning. The broader goal is that the countries will use the Annual Mekong Flood Forum as a mechanism to review and improve their own flood policies, strategies, plans and projects.

Based on the outcome of AMFF-6, the MRC-RFMMC and MRC Member States will be able to improve their flood forecasting services, and strengthen their systems, capabilities and collaboration mechanisms for real and near real-time data collection, transmission, processing and presentation in order to address the needs of the MRC Member States, which prefer the MRC-RFMMC to produce and timely disseminate medium-term flood forecasts and early warning information.

The 6th Annual Mekong Flood Forum for 2008 is set to discuss the following issues related to the establishment in the MRC-RFMMC of data transmission systems, database systems, interface platforms, models and model environments. The challenge is the integration of systems and subsystems into an overall concept, allowing future extension to processing more data and data sources and applying a greater variety of models and model environments.

The following elements are considered key to the enhancement of short-term and medium-term forecasts:

- to present and share lessons learned on the previous year flood (2007) by the concerned line agencies of the MRC Member States;
- to present and discuss the current status of data collection and transmission as well as data base systems, and interface platforms, visualisation/presentation and dissemination tools for flood forecasting and early warning products produced by the MRC-RFMMC and the National Centres;
- to share and discuss new systems and procedures for real and near real-time data collection and transmission, as these are required for operational short-term and medium-term flood forecasting to be carried out by the MRC-RFMMC;
- to keep the MRC Member States and their concerned line agencies informed about the progress with respect to the MRC-RFMMC flood forecasting database system. The database system as well as the exchange of data and data sharing among the MRC Member States and the MRC-RFMMC is essential for operational short-term and medium-term flood forecasting for the mainstream of the Mekong River, based on basin wide rainfall and water level availability;
- to exchange experience and best practices with international organizations, academic institutions, and CSOs on the processes and systems for data (real and near-real-time) collection and exchange for flood forecasting as well as database hardware and software for data storage and processing; to strengthen cooperation and information exchange among international community, international organisations (IO) and CSOs;
- to exchange experience on the requirements that the different types of land use and various types of measures pose to the flood forecasting and early warning systems in the conditions of the Mekong River Basin;
- to exchange information on to what extent flood forecasting and early warning results in information that enables institutions or individuals to take the best possible measures to reduce damage and number of casualties;
- to exchange experiences on lessons learned during previous flood events.

Excellencies, Distinguished Delegates, Ladies and Gentlemen,

I hope that this 6th Annual Mekong Flood Forum will be another inspiring event, where participants together create the environment and spirit to exchange experiences and viewpoints, aimed at the improvement of the approach, methodologies and practices to reduce the negative impacts of floods, while maintaining the environmental benefits of the floods.

May I thank you for your attention.

CAMBODIA'S COUNTRY FLOOD REPORT FOR 2007

SOK BUN HENG

National Flood Expert, National Flood Unit, Cambodia National Mekong Committee

ABSTRACT

A large part of Cambodia is situated in the Lower Mekong River Basin. Every year, it receives Mekong recurrent flood. The flood provides both important benefits, mainly during a normal flood, but also takes away many lives and causes tremendous economic damage during extreme floods. Cambodia has also experienced flash floods caused by heavy rainfall mostly in tributaries around the Tonle Sap Great Lake and eastern tributaries of the Mekong. This flood is swift and could last only for a few days, but often causes severe damage to crops and infrastructure.

In addition to Mekong floods or flash floods caused by heavy rainfall, drought is another risk, especially for rainfed cropping due to little rainfall.

Compared with floods in previous years, with the wettest years in 2000 and 2001 and the driest year in 1998, floods in 2007 can be considered as normal floods, which somehow bring benefits rather than destruction. The observed water level at almost all mainstream stations along the Mekong, Bassac and Tonle Sap rivers in Cambodia were lower than the alarm level, except at Koh Khel station, where from 17 - 19 October a water level was observed that was exactly equal to the alarm level of 7.40 m. Flood arrival time for 2007 was about 2 - 3 weeks later than normal with a peak value of 9.84 m on 8 October at Mekong-Stung Treng station, while the peak value in 2006 was 10.24 m on 17 August.

In early August of 2007 a tropical storm 'Pabuk' with strong intensity covered the northern part and coastal area of Cambodia, produced heavy rainfall over those areas and caused flash floods in the some provinces.

According to the Provincial Committees for Disaster Management (PCDM) in the provinces along the Mekong, damage by Mekong floods for 2007 was somehow smaller than in previous years. A report shows that damages by 2007 floods were: 4 sites of small roads in the villages, 600 m of dykes and canals, 2 small bridges in the villages, 1,239 ha of rice and other crops, and 773 ha of rice and other crops affected by drought. The reports from the provinces affected by 2007 flash floods show that 16,100 families with more than 160,000 persons were affected, 5 people were killed, damages to more than 37,231 m of small roads in the villages, 8 public buildings and pagodas, more than 9,577 m of dykes and canals, rice and other crops at 8,245 ha, while 158 ha in Siem Reap were affected by drought.

Many concerned organizations have been working very hard to provide flood forecasting, flood warning and flood preparedness services, but due to limited financial and technical expertise there are gaps between the needs and the services available. More efforts are needed to meet the needs and to build the capacity for people to rely on themselves to reduce the risks.

This paper gives the review of the 2007 floods, the efforts and lessons learned, and provides some recommendations for improvement for the flood year to come.

INTRODUCTION

In general, Cambodia experiences two kinds of floods, Mekong floods and flash floods. For many years, people have been living with floods, taking the advantages from floods and also

suffering mainly from extreme floods. The Mekong floods play an important role in the development of the country as they carry and distribute fertile silt into the floodplain for agriculture production, feed the food chain for fisheries, provide water supply for people living along the river side, provide navigation routes and necessary environmental functions, but extreme floods usually cause severe damage and suffering, especially to people lving in low lying areas. It is, therefore important to find ways how to get the maximum benefits from floods and to minimise risk or damages from floods. To achieve this more effort and commitment as well as coordination and cooperation between institutions and people concerned are needed.

This report is the seventh in the series of national flood reports presented at each of the MRC Annual Mekong Flood Forums. The topic of the Forum for 2007 is 'Integrated Approaches and Applicable Systems for Medium Term Flood Forecasting and early Warning in the Mekong Basin'. The report intends to present an overview of flood and drought characteristics of the country, reports on the lessons learned from 2007 floods and provides some recommendations for improvement for the flood year to come.

OVERVIEW OF THE 2007 FLOODS AND FLOODING

Compared with the floods in previous years, with the wettest years in 2000 and 2001 and the driest year in 1998, floods in 2007 can be considered as normal floods, which somehow bring benefits rather than destruction. The observed water levels at almost all mainstream stations along the Mekong, Bassac and Tonle Sap rivers in Cambodia were lower than the alarm level, except at Koh Khel station, where from 17 - 19 October a water level was observed that was exactly equal to the alarm level of 7.40 m. Flood arrival time for 2007 was about 2 - 3 weeks later than normal with a peak value of 9.84 m on 8 October at Mekong-Stung Treng station, while the peak value in 2006 was 10.24 m on 17 August. There were little damages compared to extreme floods in some other years. According to the reports provided by the Provincial Committees for Disaster Management (PCDM) in three provinces along the Mekong River the flood in 2007, as shown in Table 1, caused damage to 4 sites of small roads in the villages, 600 m of dykes and canals, 2 small bridges in the villages, 1,239 ha of rice and other crops, while 773 ha of rice and other crops were affected by drought.

Table1. Impact of floods during 2007 in some provinces

Description	Provinces								
	Mekong flood				Flash flood				
	Kg Cham	Kratie	Stung Treng	Total	Prash Vihear	Ratana kiri	Kg Thom	Siem Reap	Total
Households affected					3,025	1,876	11,207		16,108
House damage					11				11
People affected						91,135	56,035		147,170
People killed					3		2		5
Roads affected		4 sites		4 sites	34,056 m		3,175 m		37,231 m
Schools and pagodas							6		6
Public buildings							2		2
Dykes and canals in m		600		600	8		9,577		> 9,577
Bridge sites		2		2	7				7
Animals					273	14			287
Rice and crop (drought) in ha	773			773				158	158
Rice and crop (flood) in ha		426	813	1,239	2,545		5,700		8,245

During 4 - 7 August the low-pressure area and topical storm 'Pabuk' with strong intensity covered the northern part of Cambodia, produced heavy rainfall over those areas and caused flash floods in the provinces of Ratanakiri, Preah Vihear and Kampong Thom. The reports from

these affected provinces, as shown in Table 1, show that 16,100 families with more than 160,000 persons were affected, 5 people were killed, there was damage to more than 37,231 m of small roads in the villages, 8 public buildings and pagodas, more than 9,577 m of dykes and canals, rice and other crops at 8,245 ha, while in Siem Reap 158 ha were affected by drought.

According to the PCDMs in the provinces along the Mekong, damages by Mekong floods for 2007 were somehow smaller than in previous years. These positive results surely came also from better forecast, warning and preparedness services provided by the concerned agencies and cooperation of the local authorities and local people themselves, while damages by flash floods remained a big issue with little or no measures in place to cope with the risk, except emergency relief or rehabilitation after floods.

Hydrometeorological characteristics of flood and flooding

The climate characteristics of Cambodia are tropical monsoon with alternating wet and dry seasons. The dry season (Northeast monsoon): occurs from October/November to May/June. During this period there is a relatively cool and dry season from November to February with mean monthly temperature from 25 - 28 ^{o}C and a daily minimum of 19 ^{o}C in November. From mid-March to mid-May humidity increases and mean monthly temperature can range from 28 - 31 ^{o}C. The daily maximum rises to 36 ^{o}C in March/April and the relative humidity varies from 64 - 83%. From June to October the wet season has mean monthly temperature of 26 - 30 ^{o}C and relative humidity from 80 - 94% with heavy and frequent rains. A short drought period of 1-2 weeks is occasionally encountered between June and August.

In 2007 maximum temperature could range from 31.4 - 33.6 ^{o}C and average temperature was 32.4 ^{o}C. The minimum temperature could range from 21.0 - ^{o}C with average of 23.4 ^{o}C. The annual rainfall was about 1,757 mm and it ranged from 1,097 - 3,860 mm as shown in Figure 1. The relative humidity was observed in Pochentong station and was 47% in April and 95% in September. In 2007 the rainfall distribution was good enough in the whole country but it did not contribute to a high flow of Mekong River. Flash floods mostly occur in the mountainous areas with high rainfall intensity and affected by typhoons or storms in the region. During the first week of August some parts of the country were affected by a tropical storm, which produced very heavy rainfall and caused flash floods in some provinces in the north-eastern and south-western part of the country. The total of rainfall distribution in Cambodia in 2007 is shown in Figure 2.

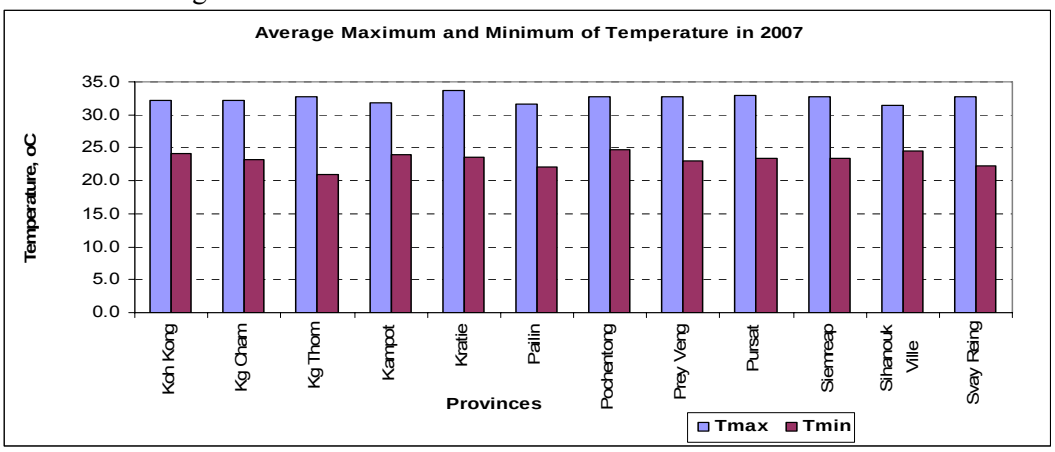


Figure 1. Average maximum and minimum temperature in 2007

In general, the rainfall in Cambodia is distributed according to the geographical characteristics of the country, which are coastal area, mountainous area, the highland and lowland areas with more rain in the coastal area, medium in the highlands and less in the lowlands.

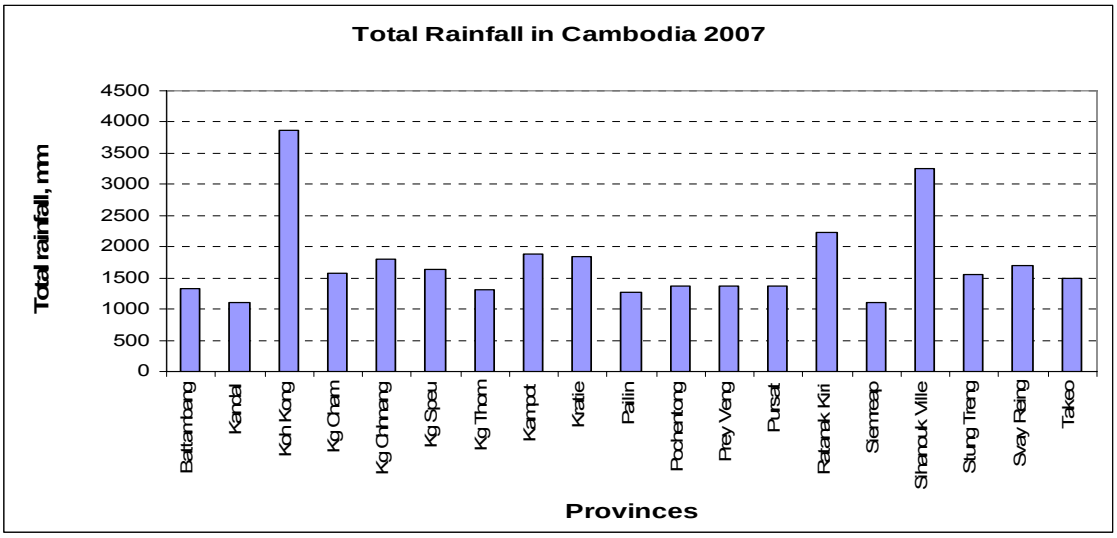
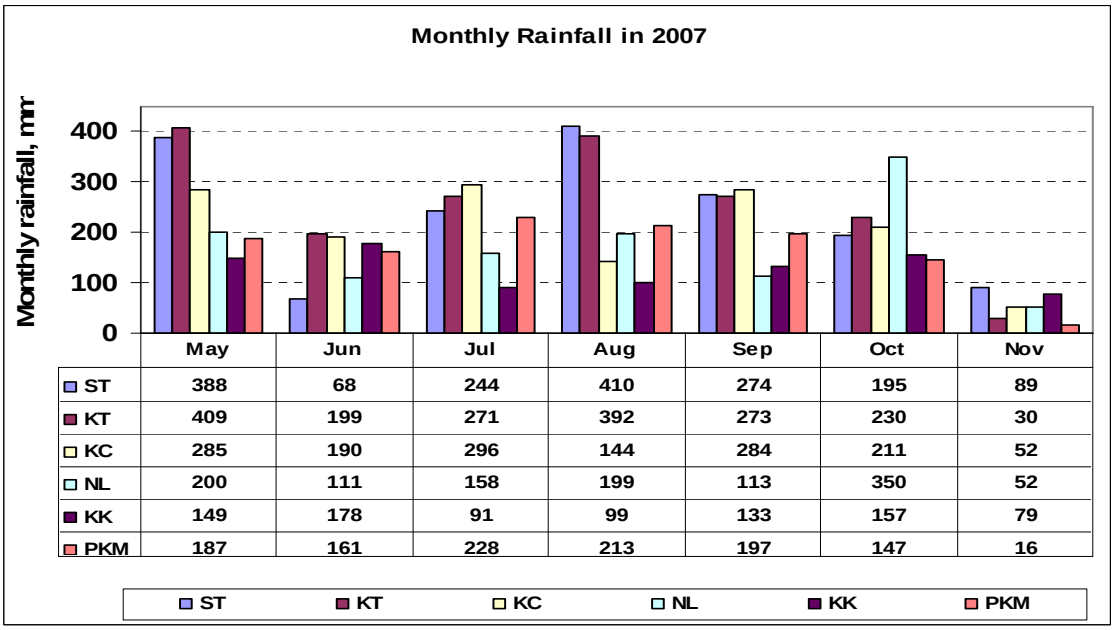


Figure 2. Total annual rainfall by province in Cambodia in 2007

Rainfall distribution at main stations of the Mekong, Bassac and Tonle Sap rivers in Cambodia in 2007

In 2007 monthly rainfall as observed in the main hydrological stations shows that the rainfall increased from the beginning of May with a high amount of rainfall. In 2007, as shown in Figure 3, the maximum rainfall occurred in May and August at Stung Treng and Kratie. But in 2006 the maximum rainfall occurred in July and August as shown in Figure 4.



	May	Jun	Jul	Aug	Sep	Oct	Nov
ST	388	68	244	410	274	195	89
KT	409	199	271	392	273	230	30
KC	285	190	296	144	284	211	52
NL	200	111	158	199	113	350	52
KK	149	178	91	99	133	157	79
PKM	187	161	228	213	197	147	16

Figure 3. Monthly rainfall along the mainstream of the Mekong, Bassac and Tonle Sap rivers in 2007

Local heavy rainfall in some provinces during 4 - 5 August

Cambodia is situated in the monsoon region receiving frequent heavy rainfall with strong winds caused by typhoons and low atmospheric pressure during the rainy season. Usually those heavy rains caused by typhoons or storms affect the central areas of Vietnam or Thailand. On 4 - 7 August the low-pressure area and topical storm 'Pabuk' with strong intensity covered the

northern part and coastal area of Cambodia, produced heavy rainfall over those areas and caused flash floods in the provinces of Kosh Kong, Ratanakiri, Preah Vihear and Kampong Thom, Bantay Meanchey, Battambang, Sihanoukville. The daily rainfalls recorded during the period from 1 - 10 August with high intensity of rainfall in some provinces are shown in Table 2 and Figure 5. General weather conditions in the region, associated with this period are presented in Figure 6.

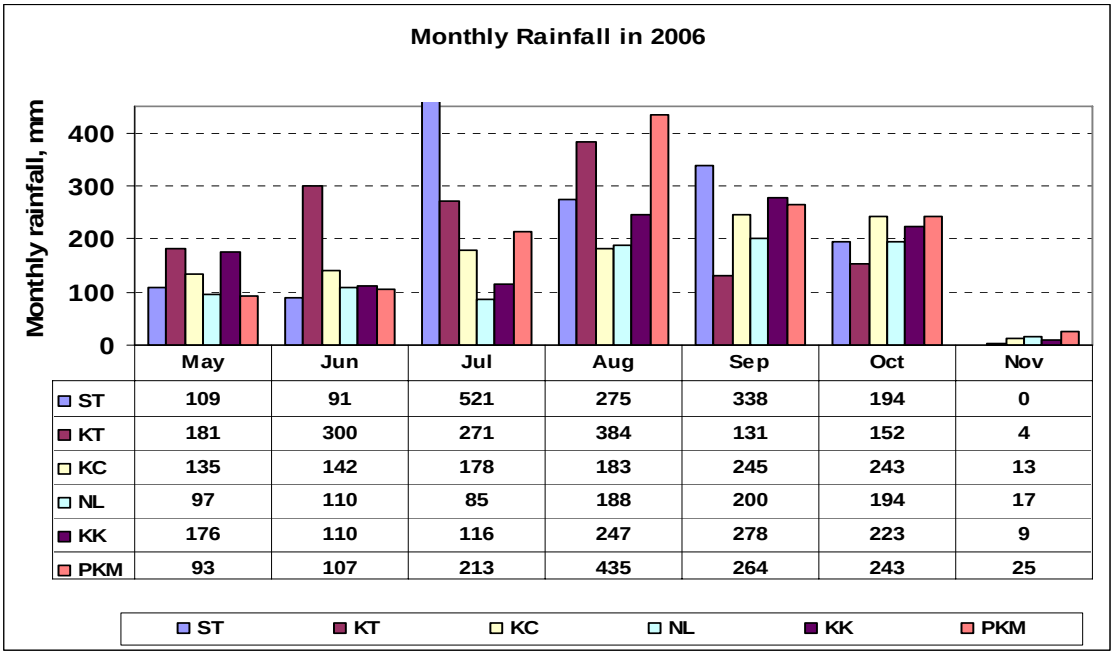


Figure 4. Monthly rainfall along the mainstream of the Mekong, Bassac and Tonle Sap rivers in 2006

Table 2. Daily Rainfall in millimetres recorded during the period from 01-10 August

Date in August 2007	24 hours rainfall from 1 – 10 agust 2007 in 5 provinces				
	Kon Kong	Mondulkiri	Preh Vihear	Ratanakiri	Stung Treng
1	11.5	25.0	3.0	57.0	8.6
2	17.0	23.8	0.0	36.4	3.5
3	0.5	57.0	2.0	0.0	5.5
4	173.6	102.0	0.0	21.2	37.8
5	96.7	68.4	359.5	143.1	131.1
6	7.5	17.8	33.5	9.2	30.1
7	66.5	14.6	0.0	13.4	0.0
8	32.0	11.3	1.0	13.8	0.0
9	61.0	16.0	0.0	5.8	0.0
10	52.2	6.4	0.0	8.2	20.5
Maximum	173.6	102.0	359.5	143.1	131.1
Mean	51.9	34.2	39.9	30.8	23.7

Mekong floods

The Mekong flood in 2007 can be considered as a normal flood with observed water levels at almost all mainstream stations along the Mekong, Bassac and Tonle Sap rivers in Cambodia that were lower than the alarm level, except at Koh Khel station from 17 - 19 October a water level was observed that was exactly equal to the alarm level of 7.40 m. Flood arrival time for 2007 was about 2 - 3 weeks later than normal with a peak value of 9.84 m on 8 October at Mekong-Stung Treng station while the peak value in 2006 was 10.24 m on 17 August.

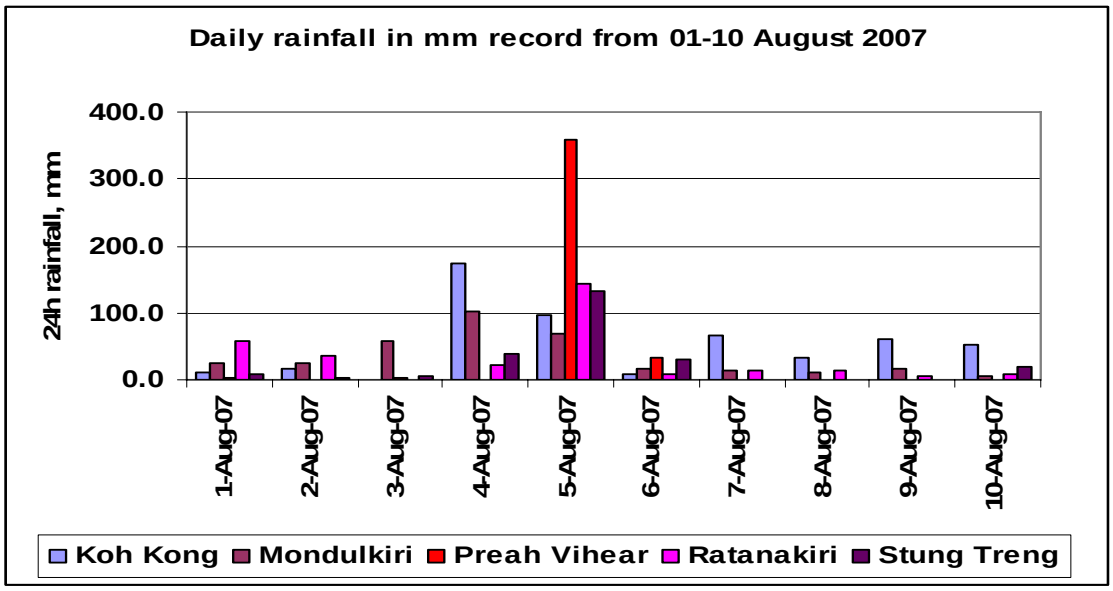


Figure 5. Daily rainfall in mm recorded from 1 - 10 August

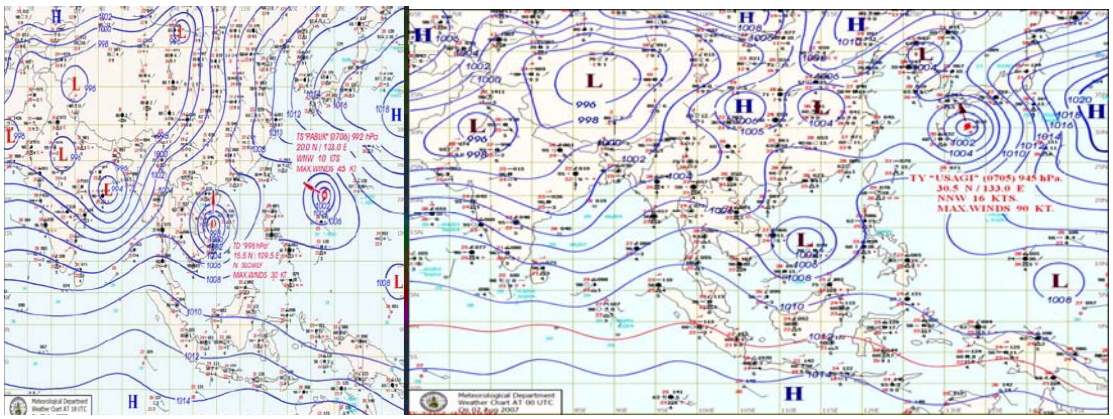


Figure 6. General weather condition observed at 7:00 hr on 2 and 6 August

Figures 7 to 9 show the hydrographs of the flood situation in 2007 compared with previous years in some stations along the Mekong, Basac and Tonle Sap rivers, in 1998, 2000, 2001, 2005, 2006, and mean from 1991 - 2006.

In general, the flood in 2007 was below the warning/alarm level. It was -0.88 m at Stung Treng, -1.66 m at Kratie, -0.68 m at Kompong Cham, -0.89 m at Chaktomuk, -0.49 m at Neak Loung, and -0.72 m at Prek Kdam, but, as said, at Koh Khel the water level reached exactly the alarm level of 7.40 m during 17 - 19 October.

Table 3 shows the annual maximum water level, date, flood warning level and flood level at 7 stations of Stung Treng, Kratie, Kompong Cham, Chaktomuk, Neak Loung, Koh Khel and Prek Kdam from 1991 to 2007. Long-term observations show that flood peaks occur during August to October and start to recede not later than at the end of November.

The Tonle Sap Great Lake

The Tonle Sap Great Lake in Cambodia, which is fed annually by the Mekong reverse flow, plays an important role in flood peak attenuation and flow control to the Mekong delta. The Lake receives over 50% of its volume from the Mekong flood flow. There is a limited comprehensive hydrological data collection in the Tonle Sap Great Lake area. The Lake is the biggest water lake in Southeast Asia with its volume and flooded areas fluctuating on an annual

basis and normally the lake water level reaches its peak during the period of heavy rainfall in the Tonle Sap Great Lake sub basins. The Tonle Sap Great Lake has a mean dynamic surface area of 8,200 km^2, from about 2,500 km^2 in the dry season to over 15,000 km^2 in some wet seasons. A unique phenomenon occurs annually. That is, the water flows into the lake during May/June and the stored water flows back into the Lower Mekong and Bassac rivers in September/October. The water level in the Tonle Sap Great Lake fluctuates between wet and dry season by about 7 to 8 m. The lake water level in 2007 reached its peak level at 8.34 m on 23 October. Figure 10 shows hydrographs of the flood situation in 2007 compared with previous years in the Tonle Sap Great Lake in Kampong Loung for 1999, 2000, 2001, 2002, 2004, 2006 and 2007.

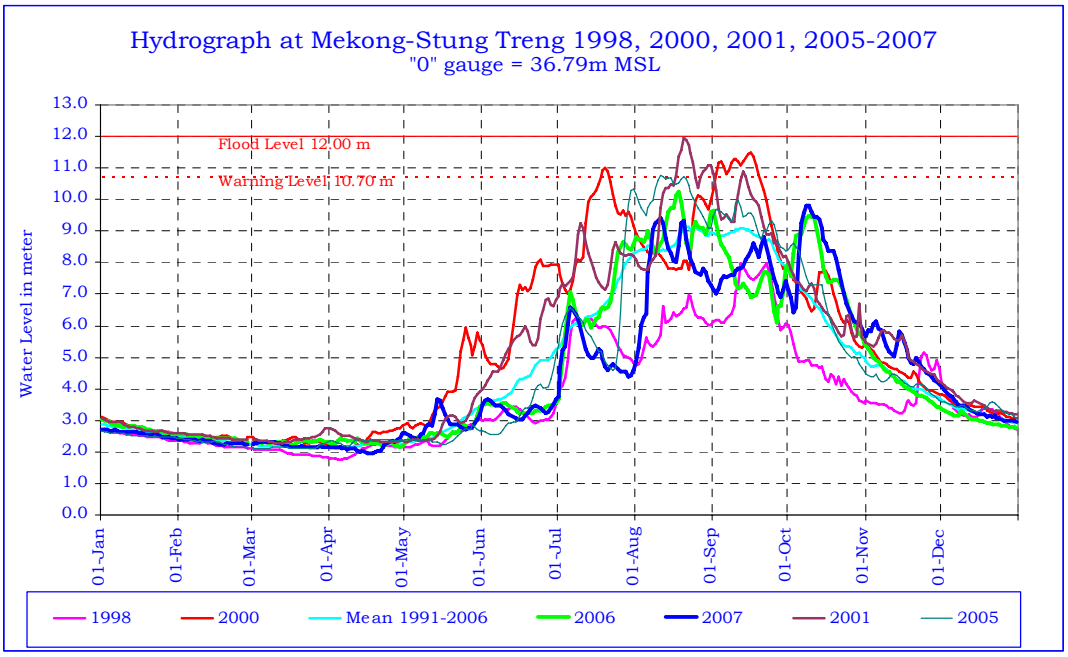


Figure 7. Hydrograph at Mekong River - Stung Treng in 1998, 2000, 2005-2007

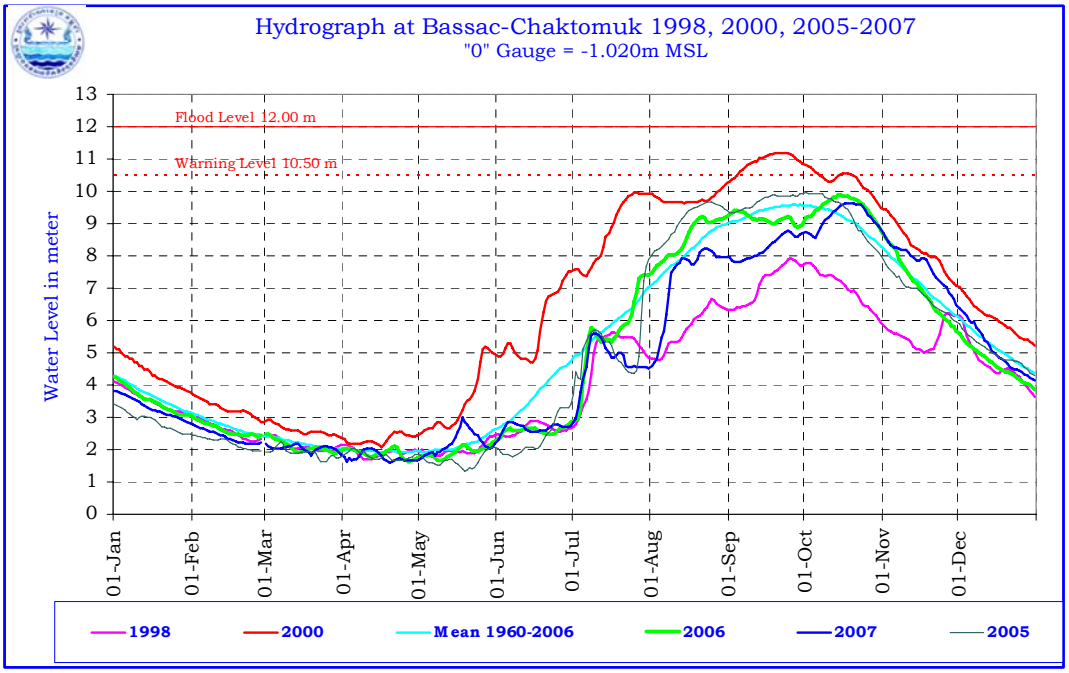


Figure 8. Hydrograph at Bassac River - Chaktomuk in 1998, 2000, 2005-2007

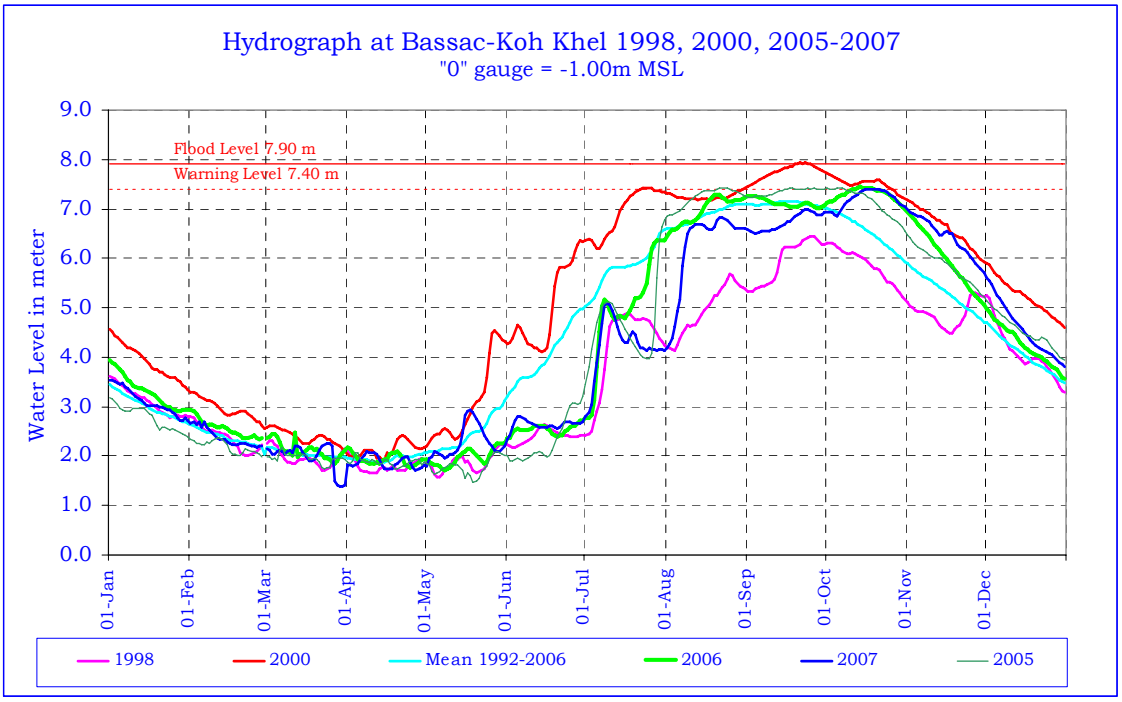


Figure 9. Hydrograph at Bassac River - Koh Khel in 1998, 2000, 2005-2007

Flash floods in 2007

The flash floods in Cambodia are caused by heavy local rainfall in its river basins or by typhoons or storms affected from the neighbouring countries, Vietnam and Thailand. There are no comprehensive data on these river basins, even not on the rainfall distribution.

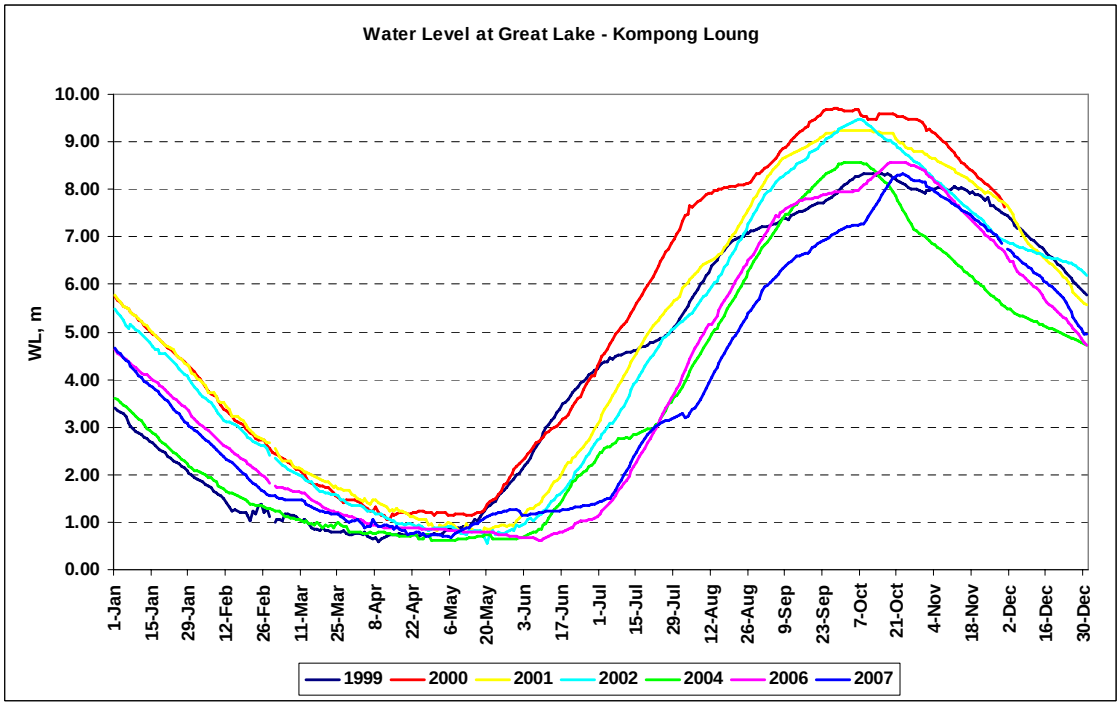


Figure 10. Hydrograph at Tonle Sap Great Lake - Kampong Loung in 1999, 2000, 2001, 2002, 2004, 2006 and 2007

Table 3. Annual maximum water level along the Mekong, Bassac and Tonle Sap rivers from 1991 - 2007

Station Name Station Code	Stung Treng 014501		Kratie 014901		Kampong Cham 019802		Chak Tomuk 033401		Neak Loeung 019806		Koh Khel 033402		Prek Kdam 020102	
Flood Level	12.00		23.00		16.20		12.00		8.00		7.90		10.00	
Warning Level	10.70		22.00		15.20		10.50		7.50		7.40		9.50	
Zero Gauge, m MSL	+36.79		-1.08		-0.93		-1.02		-0.33		-1.00		+0.08	
Year	Max	Date	Max	Date	Max	Date	Max	Date	Max	Date	Max	Date	Max	Date
1991	11.58	30-Aug	22.55	8-Sep	15.70	9-Sep	10.56	11-Sep	7.68	12-Sep			10.05	5-18 Oct
1992	9.08	28-Aug	20.08	23-Aug	14.06	2-Sep	9.01	2-3 Sep	6.24	3-Sep	6.99	27-28 Jul	7.54	6-Sep
1993	8.82	22-Aug	19.28	16-Sep	13.43	17-Sep	8.95	19-Sep	6.20	19-Sep	6.85	20-Aug	7.79	22-Sep
1994	10.77	5-Aug	21.65	6-Aug	15.17	12-13 Sep	10.53	29-30 Sep	7.52	15-16 Sep	7.53	26Aug-03Sep	9.69	2-Oct
1995	10.75	7-Sep	21.66	8-Sep	15.26	9-10 Sep	10.14	18-19 Sep	7.32	17-Sep	7.40	21-Aug	9.40	12-Oct
1996	12.19	24-Sep	23.01	28-Sep	16.11	29-Sep	10.94	2-Oct	8.00	2-Oct	7.78	2-5 Sep	9.74	2-3 Oct
1997	11.83	4-Aug	22.46	6-Aug	15.74	7-Aug	10.05	1-Oct	7.24	26-Aug	7.40	10-Jul	9.07	9-Oct
1998	7.97	22-Sep	17.86	24-Sep	12.24	25-Sep	7.92	25-Sep	5.42	25-Sep	6.44	26-27 Aug	6.70	2-Oct
1999	10.46	2-Aug	20.96	5-Aug	14.72	8-9 Aug	9.88	4-6 Oct	7.00	5-Oct	7.28	4-Oct	8.81	7-Oct
2000	11.49	16-Sep	22.61	17-Sep	15.91	18-Sep	11.20	21-Sep	8.12	20-Sep	7.94	23-Sep	10.26	23-25 Sep
2001	11.96	20-Aug	22.90	22-Aug	16.09	22-23 Aug	10.75	19-Sep	7.85	26-Sep	7.72	3-Sep	9.78	26-Sep
2002	11.53	23-Aug	22.49	23-Aug	15.91	25-Aug	10.65	29-Sep	7.89	29-30 Sep	7.72	29-Sep	9.92	30-Oct
2003	10.23	15-Sep	20.98	17-Sep	14.89	18-Sep	9.41	22-23 Sep	6.98	23-Sep	7.37	21-Sep	8.34	23-Sep
2004	10.22	15-Sep	21.19	17-Sep	15.07	18-19 Sep	9.97	25-26 Sep	7.41	25-Sep	7.53	25-Sep	9.09	27-Sep
2005	10.76	11-Sep	21.62	21-Aug	15.35	22-Aug	9.95	1-Oct	7.33	18-Sep	7.42	1-Oct	9.21	1-Oct
2006	10.23	18-Aug	21.19	18-Aug	14.96	19-Aug	9.90	14-Oct	7.16	16-Oct	7.44	14-Oct	9.07	14-Oct
2007	9.82	8-Sep	20.34	9-10 Oct	14.52	14-Sep	9.64	18-19 Oct	7.01	18-Oct	7.40	17-19 Oct	8.78	22-Oct

On 4 - 5 August the low-pressure area and topical storm 'Pabuk' with strong intensity covered the northern part and coastal area of Cambodia, produced heavy rainfall over those areas and caused flash floods in the provinces of Kosh Kong, Ratanakiri, Preah Vihear and Kampong Thom, Bantay Meanchey, Battambang, Sihanoukville. The daily rainfall recorded during the period from 1 - 10 August with high intensity of rainfall in some provinces is shown in Table 2. The general weather condition in the region observed at 7:00 hr on 2 and 6 August is shown in Figure 6.

Maximum daily rainfall observed during the days of large amounts of rainfall in 5 provinces is respectively 174 mm (4 August) in Koh Kong, 102 mm (4 August) in Mondulkiri, 360 mm (5 August) in Preah Vihear, 143 mm (5 August) in Ratanakiri and 131 mm (4 August) in Stung Treng. During that time the maximum daily rainfall in those provinces reached the range from 131 to 177 mm/day. This very heavy rainfall reached the ground and caused flash floods in those provinces. The most severe was Kampong Thom followed by Prah Vihear and Ratanakiri. Figure 11 shows the hydrograph at Sre Pork-Lumphat-Ratanakiri observed in 2000, 2001, 2002, 2003, 2004, 2005 and 2007 and Figure 12 shows the hydrograph at Se San-Ban Kamphun-Stung Treng observed in 2000, 2001, 2005, 2006 and 2007.

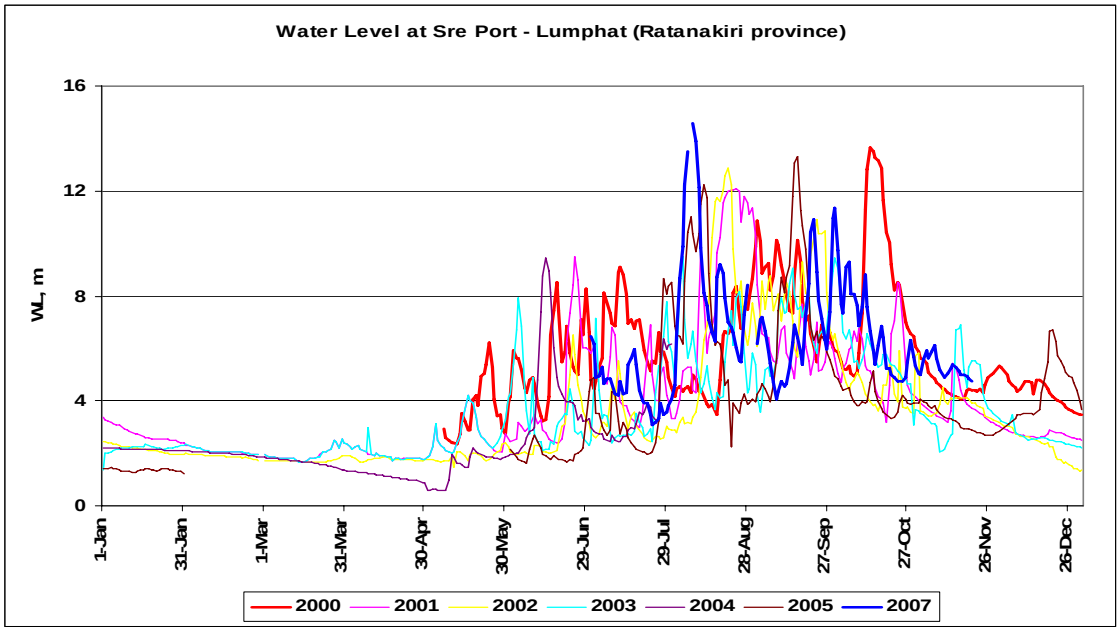


Figure 11. Hydrograph at Sre Pork-Lumphat-Ratanakiri in 2000, 2001, 2002, 2003, 2004, 2005 and 2007

Summary of positive and negative effects of the floods

Floods in Cambodia produce both negative and positive effects. Usually normal floods produce more benefits rather than destruction. While enjoying with positive effects of floods people also suffer from the extreme flood years. Excess water of high level washes away dams, dikes and distribution structures, destroys crops and livestock, damages homes, temples, schools, clinics, roads, and other infrastructure of the flooded communities. The floods may cause great loss of properties and human lives, disrupt livelihood and socio-economy of the country, hinder country's development and even adhere the poverty line of the people. Recent extreme floods during 2000, 2001 are the examples of destructive floods.

Positive impacts of floods include improved soil moisture and fertility for agriculture, groundwater and surface water recharge, and ecological benefits for fisheries and forests.

Floods in the basin are parts of the daily life of the people as water nourishes large tracts of forest and wetlands, which produce housing materials, medicines and food, provides habitats for thousands of species of plants and animals and supports inland navigation and capture

fishery. Recession agriculture along the Mekong River and around the Tonle Sap Great Lake waiting for floodwater to fill the reservoir or lake and people start to do their recession agriculture when water starts to recede. Farmers in these areas will suffer from food shortage if there is no floodwater to fill their water storages. Up to 65% of the cultivated land is covered each year by floodwater. About 3 million people earn subsistence-level incomes from fishing from the Tonle Sap Great Lake and other seasonally flooded areas of Cambodia. Fish provides 60% of the protein intake of the population. It is believed that extreme floods produce good fish production. Moreover, floods also play an important role in maintaining biodiversity values for theMekong River Basin, especially in the wetlands in the Lower Mekong Delta (LMD).

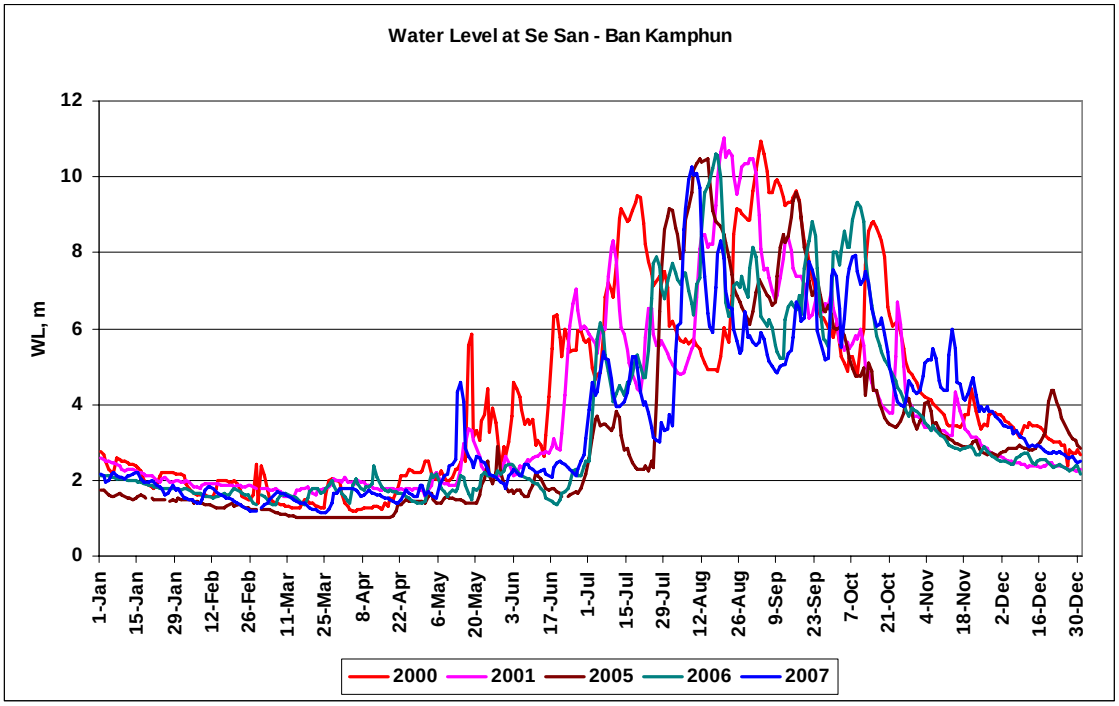


Figure 12. Hydrograph at Se San-Ban Kamphun-Stung Treng in 2000, 2001, 2005, 2006 and 2007

LESSONS LEARNED

Natural floods and man-induced floods are interrelated. Based on its scale a flood can be a benefit or a disaster. For many years, there have been efforts to reduce flood effects, especially after the 2000 severe floods. Flood damages will be reduced if the gaps and needs in terms of flood management and mitigation are fulfilled and met. According to previous experiences better preparedness will help to considerably reduce damages by flood. The key gaps identified in the past are:

- lack of systematic flood preparedness planning process at provincial, district and commune level;
- weak or limited coordination between institutions and agencies concerned;
- poor access to flood information;
- lack of funds to support field staff to collect data from hydrological stations;
- lack of funds for operation and maintenance of equipment;
- isolated intervention will never assure comprehensive data collection and continuation of activities initiated by the projects. Usually activities stop after completion of the project;
- flash floods are even more destructive as it are rare events, and the country still lacks human and financial resources, capacity and a methodology for flash flood forecasting;

- lack of continuity and technical expertise to assess aggregated cause-and-effect relationships.

Flash flood in Ratanakiri on 6 August

Flash flood in Kampong Thom on 5 August

Flash flood in Prash Vihear on 5 August

UPDATE ON THE NATIONAL FORECASTING AND WARNING CENTRES

In general, flood forecasting in Cambodia can be described as in its early stage of development and still facing many challenges. The Department of Hydrology and River Works (DHRW) of the Ministry of Water Resources and Meteorology (MOWRAM) in Phnom Penh is responsible for hydrological data collection and forecasting in the country. The Department of Meteorology (DOM) is responsible for meteorological data collection and weather forecasting. The National

Committee for Disaster Management (NCDM) and Cambodian Red Cross (CRC) use forecast products of the two departments to disseminate it to communities.

Current status of National Centres

Department of Hydrology and River Works (DHRW)

The Department of Hydrology and River Works (DHRW) is responsible for hydrological data collection and forecasting in the country. The DHRW also cooperates with the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) in forecasting and dissemination of flood information. DHRWs forecasting time is only three days while MRC-RFMMC forecasts for 5 days.

There are about 40 stations serving for hydrological data collection in the country. At the moment, not all the stations are operational due to the lack of operational and maintenance funds. Currently DHRW forecasts only on the mainstreams of Mekong, Bassac and Tonle Sap rivers. Data for flood forecasting on these 7 hydrological stations are transmitted real time water level and rainfall data to DHRW before 7:00 hr by telephone. Usually data are collected and transmitted twice a day at 7:00 hr and 19:00 hr. In extreme cases the data can be sent up to 6 times per day, especially during the peak flood. Those 7 stations are: 1. Mekong-Stung Treng, 2. Mekong-Kratie, 3. Mekong-Kompong Cham, 4. Bassac-Chaktomuk, 5. Mekong-Neak Loung, 6. Bassac-Koh Khel, and 7. Tonle Sap-Prek Kdam.

The DHRW reports to MOWRAM and other key agencies once data and information are received from the real time stations. The DHRW then enters these data into a computer base forecasting system for checking, analysing, processing and producing forecasts for 3 days ahead by using the method of station correlation.

Finally, a Flood Forecasting Bulletin is printed, approved and then send to mass media, concerned line agencies and the end-users by fax around 9:00 hr everyday to about 60 users.

The DHRW also exchanges data and information between countries in the Lower Mekong River Basin though the Mekong River Commision Secretariat (MRCS) by using e-mail and Internet. DHRW receives the MRCS flood forecasting products by e-mail and also sent back to MRC-RFMMC its Flood Forecasting Bulletin by fax.

Under a five-year project (2003 - 2007) of the MRC-RFMMC funded by the U.S. Agency for Development, Office of Foreign Disaster Assistance (OFDA) *'Flood Early Warning to Flood-Vulnerable Communities in the Lower Mekong Basin'*, DHRW makes water level forecasting under a services contract agreement with MRC-RFMMC for 40 pilot villages along the mainstream of the Mekong River by using a simple regression method. The DHRW produces the 3 days Flood Forecasting Bulletin and sends it to the 40 flood vulnerable villages at 11:30 hr everyday during the flood season through the CRC flood warning network. Through this channel DHRW also receives water level data from 40 flood marks of 40 targeted villages of 5 provinces in Cambodia by email from CRC (Figure 13). The DHRW also sends the flood forecasting products to CRC and MRC-RFMMC via e-mail before 13:30 hr.

Recently forecasting by DHRW was limited to only major mainstream stations along the Mekong, Bassac and Tonle Sap rivers with a maximum lead time of 3 days and applying simple forecasting methods-station correlations.

The capacity of DHRW is still limited both in terms of financial and human resources. They still lack adequate data, forecasting tools and qualified forecasters. Data collection has been neglected for many years due to lack of funds and qualified technical personnel and weak management. The current data collection system is not sustainable and limited to the mainstream stations only, which is mainly supported by the MRC program. Only some stations can keep proper records with limited funds of the Provincial Department of Water Resources and Meteorology (PDWRAM).

The extension of forecasts to other vulnerable communities is supported by projects, which leaves an uncertain future after the end of the project.

Department of Meteorology (DOM)

The Department of Meteorology (DOM) is responsible for meteorological data collection and weather forecasting in the country. Although weather forecasting is limited due to various reasons it also can serve as complementary information for flood forecasting. There is no practical forecast and rainfall forecast. Currently weather forecast done by DOM is mainly based on information obtained from Internet and the forecast is limited to a simple description of weather and temperature conditions. Due to the low capacity, it is foreseen that longer term forecasting using national rainfall forecasting is not possible in the near future.

There are some automatic rainfall stations that have been installed countrywide by different projects, but only some of them are in operation due to lack of operation and maintenance, inadequate training and poor management.

Other manual rainfall data are collected at the provincial and district level but not properly or not timely reported on a daily, monthly or annual basis to DOM. Often small monthly observation fees were paid to observers, creating difficult personnel communication. After each severe event such as droughts or storms, there is no report and analysis available in the media as reference to the degree of severity of the events. Archived data are not accessible without payment and usually only monthly data are available.

National Committee for Disaster Management (NCDM) and Cambodian Red Cross (CRC)

The National Committee for Disaster Management (NCDM) which was established in 1995, is responsible for providing timely and effective emergency relief to the victims of all kinds of disasters and also develops preventive measures to prevent or reduce the effects of the disasters. NCDM used to work closely with CRC as CRC has a quite good network down to the communities. The NCDM currently has developed down from the national level to the commune level and from early 2007 this network even has taken the role of the CRC in terms of warning and dissemination of flood information. The committee for disaster management at the provincial level, that is the Provincial Committee for Disaster Management (PCDM), organizes annual seminars to prepare the provincial preparedness plan before each flood season. Under the project to support the implementation of the Flood Preparedness Program of MRC-RFMMC the provincial and district committees for disaster management of the provinces along the Mekong River have developed provincial and district Flood Preparedness Programs. The NCDM and concerned institutions have been working very hard under their respective responsibilities to reduce flood effects. Each PCDM has prepared its strategy and emergency plan to cope with flood, including safe water, food, safe areas, etc.

Extreme floods usually bring negative effects to the societies living in the flooded areas, therefore it is necessary to take immediate action after a flood to rehabilitate, especially the infrastructure damaged during the flood season. PCDM with other agencies and private sector have been working together to mobilize funds for rehabilitation of the damaged infrastructure, but this kind of practice usually can cover only small rehabilitation. NCDM mobilizes all kind of supports from different sources to distribute to the victims such things as dry food, drinking water, rice, mosquito nets, etc.

Assessment of flood damage is usually aggregated at provincial level with data and information provided from communes and villages. The provincial areas are generally too large leading to data and information on the actual damages that are not really reliable. The PCDM then sends their annual report to NCDM, which will be later on compiled as national disaster report. There is no proper method to assess the actual damages due to floods. The assessment of losses concerns mainly the most direct economic loss and excludes the recovery cost, cost for replacing damaged means of production and infrastructure and other indirect cost.

In general, NCDM is relatively a newly established organization, which needs improvement in many aspects.

Unmet need for forecast and warning product dissemination to flood-at-risk communities

There is no forecasting centre in the country, which integrates weather and hydrological forecasting. The Department of Hydrology and River Works (DHRW) of the MOWRAM produces 3 days flood forecasts for seven stations along the mainstream of the Mekong River, while the Department of Meteorology (DOM) carries out separate weather forecasts. Flood forecasting and early warning products are disseminated by DHRW through daily bulletins, emails and fax to relevant agencies and be disseminated further to the public by newspapers, hydrological boards, and public media networks.

The DHWR received contracts from the MRC-RFMMC for the forecasting and dissemination at referencing stations for 44 villages along the mainstream of the Mekong River and in the floodplain, but this activity was completed at the end of 2006 when contract ended.

The NCDM which is mandated for disaster management uses flood and weather information from the DHRW and MRC-RFMMC to disseminate to communities through its provincial, district and commune committee for disaster management through hydrological boards, radio VHF and cell phone. CRC has also been doing a wonderful job in dissemination of flood forecast and warning products.

However, due to the lack of capacity and financial support, the forecast and the products can be made and reach only limited areas. Because of the low level of education not all community members in those areas can access and understand all information provided.

There are many other kinds of efforts to disseminate forecast and warning products to flood-at-risk communities, but mostly those activities are carried out under programs and projects with limited time frame and usually stop after the end of the project.

People who are involved in recession agriculture along the Mekong River and around the Tonle Sap Great Lake need seasonal forecasts so that they can plan properly the planting time, which is presently not available.

Aspects of the centre-community relationship that must be strengthened

Life of the people along the Mekong River system depends very much on and follows the rhythm of annual floods. Their livelihoods can be considerably improved if they can successfully cope with the floods. Many agencies have been working hard with people living in flood prone areas to cope with floods, but due to limited funds, lack of competent personal, poor management or coordination and commitment these efforts are not very efficient in reducing flood risk. Therefore, close coordination and cooperation between agencies working in flood management and mitigation and the communities in flood prone areas is needed. To achieve this some aspects need to be strengthened:

- agencies carrying out flood forecasting and early warning should focus more on products that are useful for day to day activities of the people living in flood prone areas so that they provide practical information to the public and vulnerable people. This means that these agencies have to consult regularly with communities to get to know what kind of information is useful for them;
- regular meetings and workshops need to be held to share and exchange information, knowledge and experiences among community members and with centres;
- more involvement of communities in preparedness programmes is needed. In addition they would have to be provided with appropriate training in order to help them with better understanding of flood related issues.

ACTIVITIES AND ISSUES WITH RESPECT TO THE THEME AND TOPICS OF THE 6TH FORUM

Theme. Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin

There is no forecasting centre in the country. The DHRW is responsible for water level forecasting, and the DOM is responsible for weather forecasting. It is essential to improve weather and rainfall forecasting and knowledge of the sub-river basin characteristics in order to achieve better medium-term flood forecasting and early warning. So far there is no forecasting centre in the country, which integrates weather and hydrological forecasting, and early warning. The DHRW and the DOM carry out separate forecasting activities. The DHRW forecasts 3 days water level using a station correlation method without any link with meteorological data from DOM and DOM makes weather forecasts based on information from Internet, Thai Meterological Department (TMD) and Japan Meteorological Agency (JMA) and can produce only simple temperature and simple description of weather conditions. There is no such an attempt to integrate or improve coordination between the two agencies yet. The NCDM uses the forecast products of DHRW and MRC-RFMMC to disseminate them to communities at flood risk.

Topic I. New developments with respect to flood forecasting and early warning

There are significant investment for the strengthening of rainfall, climatic and weather data collection in the country but they are not fully operational due to lack of coordination and operational funds.

The DOM has just signed a contract for 5 years with MRCS for network improvement of data transfer from DOM to MRC-RFMMC with the objective to upgrade and improve the network coverage of rainfall stations of the DOM and to secure proper delivery to the MRC-RFMMC timely, accurate and reliable real-time and near real-time rainfall data. MOWRAM has signed an MOU with MRCS on data transfer from the line agencies to the MRC-RFMMC with the objective to secure understanding and agreement in principle from the MOWRAM in order to allow the DHRW and the DOM to deliver directly to the MRC-RFMMC daily real time and near-real time water level and rainfall data, which will be used for improvement of short-term flood forecasting and the development of the medium-term flood forecasting system.

CRC used to work closely with the NCDM in warning and dissemination of flood information as it has a good network in the communities. The NCDM currently has developed down from national level to commune level and from early 2007 this network even has taken the role of the CRC in terms of warning and dissemination of flood information. The PCDM in each province, under guidance of the NCDM, organizes annual meetings to prepare for an eventual flood of the year, which might occur. The objective of the meeting is to share information and responsibility, evaluation of current provincial financial, logistics, technical and human resources and operation modalities in case of an eventual severe flood event.

Activities of the DHWR under contracts with MRC-RFMMC for the forecasting and dissemination of flood forecasts at referencing stations for 44 villages along the mainstream of the Mekong River and in the floodplain was completed by the end of 2006 when the contract ended. There is no such effort that continues in those villages due to the lack of financial support and commitment.

Topic II. Land use based requirement for flood forecasting and early warning

Data and information on land use is one of the essential parts for better flood forecasting and early warning. Moreover a detailed study for flood management and mitigation requires good

quality topographic data. In Cambodia agriculture is the predominant land use. To secure production from planting of recession rice and other crops after the flood season in the Tonle Sap Great Lake areas and in the floodplain a seasonal forecast of the expected flood is more relevant while a water level flood forecast is more useful for areas that potentially may suffer from flooding.

In Cambodia, due to the lack of financial and human resources, very little data and information on land use and topographic data exist, with exception of some areas. Land use maps exist only for some areas produced under specific projects. Under Component 5 MRC-RFMMC flood probability maps for three districts in three provinces along the Mekong River were produced.

The Ministry of Land Management, Urban Planning and Construction is responsible for commune land-use planning, land title and master planning, but there is little consideration on flood mapping and/or flood risk management. Participatory Land Use Planning (PLUP) was moved at the end of 2006 from the Ministry of Land Management, Urban Planing and Construction (MLMUPC) to the Department of Local Administration (DOLA) at the Ministry of Interior. DOLA is implementing a revised approach, Commune Land Use Planning (CLUP) in collaboration with the Natural Resources and Environmental Management (NREM) project, funded by Danish International Development Agency (DANIDA) and the Department of International Development (DFID) of the British Embassy. CLUP Guidelines have been prepared that were reviewed and approved in early 2008. Assessment: the guidelines are very generic and do not mention flood risk management. However, the DOLA/NREM project will prepare training manuals that may be an 'entry' point for consideration of flood risk management. The implementation of CLUP is currently in 10 NREM provinces. This year four additional provinces will be added. The 2007 - 2010 programs areUS$ 65 million with targets of 94 districts and 707 communes.

To achieve better flood forecasting and early warning topographic surveys need to be conducted, land use maps prepared and relevant hydrological data be collected. Moreover, coordination and cooperation between institutions responsible for land use planning and the institutions responsible for flood forecasting and early warning need to be strengthened.

Topic III. Cost and benefits of flood forecasting and early warning

It is without any doubt that flood forecasting and early warning provide useful information for flood-at-risk communities so that they can prepare well ahead before a flood comes. This will become more relevant during extreme floods. During critical periods hydrological boards can attract crowds of all groups of people. Although people living along the Mekong River have somehow good experience in living with floods, and this information will help them to effectively reduce damages by floods. Farmers living in the Tonle Sap Great Lake areas and floodplain who plant recession rice or other crops after the flood always start to prepare their land or broadcast seed, if they are sure that there will be no more flood to come. Some farmers are willing to take the risk by broadcasting their seeds and sometimes they lose not only their seed, but also their labour, if flood comes again. These people are curious to know whether more floods will come. This illustrates the real need of the forecast not only for disaster preparation but also for agricultural planning of which the progress of the flood in magnitude and timing, including flood recession, their dates, speeds and magnitude at each location, since farmers or other river users might not always remember what the river did in the previous years and what is expected in the coming days, weeks and months.

However, to carry out flood forecasting and early warning needs considerable investment, both human and financial, for station installation, data collection, forecasting and dissemination of the forecast and warning. In Cambodia, due to lack of financial and human resources these activities, except water level forecasts by DHRW and weather forecasts by DOM, are usually carried out under specific projects with a limited timeframe and most of the activities stop after completion of the project.

To assure continuity of the forecast and warning there is a need to allocate funds for all related forecast and warning activities and provide technical support to relevant staff.

Topic IV. Lessons learned from past flood events

- although it is understood that floods have dual effect, positive and negative, a normal flood seems to provide more benefit rather than destruction;
- activities in the past for flood disaster management focused mainly on relief operations with little effort on other aspects or lack of funds to cover other activities;
- flood forecasting, preparedness and early warning have helped to reduce significantly to loss of live, damage to infrastructure and crops in recent years;
- for better flood management and mitigation flood information, integration, cooperation and coordination between line agencies involved need to be improved;
- flood mapping is very important for flood risk areas;
- a seasonal forecast is essential for recession agriculture in Cambodia;
- basic data collection such as rainfall, water level, river discharge and weather conditions, land cover and land use, etc. are of utmost importance for flood forecasting, therefore funds need to be properly allocated for these activities;
- isolated intervention will never assure a comprehensive and sustainable data collection system in the country and usually stop with the completion of a project;
- capacity of flood aftermath survey is still very weak or non existent among agencies in charge of disaster management; their focus is rather on damages and humanitarian assistance;
- knowledge on flood conditions such as estimation of the magnitude of floods in terms of rainfall amount, and maximum discharge and their direct and indirect causes must be improved;
- capacity of the media to report to the public need to be extended;
- with active participation of all institutions and people concerned unnecessary damage due to floods can be prevented or considerably reduced.

RECOMMENDED PRAGMATIC WORKING ARRANGEMENT BETWEEN NATIONAL CENTRES AND THE MRC-RFMMC

- MRC-RFMMC is located in the same compound as the DHRW who is responsible for forecasting in the country. This provides a good opportunity to exchange regularly knowledge and information;
- MRC-RFMMC should help strengthening capability of national forecasting institutions, from data collection, processing to development of forecasting models;
- MRC-RFMMC should allocate funds for longer term data collection and provide technical support;
- MRC-RFMMC should help to install more hydrological stations to extend the coverage areas, so that they can cover also main tributaries;
- MRC-RFMMC should continue to help taking care of some other manual hydrological and meteorological systems as they will continue to be served as a back up.

OTHER NATIONAL SUGGESTIONS ON FLOOD FORECASTING AND EARLY WARNING AT MEDIUM-TERM

Institutions dealing with flood issues such as the DHRW and the DOM of the MOWRAM, NCDM and non-governmental organizations, have been working very hard to reduce flood

effects, but their capacity and resources limits them from performing effective tasks. Hydrological data and information for the mainstream of the Mekong River are somehow efficient to assess the annual flood from year to year, while in tributaries they are incomplete. In general financial resources for data collection and forecasting operation are limited. In order to achieve better flood forecasting and early warning at medium-term the following aspects need to be considered:

- flood management and mitigation need to be well placed in modern planning and operation;
- there is a need to build capacity in flood management and mitigation at all levels from data collection, processing to model development and operation. Funds for these activities need to be allocated;
- tasks of all institutions and people concerned need to be clarified and coordination among them need to be promoted in order to avoid duplication of tasks and to encourage the sharing of data and information;
- awareness on basic flood risk reduction and mitigation measures and knowledge to use hydro-meteorological information have to be provided to communities at flood risk areas so that they can somehow help themselves to some extent to reduce flood risk;
- quantity, quality and timeliness of data need to be improved;
- little is known on flash flood behaviour due to lack of data and information on their river basins. Therefore, building knowledge on flash floods and finding a mechanism, methodology and facilities for flash flood forecasting and preparedness must be encouraged. More hydrological stations need to be installed.

USEFUL REFERENCES, WEB SITES AND CONTACT ADDRESSES

Cambodia National Mekong Committee: #23, Mao Tse Tong Road, Phnom Penh, Cambodia. Tel: 855 23 216 514. Fax: 855 23 218 506. Email: cnmc@cnmc.gov.kh.

Department of Hydrology and River Works: #576, NR. 2, Sangkat Chak Angre, Khan Mean Chey, Phnom Penh, Cambodia. Tel/Fax:855 23 425 645. Email: dhrw.cambodia@online.com.kh. Website: www.hydrologycambodia.50megs.com.

Mekong River Commission (MRC), 2007. Annual Flood Report 2006.

Ministry of Water Resources and Meteorology (MOWRAM), Final report on flood forecasting and flood information transfer to 40 villages in flood prone areas.

Ministry of Agriculture Forestry and Fisheries (MAFF), Draft annual report 2007.

National Committee for Disaster Management (NCDM), Draft annual report 2007.

National Committee for Disaster Management: Road No. 516, Sangkat Toul Sangker, Khan Russey Keo, Phnom Penh, Cambodia. Tel/Fax: 855 23 882 045.

LAO PDR'S COUNTRY FLOOD REPORT FOR 2007

PREPARED BY VIRANA SONNASINH

National Flood Expert, National Flood Unit, Lao National Mekong Committee Secretariat
Water Resources and Environment Administration, Vientiane, Lao PDR

ABSTRACT

Lao PDR is one of the countries in the Mekong River Basin, which is often subjected to flooding, both from the Mekong River and its tributaries. During 2007 a number of cases of flooding can be observed in different parts of the country. However, only few of them are worth mentioning.

The typhoon Lekima, which occurred from 30 September to 4 October 2007 and had degraded to a tropical storm after landfall, caused significant losses to life and limb in the central and southern part of Lao PDR, namely in Khammouane, Savannakhet, Saravane Provinces. It moved from the China Sea westward to Khammouane Province in the central part of Lao PDR with a speed of more than 227 km/hr. The observed daily rainfall at several stations during the passage was recorded between 41 - 141 mm on 3 October in the southern provinces. The result of cumulative rainfall has caused flash floods in the major tributaries of Mekong River (Xebanghien, Xebangfai, and Xedone rivers) with more than 1 m depth. The damage caused by Lekima was US$ 19,430 for Savanakhet Province only.

With the recent establishment of Lao PDR Water Resources and Environment Administration, flood forecasting information and the warning massages from the Department of Meteorology and Hydrology to the likely affected areas can be made more efficient with the reduction of bureaucratic official protocol. Moreover, the establishment of Disaster Management Committees at national and local level has helped to facilitate the execution of flood countered measures at all levels and resulted in better flood management and mitigation in Lao PDR. This paper focuses on the review of the significant flooding which occurred during 2007 by looking at the nature of flooding and the responsive measures to its impacts.

INTRODUCTION

Lao PDR is a land locked country, which is bordered by China, Myanmar, Thailand, Cambodia and Vietnam. It is categorized in the group of least developed countries of the United Nations Human Development Index with a Gross Domestic Product (GDP) per capita on average during the 5th Socio Economic Development Plan (2001 – 2005) between US$ 500 and 550. 70% of its land surface is dominated by hills, plateaus and mountains ranging from 200 to almost 3,000 m+MSL (Mean Sea Level). The country covers an area of 236,800 km^2, 97% of which falls within the lower river basins of the Mekong River that traverses the country from North to South.

The climate characteristics of Lao PDR are tropical monsoon with alternating wet and dry seasons. The dry season (northeast monsoon) occurs from mid October to mid May when the atmospheric pressure is high, it is a dry period with low humidity and temperature. The temperature is lowest in December - January and highest in April. The rainy season (southwest monsoon) occurs from mid May to mid October, it is a period of frequent and heavy rainfall with high humidity. Most of the heavy rainfall is concentrated from May to September. The drought period is short; 2 weeks of drought are often experienced from the end of June to the beginning of July.

The monthly distribution of the flow of the rivers in Lao PDR closely follows the pattern of rainfall: about 80% during the rainy season (May - October) and 20% in the dry season (November - April). For some rivers in the central and southern parts of the country (particularly Se Bang Fai, Se Bang Hieng and Se Done) the flow in the dry season is less: around 10 to 15% of the annual flow. Annual rainfall ranges from about 1,300 mm/year in the North to 3,700 mm/year in the South, the total annual flow of the Mekong's tributaries within the territory of Lao PDR is estimated at 270,000 MCM (million cubic metres), equivalent to 35% of the average annual flow of the whole Mekong River Basin.

HYDRO - METEOROLOGICAL CONDITION

Meteorological condition

In 2007, the frequency of extreme weather phenomena was observed less than in 2006. During the transition period between February and May, about one whirlwind occurred in Laos. The onset of the southwest monsoon took place similarly normal (mid – May) with weak intensity. No typhoon hit Laos during the rainy season (June – September). Only by the end of the rainy season, heavy rainfalls have caused flooding in different parts of the country. The degree of flooding varied from the North to the South, although flooding was reported in several provinces such as: Luangnamtha, Vientiane Capital, Khammouan, Savanakhet, Saravanh, and Champasack. Only the flooding due to the tropical storm Lekima is worth mentioning, it caused overflow at main tributaries of the Mekong River in the central and southern part of Lao PDR, resulting in local flash floods. The locations of occurrence of local storms and flash floods in 2007 are shown in Figure 1.

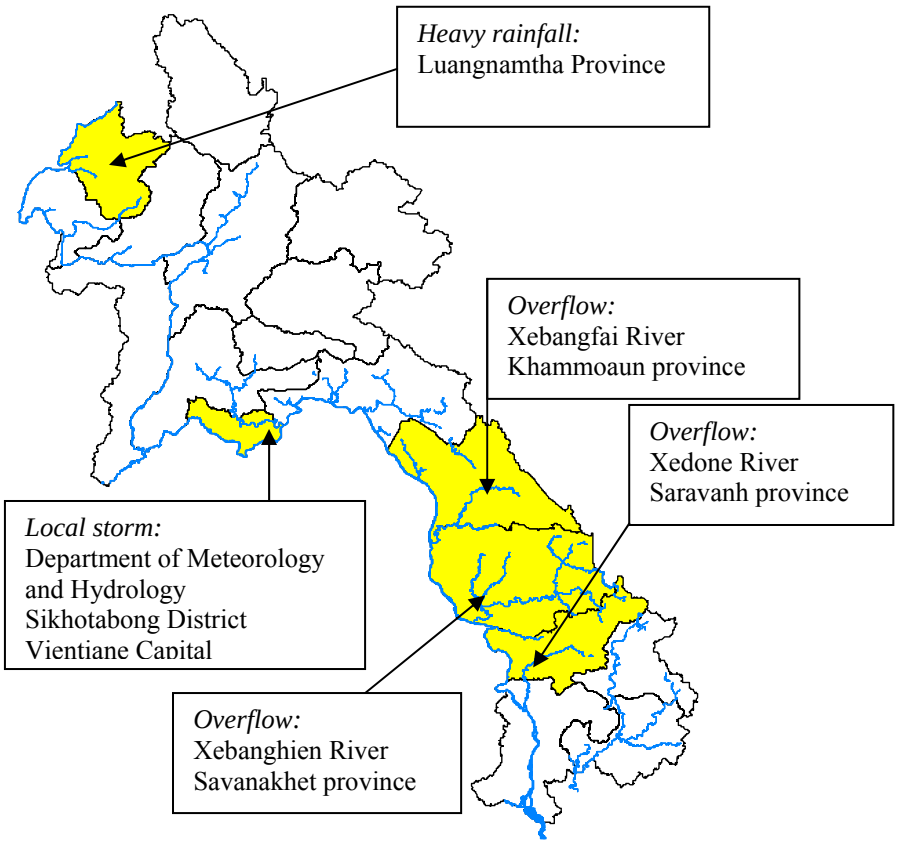


Figure 1. Provinces affected by local storms and flash floods in 2007

Local storm (whirlwind)

On 6:40 hr local time of 29 April, the northerly with gust wind of about 49 m/s (130 - 140 km/hr) destroyed part of the Department of Meteorology and Hydrology's training centre, which is located along the Mekong River in Vientiane Capital, fruits and decorative trees along the bank of Mekong River at Akart village, Sikhottabong District (Vientiane Capital) were damaged, with 24 hours rainfall 19:00 hr 29 April - 7:00 hr 30 April local time recorded 63.0 mm. However, the local storm did not cause any severe flooding.

Tropical storm Lekima (0714)

Lekima (0714) was upgraded to tropical storm (TS) intensity in the South China Sea at 00 UTC (Universal Time Coordinate) on 30 September. It moved westward and was upgraded to severe tropical storm (STS) intensity 21 hours later. After turning to the Norwest, it reached peak intensity with maximum sustained winds of 227 km/h (60 knots) and a central pressure of 975 hPa over the sea southeast of Hainan Island at 00 UTC on 2 October. It turned to the West again and then hit Vietnam with STS intensity on 3 October, after that it downgraded into a TS and passed through Khammouan province on 19:00 hr local time on 3 October with movement speed of 34 km/h (9 knots), it weakened to Tropical Depression (TD) intensity around the border between Laos and Thailand at 6:00 UTC on 4 October. MTSAT-1R Infrared and visible channel imageries are shown in Figure 2 and the specific severe tropical storm Lekima tract is shown in Figure 3. With the impact of tropical storm Lekima (0714) associated with a strong southwest monsoon heavy rainfall from Gulf of Thailand, overflow occurred in the major tributaries of the Mekong River, namely, Xebangfai (Khammouan Province), Xebanghien (Savanakhet Province), and Xedone (Saravane Province). The observed daily rainfall at several stations during the passage of the typhoon was recorded almost at southern provinces between 41 - 141 mm on 3 October as shown in Figure 4.

Table 1. List of tropical best track over Lao PDR during 3 October 2007

Name of tropical storm	Duration (beginning – end)	Time/location during the passage of TCs, time (UTC) (n) / (e)		Pressure (hPa)	Max wind (kt)	Grade
TY.0714 Lekima	30 September to 4 October 2007	Oct. 3/00 Oct. 3/12	17.6/108.2 Thakhek (Khammouan)	980 985	50 45	STS TS

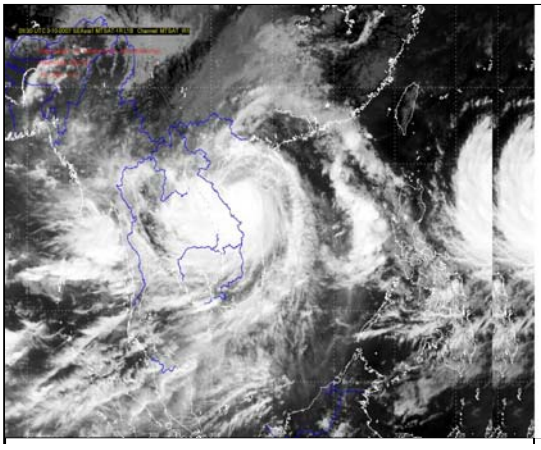


Figure 2. The MTSAT-IR Infrared channel Imagery on 5:30 UTC, 3 October 2007

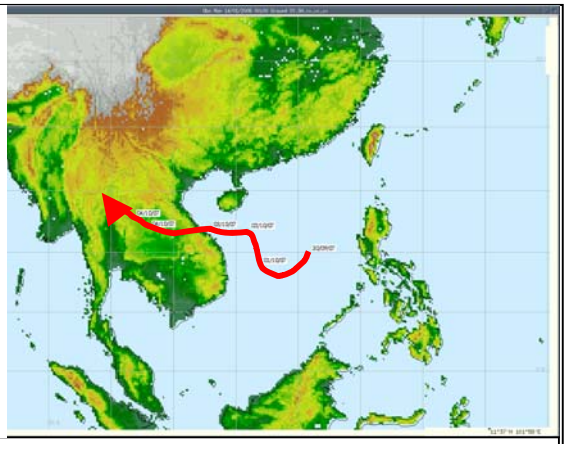


Figure 3. Severe tropical storm track Lekima (0714) over Lower Mekong River Basin countries on 3 October 2007

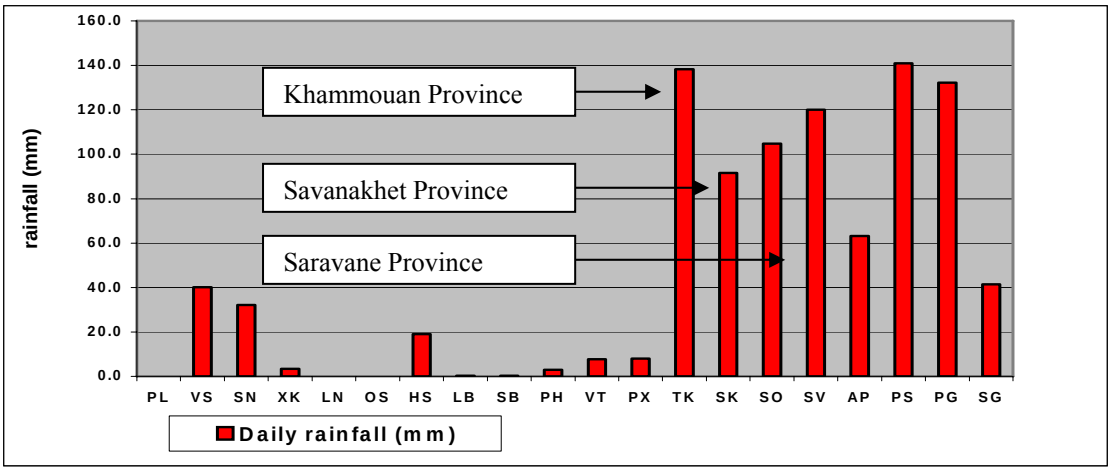


Figure 4. Daily Rainfall distributions by tropical storm Lekima (0714) on 3 October. 2007

2.2 Hydrological condition

Water level at main stations of Mekong River in Lao PDR

In 2007 the maximum water level at locations where frequently floods occur, such as Pakxane, observed in the rainy season on 11 September 12.47 m, which was less than in 2006 (0.27 m) and less than in 2005 (1.49 m). At Thakhek 11.47 m was recorded on 11 September that is less than in 2006 (0.20 m) and in 2005 (2.49 m). From the onset the southwest monsoon took place over Lao PDR with weak intensity and the effect from tropical storm Lekima, for station Pakse was a maximum observed water level of 10.85 m at the end of the rainy season, which is higher than in 2006 (0.39 m) and lower than in 2005 (1.37 m). The comparison of the annual maximum water level at different sites in Lao PDR for 2007, 2006 and 2005 is shown in Table 2.

Table 2. Comparison of the annual maximum water level at different sites in Lao PDR for 2007, 2006 and 2005

No	Station code	Mekong River station name	Maximum water level (m+MSL)				
			2007	2006	2005	Critical level	Danger level
1	019594	Luangprabang	14.41 (9 Sep.)	15.40 (14 Oct.)	16.02 (20 Aug.)	17:00	18:00
2	019801	Vientiane km 4	10.16 (10 Sep.)	10.83 (1 Sep.)	11.08 (21 Aug.)	11:50	12:50
3	012703	Paksane	12.47 (11 Sep.)	12.74 (3 Sep.)	13.92 (23 Aug.)	13:50	14:00
4	013102	Thakhek	11.47 (11 Sep.)	11.67 (30 Aug.)	13.96 (23 Aug.)	13:00	14:00
5	013401	Savanakhet	9.11 (10 Oct.)	9.35 (31 Aug.)	12.22 (24 Aug.)	12:00	13:00
6	019802	Pakse	10.85 (10 Oct.)	10.46 (31 Aug.)	12.22 (19 Aug.)	11:00	12:00

Flash flood by tropical storm Lekima

During 2007, the tropical storm Lekima has caused significant overflow in the main tributaries of the Mekong River in the central and southern part of Lao PDR which are Xebangfai, Xebanghien, and Sedona, the location of the flash flood is shown in Figure 5.

Figure 5. Location of major rivers that overflowed during the tropical storm Lekima

For the station of Mahaxay in Khammouan province the rain gauge station recorded 138 mm on 3 October 2007. The consecutively heavy rain over those areas, where the maximum flood peak at Mahaxay hydrological station (Xebangfai River) raised up to 15.50 m (critical level is 13.64 m and danger level is 14.64 m) at 19:00 hr of 11 October. On that time the water overflows have covered in the floodplain 193 villages of 7 districts such as: Mahaxay, Ngnommalath, Boualapha, Thakhek. Xaybouathong, Xebangfai and Nongbok with average flood deep of 1.50 m.

Similarly, heavy rain was observed between 35 and 170 mm in 4 consecutive days from 2 to 5 October at many stations over Savanakhet province, where devastating deluges plagued in the Xebanghien River on 4 to 12 October. At about 19:00 hr local time of 4 October was a water level recorded of 13.90 m. Water began to spill over the Xebanghien tributary (Sechamphone, Sesangsoy sub-rivers) to lower plain areas. Almost 117 villages of Champhone, Sonbouly, and Atsaphone districts were inundated with a flood depth ranging between 0.4 and 0.5 m. When the water level had risen up to 15.00 m on 7:00 hr local time of 5 October the water spilled rapidly over from the Xebanghien river, Sechamphone and Sesangsoy sub-rivers to floodplains, 234 villages were inundated with average flood depth ranging from 0.9 - 1.1 m. The flood peak value at hydrological station Lahanam recorded 16.10 m on 7:00 hr of 7 October, the water overflowed to cover floodplains.

Heavy rain was also observed between 68.7 and 134.7 mm during 3 consecutive days from 1 to 3 October over Saravane province (Table 3), where for every half day (12 hours) the water level of Sedona river had risen about 2.91 m during 2 - 3 October. At about 19:00 hr local time of 3 October, water began to spill over the Sedona River to lower plain areas with flood depth between 0.3 – 0.5 m. When the water level at that station went up to 13.22 m on 19:00 hr,

water had rapidly spilled over, the floodplains of 80 villages of Kongsedone District were inundated with average flood depth ranging from 1.0 - 1.5 m as well as about 70 villages of Saravane, Vapy and Toumlam districts (Saravane province) were inundated with average flood depth ranging from 0.5 - 1.0 m. The flash flood affected 110 villages, 5,063 households of 4 districts (Kongsedone, Saravane, Vapy and Toumlam) with average flood depth between 1.0 and 1.2 m.

IMPACTS OF FLOODING IN 2007

The central and southern parts of Lao PDR were the most affected areas by flooding in 2007. The tropical storm Lekima (0714) best track over Lao PDR associated with strong southwest monsoon from the Bay Bengal brought abundant precipitation, caused severed flash floods in Khammouan Savanakhet and Saravane provinces. According to the Ministry of Agriculture and Forestry, the National Disaster Management Office (NDMO) flood statistics 2007, field data collection by representatives from NDMO, Department of Meteorology and Hydrology (DMH), Lao National Mekong Committee Secretariat - National Flood Unit (LNMCS NFU) and the Flood Management and Mitigation Programme (FMMP) of the Mekong River Commission (MRC) on 2 - 6 January, about 4 provinces, 27 districts, 614 villages, 25,292 households and 118,074 persons in Khammouan, Savanakhet and Saravane provinces were affected, 2 persons (1 boy 4 years old and 1 female 39 years old) were killed, more than 256,000 ha of rice and 490.62 ha farmland were damaged and national infrastructure (roads) was also damaged. The direct economic losses were 180,701,550,000.00 kips (approximately US$ 19,430) for Savanakhet province only. In comparison with 2006, 2005, and 2002 the damages caused by flood were more severe in terms of affected people and damaged rice field (Table 6).

Table 3: Comparison of impact from disaster in 2007, 2006, 2005 and 2002

Description	Flash flood damages in 2007	Flash flood damages in 2006	Flood damages in 2005	Flood damages in 2002
Provinces affected	4	5	16	13
Districts affected	27	20	84	62
Villages affected	614	404	2,510	1,142
Families affected	25,292	13,549	85,530	50,342
People affected	118,074	89,849	480,913	249,782
People killed	2	5	5	3
Hectares of rice and crop damaged	747,398	6,913	55,955	33,702
Total estimated cost damages in million US$	N/A	3.1	18.3	N/A

Data sources from Ministry of Agriculture and Forestry (MAF) and NDMO, 2007, 2006, 2005 and 2000

FLOOD MANAGEMENT AND MITIGATION MEASURES

Institutional arrangement

The Government of Lao PDR has regarded flood as one of the major disasters and considers the disaster management as an important issue that urgently needs to be properly managed, therefore, the National Disaster Management Committee (NDMC) was established, its secretariat, namely National Disaster Management Office (NDMO) was housed in the Ministry of Labour and Social Welfare, according to its mandate No. 158/PM dated 23 August 1999, the committee is chaired by the Minister of Labour and Social Welfare and consists of members from ministries concerned. With the mandate to oversee disaster management, NDMO has closely coordinated with line agencies at central and provincial level, Non Governmental

Organisations (NGO), and International Organisations (IO) in implementing counter measures for disaster management. The 2003 - 2020 disaster management action frameworks have placed absolute emphasis on promotion of Community Based Disaster Risk Reduction Approach. The Lao PDR has began to set up the disaster management committees at some provinces where flooding frequently occurs. The committee has focused its activities on flood preparedness at community level and flood relief.

Apart from NDMC, in July, the Government of Lao PDR has decided to establish the Water Resources and Environment Administration (WREA) under Prime Minister's Office based on Decree No. 149 with the aim to create a single agency responsible for water resource development and management, the newly established agency consists of the Department of Water Resources (DWR), Department of Meteorology and Hydrology (DMH), Lao National Mekong Committee Secretariat, Department of Environment (DOE), Institute of Water Resources and Environment (IWRE). Moreover, in parallel with the establishment of WREA, the Department of River Works (DORW) is also established under the Ministry of Public Works and Transport, according to its draft mandate, the structural measures and flood proofing will be managed by the department, its tasks include navigation, river bank protection, dike construction, structural measures for flood proofing and river monitoring. With the recent institutional reform, the more effective agencies and their clear mandate, the Lao PDR capacity in flood management and mitigation is expected to be improved.

Flood forecasting, warning and dissemination

Under the DMH, there are 50 stations in total, 17 stations are main synoptic surface stations, the rest are secondary synoptic stations (monthly data recording and rainfall observation only), and there are 113 rain gauges. Staff gauges are 119 stations, 49 discharge measurement stations, and C-Band Doppler radar at DMH Headquarter and a MTSAT – 1R satellite receiving station. The data from the stations will be collected by the Provincial Meteorology and Hydrology Office (PMHO) with the assistance from the local people who live close to the stations, the data will later be reported to the DMH in Vientiane Capital. During the past, the discharge stations were managed by two departments which are DMH and Department of Roads (DOR), Due to the government institutional reform in the mid of 2007, all management responsibility and the stations under the Water Way Administration Division (Department of Roads) were transferred to DMH with the aim to centralize all hydrological and meteorological data and information. Therefore, the observation network is expected to be managed more effectively in the coming year.

Flood forecasting

The hydrological division of DMH receives real time data (water level and rainfall observed at 7:00 hr (00:00 UTC) from 7 major stations at the mainstream (Pakbeng, Luangprabang, Vientiane, Pakxane, Thakhek, Savanakhet, Pakse) and main tributaries of the Mekong River by high frequency / single slide band (HF/SSB) and telephone. Supplementary information real time data (water level and rainfall) observed at 7:00 hr (00:00 UTC) is collected by mail from two upstream stations of the Mekong River in China (Yanjinghon 92980 and Hana 92600).

Data exchange in the form of a mathematical model between DMH and the Mekong River Commission Secretariat (MRCS) has been done by e-mail, and the DMH has received daily the MRC flood forecasting products. Additional real time rainfall, synoptic, climate data, weather situation and other information are received from the weather forecasting division of DMH, the flood forecasting in 2007 at the mainstream of the Mekong River in Lao PDR still uses the method of stage correlation regression, between upstream and downstream water levels, with related a flood propagation time of 1 or 2 days. The necessary data are processed and analysed based on Microsoft Excel, using formulas as shown in underneath box.

HVT forecast = (HLB, yesterday – HLB, day before yesterday)*0.35 + HVT today
Where:
HVT = water level observed on 7:00 hr (local time) at hydrological station Vientiane km 4
HLB = water level observed on 7:00 hr (local time) at hydrological station Luangprabang

The preparation of daily flood bulletins is completed at 10:00 hr. The product of flood forecasting lead-time is 48 hours (from 7:00 hr today to 7:00 hr day after tomorrow) and updated daily. The flood forecasting is mainly water levels and the forecasting includes only 6 stations (Luangprabang, Vientiane, Pakxane, Thakhek, Savanakhet, and Pakse). The capacity of providing flash flood forecasting at DMH is still limited, the current flash flood forecasting is based on the estimation of rainfall. This method is currently used for forecasting flood, which can occur from the river. However, with the frequent occurrence of flash floods, especially in the mountainous areas of Lao PDR, DMH is seeking the method to forecast the flash floods. The possible solution, which is being considered, is the use of the satellite rainfall estimation method, which will soon be supported by the FMMP.

It has to be noted that the flood-forecasting task has moved from the Ministry of Agriculture and Forestry to WREA, where DMH is housed since July 2007. It is expected that flood forecasting may face some difficulties due to relocation of hydrological and meteorological equipment and shortage of budget allocation for data collection in coming year.

Flood warning and dissemination

The means for flood warning and dissemination have often been the communication equipments. The HF/SSB radio transceivers, public telephone, and facsimile are commonly used for the weather and flood forecasts and tropical cyclone warnings to the public. Moreover, the website of DMH has also been established in 2007, which can provide the weather and flood forecast information (http://dmhlao.etllao.com/). The flood warning of DMH is shown in Table 4.

Table 4. Flood warning of DMH divided into two criteria

Nearly warning	Urgent warning
In the case the water level forecast at that station is expected to be at 0.50 m below warning level. DMH has to provide the warning and timely delivering to: • mass media and Ministry of Agriculture and Forestry • Prime Minister's Office, LNMC and NDMO • DMH makes an interview to mass media • DMH sent the warning information to Provincial Agriculture and Forestry Office (PAFO) and Provincial Hydro Meteorological Office (PHMO) and to focus areas • the warning message is broadcasted through national and local radio stations during daily programmes for disaster management	In the case the water level exceeds warning level. DMH has to provide the urgent warning to • mass media and DMH makes an interview to mass media • DMH reports to Ministry of Agriculture and Forestry and later report to Prime Minister • Prime Minister's Office, and LNMC • DMH sent the warning information to PAFO and PHMO and to focus areas • at the same time DMH sends urgent warning to NDMO • NDMO sends the urgent warning to Provincial disaster management office and later to district office and focus areas • national radio stations will broadcast the warning massage through its program regularly

In the past, the flood forecasting, warning and dissemination were made through Ministry of Agriculture and Forestry, an announcement is delivered by facsimile from Ministry of Agriculture and Forestry to Prime Minister's Office and to Provincial governor office and later to concerned line agencies, after DMH has moved to WREA, the warning and dissemination is expected to be made effectively, since WREA is under the supervision of the Prime Minister's

Office, the communication between WREA and forecasted flood areas could be made directly while the bureaucracy and official protocol can be reduced, the warning massage could reach the provincial authority earlier which allows the local authority to arrange for flood counter measures on time. In 2007, at the time that tropical storm Lekima entered to Khammouan Province, the warning massage was first made to the provincial agriculture and forestry office and provincial disaster management, however, no action has been made until the Provincial Governor Office was informed, therefore, the massage was re-sent to the Provincial Governor Office for provincial announcement, the local district and villages were informed and the ad hoc committee for disaster management was set up accordingly.

Flood preparedness, relief and reconstruction

Flood management and mitigation are important issues that need to receive attention, the degree of damages can be different from location to location, after flood, in most cases, the national disaster management committee in coordination with line agencies concerned at both central and local level is responsible for mobilizing all available means for flood preparedness and relief. The disaster management committee will be set up at different levels (province, district, and village), their tasks include flood warning and preparation, relief measures, damage assessment and reconstruction. The provincial division of labours and social welfare in coordination with the provincial division of agriculture and forestry had made flood data collection and access to the damages caused by flood; the data will be incorporated to the provincial reconstruction plan, which will later be submitted to the Government for consideration and approval.

LESSONS LEARNT

- hydro meteorological data are very crucial for flood forecasting, in the use of sophisticated equipment for the measurement stations the affordability and sustainability needs to be taken into account;
- damage caused by flooding in the agricultural land area is in Lao PDR more common than damage due to urban floods;
- the capacity of the Department of Meteorology and Hydrology in flood forecasting in the short term and medium term is very crucial for effective flood preparedness;
- the unplanned infrastructure development can result in increasing the degree of flooding;
- the lack of telecommunication equipment at local level and the official protocol in the Government administrative system can result in poor flood warning and dissemination;
- like in other developing countries, Lao PDR is short of budget to be used as reserve for emergency responses, the relief effort by external organizations took time, the assistance from the central Government is inadequate. However, the capacity of local communities in coping with flood proved to be effective.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It is appeared that in 2007, the frequency of extreme weather phenomena is lower in comparison with 2006, the only flood event that causes significant impact to Lao PDR in 2007 was the tropical storm Lekima, the storm has resulted in heavy rainfall and flash floods caused by overflow from Xebangfai, Xebanghien, and Xedone river in Khammouan, Savanakhet, and Saravane provinces, the maximum flood depth was estimated at 2 metres. The damages due to

tropical storm Lekima in Savanakhet province were reported to be approximately US$ 19,430.

The Department of Meteorology and Hydrology of the Water Resources and Environment Administration has timely performed its tasks, by allowing the provincial and local authorities be informed, the weather and flood forecasting is operated on daily routine and 48 hours lead time for flood forecasting and warning. The Disaster Management Committee, which was set up at provincial and district level in the flooded areas has enabled the community to achieve better flood preparedness and responses, reconstruction and relief.

Recommendations

- although the Department of Meteorology and Hydrology plays a major role in flood forecasting and dissemination, its capacity is lacking in terms of human resources and budget, therefore, its capacity urgently needs to be improved, and the national flood forecasting and early warning centre should be established;
- the flood forecasting, warning and dissemination needs to be improved, the warning needs to get into the communities on time prior to the flood, therefore, the cooperation between DMH and the communities need to be strengthened together with the awareness raising;
- currently, the flood damage assessment in Lao PDR is carried out by the local authorities in their own format, there is no standard format for damage data collection, therefore, a standard format for flood data collection should be established in support of better flood management and mitigation;
- flash floods have occurred quite often in the past few years in Lao PDR, the method for flash flood forecasting needs to be developed for addressing this problem in Lao PDR, the development of a satellite rainfall estimation method under the MRC Flood Management and Mitigation Programme should be considered for application in Lao PDR;
- the reconstruction and relief measures need to be improved, financial assistance should be made to the affected communities so that their daily live can be sustained, the technical and financial assistance need to effectively and efficiently be mobilized as soon as possible aftermath, and a financial reserve needs to be established for flood emergency response;
- community self reliance for flood management and mitigation has been proved to be effective, the disaster management committee should focus on building capacity of the local community in flood preparedness and emergency responses;
- the skill of provincial authorities in coping with floods is inadequate, especially, technical and managerial skills, therefore, a capacity building program is needed;
- the Guideline for flood management and mitigation in different sectors should be adopted so that in their sector they are better aware of the flood issue;
- the development of infrastructure is implemented without taking flood issues into consideration, e.g. the construction of bridges in Saravane and Luangnamtha provinces has escalated the flow velocity and narrowed the river channel, therefore, a national guideline for infrastructure development needs to be established;
- the MRC Flood Management and Mitigation Programme should consider orienting its activities to benefit the local level by providing a supportive role in building the capacity of national and local authorities, and of communities in flood management and mitigation.

REFERENCES

Committee for Planning and Investment, 2006. 6th Socio – Economic Development Plan (2006 – 2010), Committee for Planning and Investment, Vientiane, Lao PDR

Souvany Phonevilay, 2007. Country Report on 5th Annual Flood Forum of Mekong River Commission, Department of Meteorology and Hydrology, Ministry of Agriculture and Forestry, Vientiane, Lao

PDR
Chanthachit Ampahychit, Virana Sonnasinh, and Sovany Phonevilay, 2008. Report on Flood Data Collection 2007, National Flood Unit, Lao National Mekong Committee Secretariat, Water Resources and Environment Administration, Vientiane, Lao PDR
Mekong River Commission Secretariat, 2004. State of Basin Report 2003, Mekong River Commission, Vientiane, Lao PDR
Asian Disaster Preparedness Center, 2001. Policy Legal and Institutional Arragement and Planning for Disaster Management in Lao PDR, Asian Disaster Preparedness Center, PO Box 4 Klong Luang, Pathoumthani, Thailand
Water Resources and Environment Administration, 2007. Decree on the Establishment of Water Resources and Environment Administration, Vientiane, Lao PDR.

THAILAND'S COUNTRY FLOOD REPORT FOR 2007

TOSPORN SUDDHAJINDA AND SUPAPAP PATSINGHASANEE

Water Crisis Prevention Centre, Department of Water Resources, Bangkok, Thailand

ABSTRACT

The report describes the general meteorological and hydrological situation of Thailand and the significant flood events of 2007. In May there was a tropical depression in the Gulf of Thailand that moved towards Andaman Sea to north direction, going to Myanmar and caused heavy rain in the upper part of the southern region. In mid May there was a tropical cyclone formed in the Gulf of Bengal that moved towards Myanmar and caused rain in the central and northern regions of the country, causing inundation in various districts in 17 provinces. In August there was heavy rain almost during the whole month. In September the inter tropical convergence zone still crossed every region of Thailand. Together with the southwest monsoon it covered the Andaman Sea and the Gulf of Thailand, resulting in heavy rainfall throughout the country. At the beginning of October, the influence of typhoon Lekima passed Viet Nam and Lao PDR, and then moved towards the northeast of Thailand, it was weakened to a depression covering the upper and lower northern region causing heavy rainfall in northern and northeastern regions for the whole week. At mid October a depression covered the northern and central regions, causing heavy rains in the lower northern and central regions that resulted to inundation of various districts in 34 provinces.

In 2007, every region of Thailand had flooding that caused damages in 46 provinces. An overview of damages and casualties is given in the report. The institutional measures that have been taken in the past years to respond to the floods are described. Flood forecasting and flood preparedness planning play an important role in the measures to reduce and mitigate the impacts of floods

GENERAL SITUATION

Thailand is influenced by two types of monsoon, i.e. the southwest monsoon and the northeast monsoon, which are causes of changes in the climatic seasons in Thailand. The southwest monsoon covers Thailand during mid May to October and carries mass humid air from the Indian Ocean to Thailand causing widespread rainfall. After the southwest monsoon, the northeast monsoon starts from mid October and lasts until February. The mass dry cool air from Mongolia and China will blow and cover Thailand in upper north and northeast regions but will cause heavy rain in the south due to the fact that the monsoon will carry moisture from the Gulf of Thailand (Figure 1).

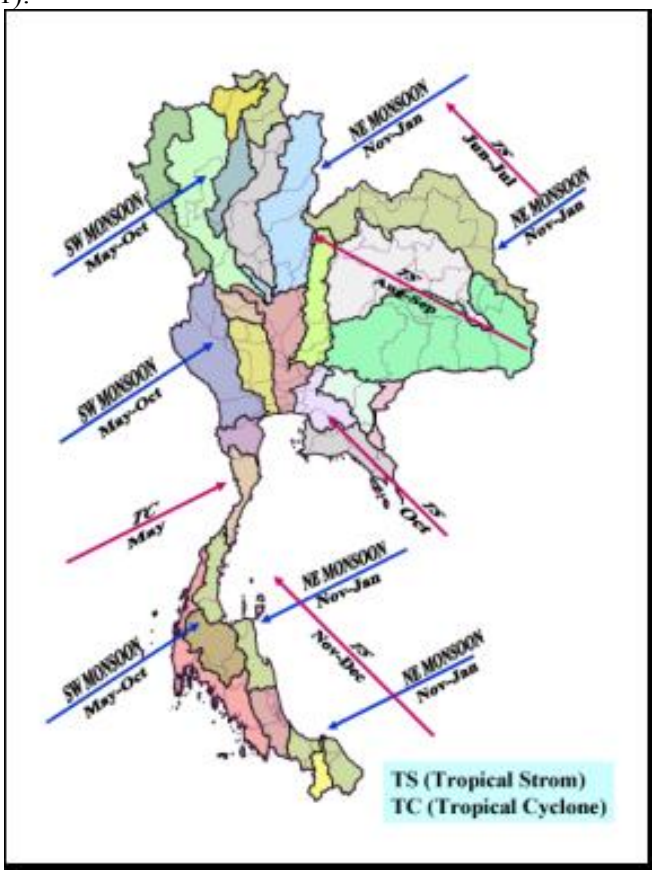


Figure 1. Storm tracks over Thailand

Since Thailand is located in between the area of tropical cyclones caused from Pacific Ocean and South China Sea at the East and from Gulf of Bengal and Andaman Sea at the West of the country, storms will increasingly move towards Thailand from the month of May and mostly are storms from the West towards upper Thailand. From June onwards most storms enter Thailand at the East, which are typhoons passing all MRC Member States and weaken to become tropical storms or tropical depressions that cause heavy or very heavy rainfall, dependent on the strength of the storm.

In 2007, the cumulative rainfall was 1,583 mm, which was very near the average cumulative rainfall value in a 30 years period but lesser than in 2006 one of the years that Thailand had the most flooding, particularly in the central region of the country (Figure 2). The rainfall in the country is caused by the inter tropical convergence zone crossing various parts of the country and influence from the southwest monsoon covering Andaman Sea, Thailand and the Gulf of Thailand, causing rainfall in every region. On May there was heavy rain in the northern region, central region and some parts of the southern region, causing flooding in 12 provinces. The amount of rainfall was 274 mm, which is already considered to be the rainy

season in Thailand. The amount of rainfall in following months was less than 200 mm (Figure 3). It still caused flooding in nine provinces in the northern region, central region, and southern region. The flooding caused damages to infrastructures and private properties. During August to October the rainfall in each month was higher than 200 mm, which was caused by depressions crossing various parts of the country and from influence by the southwest monsoon. Heavy rain in every region of the country caused severe inundation and flash floods in provinces in the upper northern region and the northeastern provinces. During the end of September, the influence of tropical storm Francisco in upper South China Sea entered Thailand and was weakened to a depression causing heavy rain in the northern region, upper central region, and northeastern region of Thailand. In October Thailand got the impact from typhoon Lekima, which was weakened to a depression that caused these two months to have more heavy rains than the previous months except in the month of May. The influence of typhoon Lekima resulted to inundation of 34 provinces and 27 casualties. During the last two months of 2007, i.e. November and December, the amount of rainfall increased in the lower southern region, which was influenced by the northeast monsoon crossing the Gulf of Thailand. Regarding other parts of the country, the amount of rainfall decreased and it was the end of the rainy season.

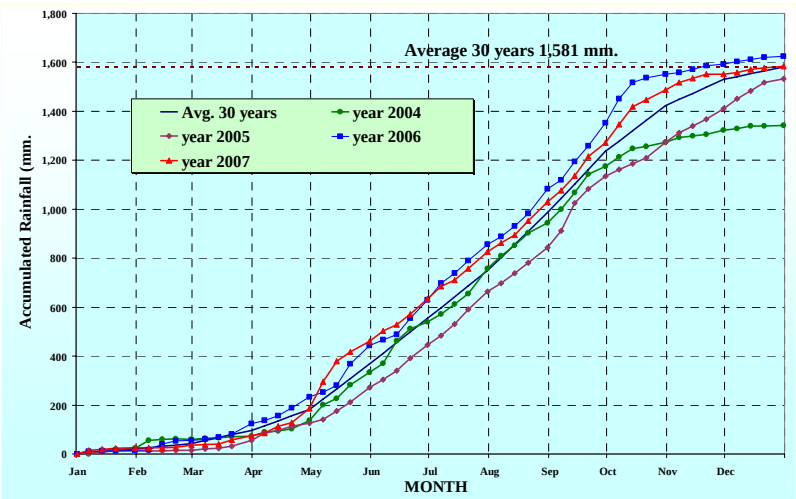


Figure 2. Comparison of cumulative rainfall

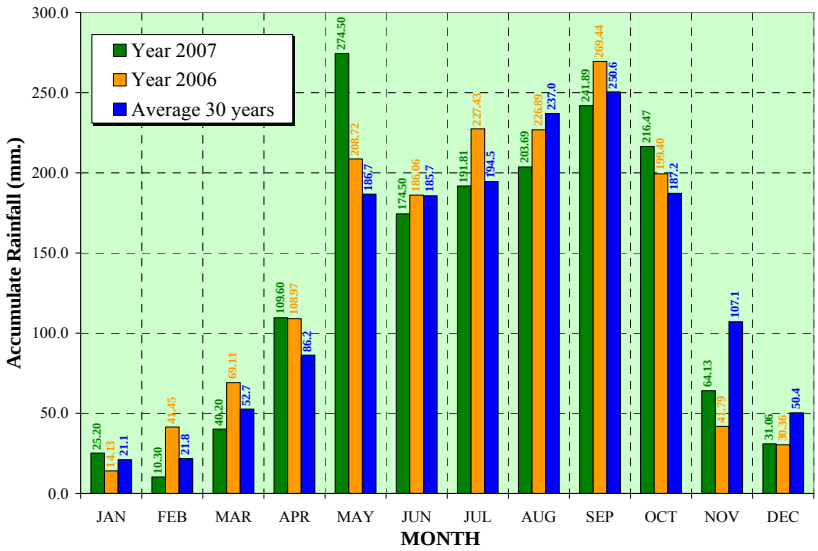


Figure 3. Monthly rainfall in 2007

SIGNIFICANT FLOOD EVENTS

Most parts of the country were inundated as shown in the map of inundation districts in 2007 (Figure 4). Heavy rainfall started from May with cumulative rainfall of 275 mm for that month. Afterwards, the amount of rainfall reduced in June, July and heavy rainfall started again in August, which was on normal rainy season causing inundation in several areas in the country. The significant amounts of rainfall that caused inundation and damages to lives and properties of the people were in May, August, September and October and caused flooding in various areas in each period of the month.

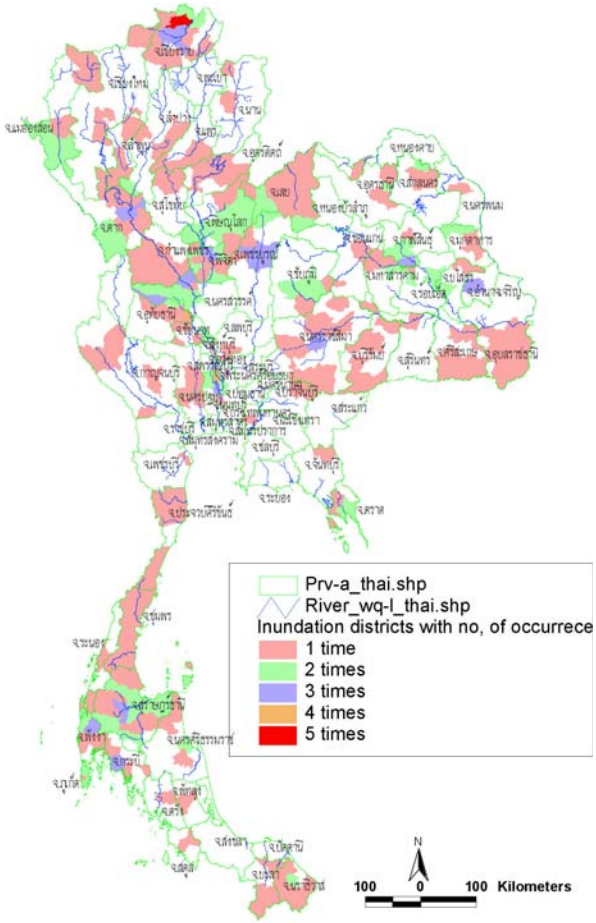


Figure 4. Map of inundation Districts in 2007

Flood in May 2007

In May there was a tropical depression in the Gulf of Thailand that moved towards Andaman Sea to north direction, going to Myanmar and causing heavy rain in the upper part of the southern region. In mid May there was a tropical cyclone formed in the Gulf of Bengal that moved towards Myanmar and caused rain in the central and northern regions of the country, causing inundation in various districts in 17 provinces as shown in Figure 5. Agricultural areas not less than 96,400 rais ***(Note: please give the conversion from rais to hectares)*** in 8 provinces were damaged. The depth of flooding varied from 50 - 100 cm. Moreover, there were also flash floods and landslides in Khao Kho Hong Amphoe Had Yai Songkhla Province, Mae Pool Amphoe Laplae Uttaradit Province, Ban Tuek Amphoe Si Satchanalai Sukhothai Province and Na Poon Amphoe Wang Chin Phrae Province.

Flooding in August to end of September 2007

In August there was heavy rain almost during the whole month. The heavy rain was caused by the influence of the inter tropical convergence zone crossing the lower northern region together with the northeast monsoon that covered Thailand resulting in heavy rain that caused flooding in various districts in 21 provinces as shown in Figure 6. Communities, roads, and some houses were flooded 30 - 70 cm. There was also flash flood in upland and slope areas in 8 provinces. The Mekong Tributaries River Basins in Thailand were also affected by flooding in 8 provinces during this period. In Ubon Ratchathani, flood from the Mun Noi River flowed into Ban Wang Daeng and Ban Tha Bo, causing flooding with a depth of 1.00 m.

In September 2007 the inter-tropical convergence zone still crossed every region of Thailand. Together with the southwest monsoon it covered the Andaman Sea and the Gulf of Thailand, resulting in heavy rainfall throughout the country. The amount of rainfall in September was 242 mm, the second highest in the whole year causing flooding in various districts in 30 provinces as shown in Figure 7. The heavy flooding caused severe inundation and flash floods in Amphoe Dan Sai, Loei Province and in Amphoe Lom Kao, Petchabun Province, there was death toll, missing and wounded a total of 23 persons. In Lom Kao municipality, the community was flooded up to 80 cm. The vendors in the market were evacuated to the area in front of the District Office and it was officially announced that the schools were closed.

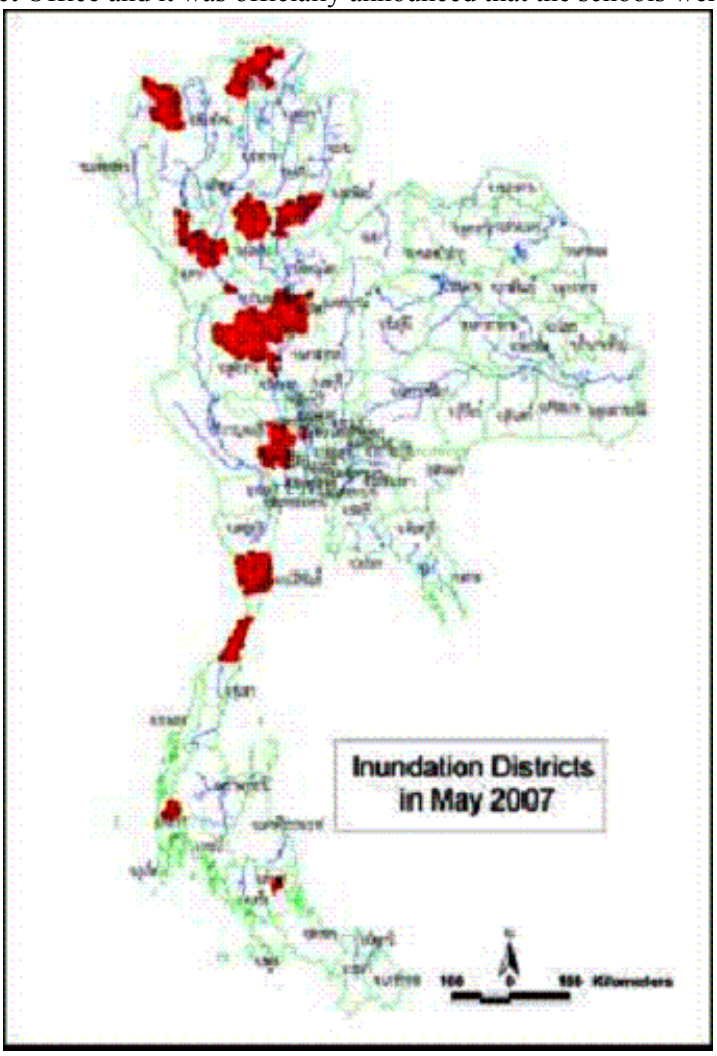


Figure 5. Inundation districts in May 2007

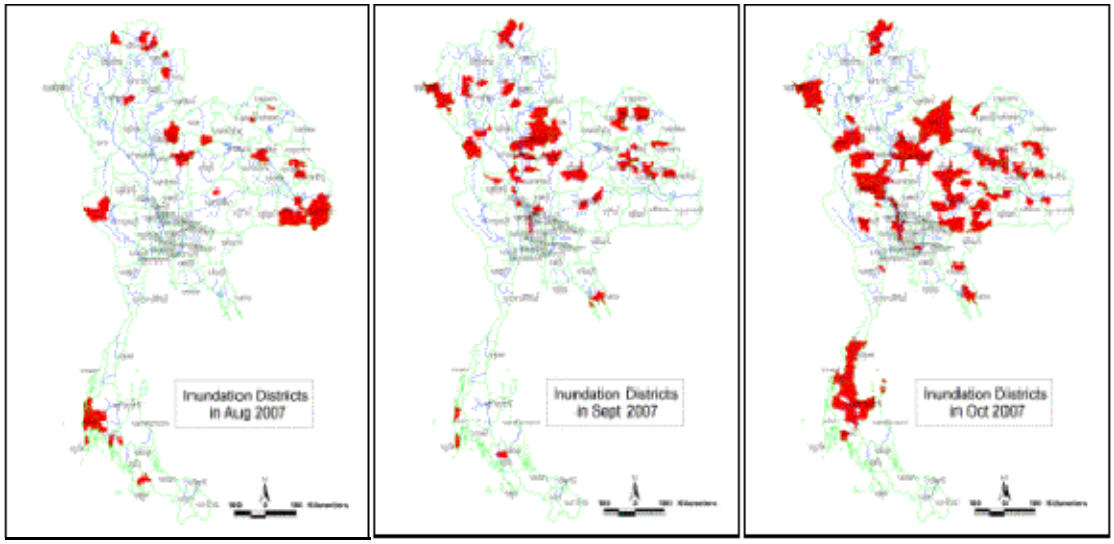


Figure 6. Inundation districts in the period of August, September and October 2007

Figure 7. Damages were by flash flood at Amphoe Dan Sai, Loei Province

Flooding in October 2007

At the beginning of October, the influence of typhoon Lekima passed Viet Nam and Lao PDR, and then moved towards the northeast of Thailand, it was weakened to a depression covering the upper and lower northern region causing heavy rainfall in northern and northeastern regions for the whole week. At mid October a depression covered the northern and central regions, causing heavy rains in the lower northern and central regions, that resulted to inundation of various districts in 34 provinces as shown in Figure 8. In communities the flood depth was 30 - 150 cm. Main highway, Mittraphap Highway, linking the central and northeastern region, was flooded 30 - 50 cm high in Saraburi to Nakhon Ratchasima section at Km 219, Km 228 and Km

229. The flooding caused small vehicles not to be able to pass or use the highway. Provinces that were most affected by the flooding were Loei, Petchabun, Pitsanulok, Chaiyaphum, Nakhon Ratchasima, Cumporn and Surat Thani, where damages were not only to houses and properties, but also there were deaths and missing persons.

Figure 8. Mittraphap highway main route to North East of Thailand became a canal

Impacts of flooding in 2007

In 2007, every region of Thailand had flooding that caused damages in 46 provinces based on the data of Department of Disaster Prevention and Mitigation as shown in Table 1. A population of 3,640,970 persons (940,663 households) has been affected. Agricultural land of (2.65 million rais) has been flooded. 8,330 routes of roads has been damaged and 62 casualties particularly during the months of September and October when the reported casualties were as high as 50 persons, which was 80.6% of the total casualties. The total value of damages to private properties and infrastructures affected in 2007 was not less than 1,697 million Baht. October was the most critical month having a damage value of 1,309 million Baht, which is 77% of the total value of damage in 2007. The damages incurring during this month consisted of adverse impacts on 2,883,747 persons, 768,563 households, (2.29 million rais) of agricultural area, and damages to 669 routes of roads.

Comparing the damages incurred in a 5-years period (Table 2), 2007 is considered the year with relatively high flood damages because the number of affected people and households was high, but the cost of damages is considered not high when compared to costs of damages in the previous years, because of preparedness and preparation to encounter the situation and preparation for relief were better than those in the previous years (Figure 9).

Table 1. Flood damage assessment in 2007

Description		Total	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Areas	Provinces	46	12	3	6	11	8	34	2	4
	Districts	486	38	5	9	61	26	305	11	31
	Villages	20,479	876	-	85	2,681	366	15,331	343	797
Human	People	3,640,978	70,025	5,042	9,335	395,436	27,942	2,883,747	42,659	206,792
	Households	940,663	19,076	1,225	2,582	88,241	9,125	768,563	2,335	49,516
	Evacuees	3,455	-	-	390	NA	600	NA	-	2,465
	Casualties	62	-	-	-	2	23	27	-	10
Assets	House	7,369	59	-	35	71	209	6,931	-	64
	Fish ponds	34,767	113	-	15	666	645	30,971	88	2,269
	Live stock	38,079	1,548	-	-	NA	-	NA	16,700	19,831
	Agriculture field (rai)	2,645,982	73,632	-	12,708	205,824	58,720	2,289,084	3,747	2,267
Infrastructure	Roads	8,330	153	15	97	657	-	6,690	432	286
	Bridges	309	50	5	10	14	5	192	3	30
	Hydraulic structures	591	82	6	2	50	2	448	1	-
	Institute buildings	271	29	-	-	4	-	198	-	40
	Drains	163	53	-	6	-	-	-	89	15
Cost million Baht		1,697	60	10	12	277	13*	1,309	15	-

Source: Department of Disaster Prevention and Mitigation.

* 1 of 3 damages in a month

Table 2. Comparison of impact from disaster in 2007, 2006, 2005, 2004 and 2003

Descriptions		2007	2006	2005	2004	2003
Areas	Provinces	46	47	63	59	66
	Districts	486	482	541	337	349
	Villages	20,499	20625	10326	9,964	5,281
Human	People	3,640,978	5,198,814	2,874,673	2,324,441	1,882,017
	Households	940,663	1,430,085	763,847	619,797	485,436
	Evacuees	3,455	-	21,260	3,3985	12,328
	Casualties	62	340	88	31	54
Assets	House	7,369	49,611	6,040	5,947	10,329
	Factories	NA	NA	46	17	2
	Hotels/Condominiums	NA	NA	15	11	NA
	Fish ponds	34,767	125,683	13,664	12,884	22,339
	Live stock	38,079	142,211	696,123	71,889	301,343
	Agriculture field (rai)	2,645,982	5,605,559	1,701,450	3,298,733	1,595,557
	Vehicles and others	NA	NA	880	148	NA
Infrastructures	Roads	8,330	10,391	5,697	4,173	5,071
	Bridges	309	671	667	173	393
	Hydraulic structures	591	778	22,527	716	179
	Institute Buildings	271	1,425	2,123	827	174
	Drains	163	1,085	1,482	594	282
Cost million Baht		1,697	7,077	5,982	850	2,050

Source: Department of Disaster Prevention and Mitigation.

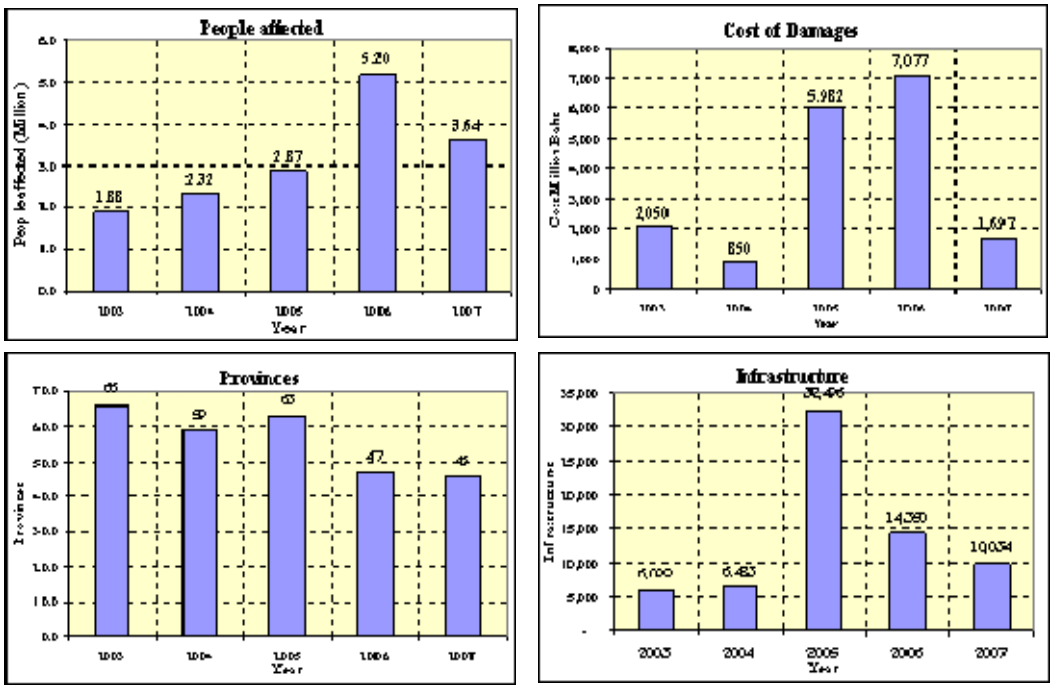


Figure 9. Number of provinces, people, infrastructure affected and cost of damage

RESPONSES TO FLOOD EVENTS IN THAILAND

National agenda on water

The Royal Government gave importance to water resources and set a policy for water resources management to be a national agenda on 21 May 2007. Flood prevention and mitigation are the

important issues, which the government had set the goal of having flood prevention systems and early warning systems in every flood risk community and main economic centre. The policies have the following strategies:

- protection and rehabilitation of upstream conditions to maintain a healthy excellent ecological condition;
- rehabilitate water resources, water ways and wetlands;
- develop and improve water resources, drainage systems and diversions;
- land use management and flood protection for economic areas;
- improve agricultural pattern and use agricultural areas as retarding pond;
- flood protection and flood relief management.

Early warning system for flood and landslide prone upland and sloping areas

According to the Cabinet's Resolution of 14 December 2004, the Department of Water Resources was assigned to develop the early warning system for the flood and landslide prone areas in the upland and mountainous sloping areas by setting up the priority taking into account the level of risk.

The automatic early warning systems are installed at different rainfall measuring stations. In case there is a heavy storm that causes higher rainfall at a level that tends to cause floods and landslides, the system will automatically send out the warning signal to the warning stations that distribute the information to all communities immediately so as to carry out disaster relief measures as already rehearsal. In Thailand, a total of 2,370 flood risk villages have been identified. In the 2005 - 2007 period, early warning systems have been installed covering 548 villages. In 2007 the early warning systems in 19 stations had send alarm signals 33 times.

Flood Forecasting in the Upper Chi and Upper Mun River Basins

The Department of Water Resources by the Water Crisis Prevention Centre has studied and installed the Tele-Metering System and established a Regional Data Centre in the Upper Chi and Upper Mun River Basin. The systems are composed of 6 remote stations and 1 regional station in the Upper Chi River Basin and 8 remote stations and 1 regional station in Upper Mun River Basin as shown in Figures 10, 11, and 12. The potential of the system shall cover the area of Khon Kaen, Chaiyaphum and Nakhon Ratcha SiMa provinces. The system was used for investigation of meteorological, hydrological and water quality data. These data will be used in the mathematic model for the theoretical analysis, simulation, and assessment of probable situations in order to minimize damages and other related hazards. The mathematic model consists of the rainfall-runoff model (NAM Model), hydrodynamic model (MIKE 11 HD), water quality model, MIKE 11 GIS and MIKE FLOODWATCH. The results of flood forecasting in the Upper Chi River are shown in Figures 13.

Figure 10. Automatic early warning system

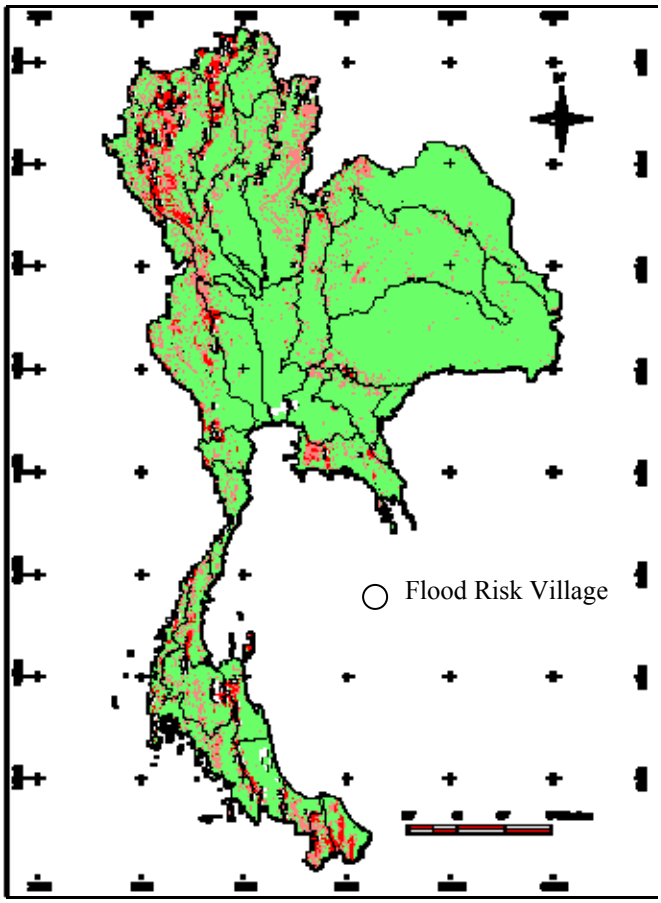


Figure 11. Location of flood risk village in 34 provinces, which are covered by the automatic early warning system

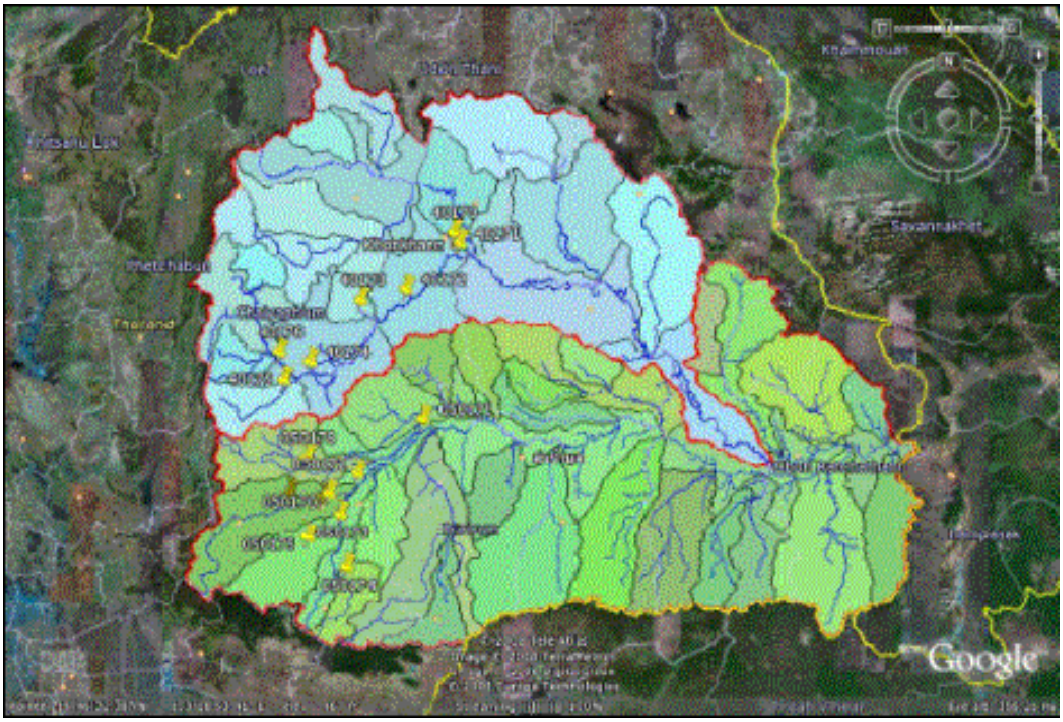


Figure 12. Location of telemetering stations in the Upper Chi and Upper Mun rivers

Flood preparedness planning

In 2007 the Ministry of Interior has established the Ad-hoc Centre for Flood, Storm and Landslide Disasters Prevention and Mitigation (Ad-hoc Centre) with the Department of Disaster Prevention and Mitigation as the Secretariat. The concepts of cooperation for implementation were specified:

- the Ad-hoc Centre in the Ministry of Interior is the centre for coordination in protection and relief of flood with other concerned agencies, integrating and connecting all data for solving problems and helping the victims of a disaster;
- the Provincial Ad-hoc Centre is the centre at the provincial level for coordination of local operations so that there will be unity in the overall operations;
- all central government agencies, regional and local administration authorities have to be ready in providing disaster warning and relief devices and equipments in solving the problems and helping the victims in emergency stage;
- improve and correct implementation regulations, criteria and steps for provision of aid to suit current situations;
- disseminate information regarding disasters in the past, which caused severe damages so that people would realize and be prepared all the time;
- in risk areas where aid is difficult to be provided, the provincial and district units should prepare and arrange for food and potable water reserves for 7 days. The local administration authorities should provide advanced financial support to give immediate relief to the victims during the disaster.

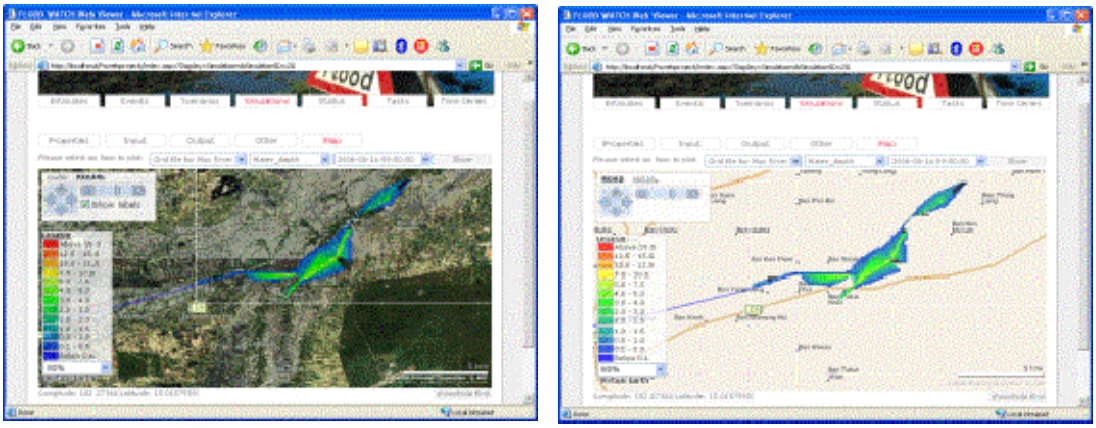


Figure 13. MIKE FLOOD WATCH shows the inundation area along the Upper Chi River

The Royal Irrigation Department (RID), Ministry of Agriculture and Cooperatives has a management plan to regulate water during the rainy season giving emphasize on flood relief and measures prior to flooding.

The working committee on monitoring and analysis of trends in the water situation held regular weekly meetings to plan for water regulation management. The working committee set up a workplan for appropriate reservoirs and large detention ponds during the start of the rainy season in order to accommodate large volumes of water, which were expected during the month of August to November 2007, and also to remove water from low lying areas to detain upstream runoff, which would alleviate impacts on downstream areas. Opening of water gates will help in discharging water to the sea during low tide. In discharging of water from hydropower dams, The Electricity Generating Authority of Thailand (EGAT) has the important role to regulate water during critical situations, the discharging of water will be minimized and when the rainfall reduces the discharge will be increased and vice versa, in order not to have severe water accumulation. Moreover, in places where there are long inundations, RID will send mobile

drainage pumps to help victims of the disaster in that area. With the support and readiness of 433 drainage pumps in 2007, RID was successful to regulate water to relieve flooding in Chao Phraya River Basin including Bangkok Metropolitan area. RID was able to control the surplus of water not to overflow the retention wall along both sides of the river and also controlled the upstream runoff to Bangkok and suburbs in 2007, therefore the impact and cost of damages is less than in the previous years.

The Department of Water Resources (DWR), Ministry of Natural Resources and Environment had prepared a plan for encountering flood comprising of: follow-up of conditions and important information affecting the flooding, i.e. rainfall data, water levels in main rivers, volume of water in reservoirs, typhoon, cyclone, monsoon crossing various parts of Thailand, etc., those were used in the analysis and preparation of daily and weekly water situation reports that were submitted to the ministry executives and other concerned agencies for disaster warning and further actions. DWR regional offices had checked and prepared tools, equipments and other machineries to be ready for use in helping the disaster victims and also to coordinate with the River Basin Committee to achieve flood prevention and mitigation in the area. During an inundation period, continuously surveillance and monitoring for 24 hours was undertaken in order to assess and analyse data that will have effect in making the flood situation more severe as well as impact to be incurred in the area. Reports covering the cause of flooding, the basic incurred damages were prepared in order to inform all concerned high level executives and to be the basis for mitigation and relief operations.

The Department of Mineral Resources (DMR) has an important role in monitoring and warning for disasters due to flash floods that cause flooding and damages to people residing in the uplands and sloping areas. There were continuous measurements of rainfall, studies on geological and geographic conditions, analysis of disaster occurrence and warning of the people for such disasters for evacuation to safe places during heavy rainfall. DMR recommend to the people to have guard shifts that will observe flash flood incidents and to recommend to village headmen to install rainfall gauges as a factor for warning of flash foods and landslides.

Thai Meteorological Department (TMD), Ministry of Information and Communication Technology monitored and followed-up reports on weather conditions and natural phenomena. There are weather forecasts, disaster warnings and dissemination of information by radio broadcasting and Internet every day, which benefits various agencies. This information is used in the analysis and assessment of occurrence of flooding and in the implementation of prevention of various disasters in their respective responsibility. The people can make use of this information in protecting their properties from damages by themselves. TMD publicized important data that comprised the rainfall data for 24 hours period, preparation of climatological maps, satellite images, follow-up of weather conditions, daily weather forecasts, 7 days and 3 months in advance, and the water situation from the telemetering systems including flood risk area forecasting.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In 2007 the rainy season in Thailand started in the month of May and had widespread heavy rainfall in almost every region of the country except in the northeastern region. The heavy rainfall was influenced by depressions formed in the Gulf of Thailand and a tropical cyclone formed in the Andaman Sea, causing a rainfall of 274 mm, which resulted in flooding in 12 provinces in the north, northeastern and southern regions. Afterwards, the amount of rainfall decreased and again increased in the months of August, September and October. The cumulative rainfall of each month was more than 200 mm causing flooding in various provinces throughout the country. The month that was most affected by flooding was October due to the influence of typhoon Lekima and a depression covered various parts of the country. The cost of

damage was as high as 1,309 million Baht, 77% of the total cost of damage for the whole year. The damage caused by flooding in 2007 was considered low when compared to damages incurred in the previous 5 year periods, although the numbers of affected people and households were relatively high.

The setting up of Ad-hoc Centres both at central and provincial level was an important mechanism to increase the efficiency in flood protection management in all stages before, during and after flooding.

The weather forecast, flood forecasting, monitoring and early warning were very important to reduce the loss in lives and properties of the people, particularly the early warning system (EWS) that can help to warn the people residing in uplands and sloping areas with high potential landslides efficiently. In 2007 the EWS in 8 provinces with 17 stations had alarmed 33 times at different risk levels, and 4 times has given an evacuation signal.

Recommendations

- flood forecasting and early warning systems play a significant role in flood prevention and mitigation, particularly in the uplands and sloping areas. Installation of systems is worthwhile and benefits to be accomplished soon to cover all those flood risk areas;
- an appropriate process for estimation and assessment of flood damages is necessary because the comprehensive assessment of damages gives important data that will reflect the economic loss of the country, which becomes significant supporting information for setting up of both structural and non-structural measures for flood prevention and mitigation;
- a great quantity of water should be retained during the rainy season and later used. This will not only relieve the flooding problem but it will also help in prevention of drought to follow.

VIET NAM'S COUNTRY FLOOD REPORT FOR 2007

TRINH HOANG NGAN

National Flood Expert (NFE) for the VNMC's National Flood Unit (VNMC-NFU), Ho Chi Minh City, Viet Nam

ABSTRACT

The territory of Viet Nam is located in the monsoon tropical zone of Southeast Area. At the same time, it is situated in the typhoon centre of the East Sea, where it is one of the five largest typhoon centres of the World. Given the coincidence of typhoon and monsoon seasons with heavy rains, and mainly mountainous topography floods and flooding occur frequently.

Of the ten sub-areas (SA) of the Mekong River Basin, Viet Nam has five SAs including SA-1V, SA-4V, SA-7V, SA-8V, and SA-10V; of which the SA-10V, concerns tidal flat plains characterised by long time flooding phenomena, while the other four SAs, the mountainous landscapes, are characterised by flash floods and river floods.

Data from 1926 to 2007 show that there were 28 big floods (water level over 4.5 m+MSL at Tan Chau station) in the Mekong Delta, of which 4 historical flood events occurred in 1936, 1961, 1966 and 2000. Two historical floods appeared in the Central Highlands in 1966 and 2000.

In 2007 it was a lower normal flood and flooding event in the mainstream in the Mekong Delta. However, flash floods occurred in the tributaries of Se San and Srepok rivers in the Central Highlands, where serious damages and deaths occurred in Dak Lak province, caused by a flash flood event resulting from typhoon No.2 Noname in early August 2007.

At present, the National Centre for Hydrometeorological Forecasting (NCHMF) is a legal agency performing both forecasting and warning at the national level. Besides, other agencies are concerned with the warning activities, including the Central Steering Committee for Flood and Storm Control (CCFSC), National Committee for Search and Rescue (NCSAR) and Department of Dyke Management, Flood Control and Storm Preparedness (DDMFCSP) that are responsible for providing indicative/instructed warnings for implementation. The key issues of these agencies, as reflected through their activities, include: (i) the National Strategy for Natural Disaster Prevention, Response and Mitigation until 2020 that was approved by the Government in November 2007; (ii) the flood warning water level system, which is under review by the Ministry of Natural Resources and Environment (MONRE); and (iii) workshops on the World climate changes that are being held more and more.

Four topics of the Theme *'Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin'* are discussed in the Country Report, of which Topic IV *'Lessons learned from past flood events'* is more detailed.

This paper presents an overview of the 2007 floods and flooding, updating the status of the flood forecasting and warning organizations; and sharing ideas regarding the 6th Annual Mekong Flood Forum, in Phnom Penh, Cambodia, on 27 - 28 May, 2008. In addition, the suggestions, recommendations as well as findings are also shown in the report.

INTRODUCTION

General introduction

Based on the hydrological conditions and country boundary, the Lower Mekong River Basin is divided into 10 sub-areas (SA) of which the Mekong River Basin of Viet Nam (MRBV) has five

SAs: SA-1V covering upper Nam Ou River; SA-4V representing upper Se Bang Hieng River, SA-7V consisting of upper Se Kong, Se San and Srepok rivers; SA-8V involving upper Prek Chh Long River; and SA-10V belonging to the Mekong Delta in Viet Nam (MDV). These 5 SAs cover an area of 7,251,307 km^2 occupying some 22% of the total country area and have 19.3 million people representing approximately 23% of the total country population. Figure 1 shows the main locations in the MRBV.

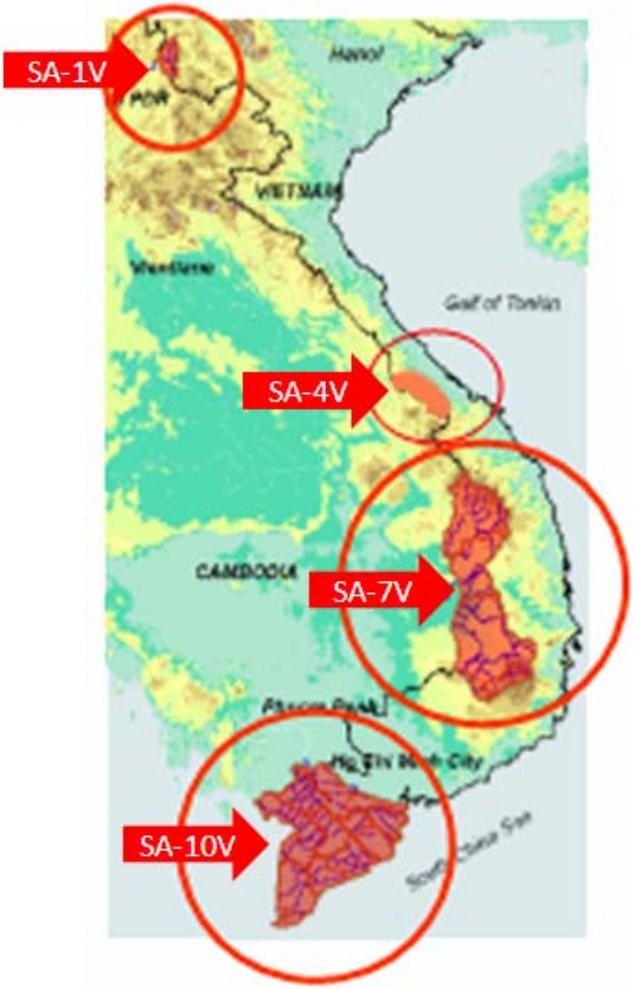


Figure 1. Location map of the Mekong River Basin in Viet Nam

Contents of the report

This report presents an overview of the 2007 floods and flooding, updating the status of the flood forecasting and warning organizations; and sharing ideas regarding the 6th Annual Mekong Flood Forum, namely '*Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin*', that to be held in Phnom Penh, Cambodia, on 27 - 28 May, 2008. In addition, the suggestions, recommendations as well as findings are also shown in the report.

OVERVIEW OF THE 2007 FLOODS AND FLOODING

In general, flood in Viet Nam is normally caused by storm rainfall in the upstream river basins and local heavy rainfall, resulting from strong tropical monsoons in the Inter-Tropical Convergence Zone (ITCZ) combined with typhoon/tropical depressions originating from the

East Sea moving towards the Viet Nam territory; while flood in the MDV is characterised by the flooding regime in the floodplains caused by basin flood flow, local rainfall and tidal fluctuation.

Based on data and information collected from the line agencies as well as from a field visit of the National Flood Unit (NFU) Mission in both the Mekong Delta and the Central Highlands in December 2007, showing that a lower normal flooding season repeated in the MDV; while flash floods dominated in the tributaries of Se San and Srepok rivers in the SA-7V. In 2007 there were seven typhoons and four depressions offshore of the Viet Nam territory, of which Typhoon No.2 Noname hit the Viet Nam territory causing serious damages and deaths in Dak Lak Province in early August 2007.

Flood in the mainstream in the Mekong Delta in Viet Nam

In the MDV floods and flooding are mainly caused by the water regime of the Mekong River, Tonle Sap Great Lake regulation, local rainfall, natural topography and man-made infrastructure as well as tidal fluctuation from two directions (West and East Seas). In 2007, only one flood duration lasting 3 months from end of July to end of October. The flood peak at Tan Chau station reached 4.08 m+MSL (Mean Sea Level), on 24 October 2007, which was a month later than the long-term annual flood peak. Figure 2 indicates the 2007 flood affected provinces in the MDV.

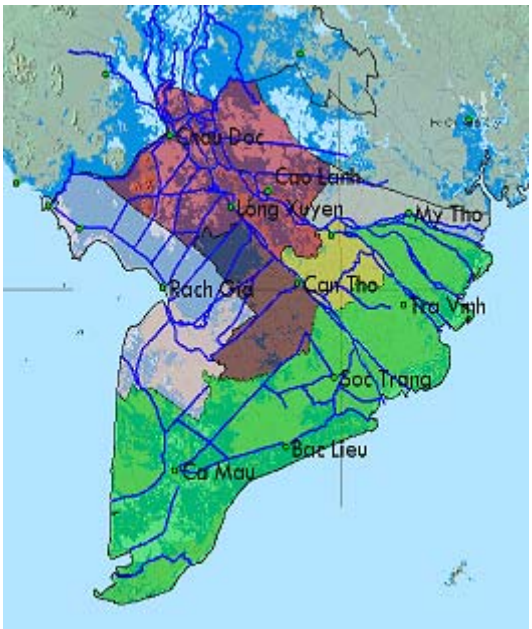


Figure 2. 2007 flood affected provinces (brown colour)

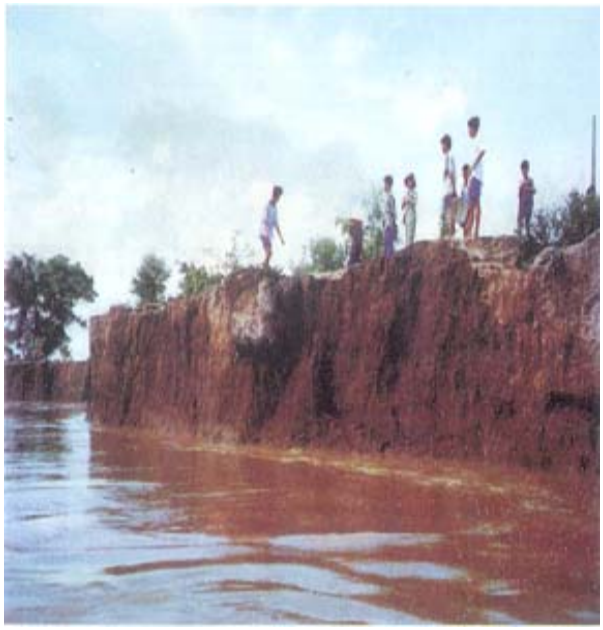


Figure 3. Bank erosion at Thuong Phuoc village, Hong Ngu district, Dong Thap province

Although there was a lower normal flood season in the MDV, bank erosion phenomena along the Mekong and Bassac rivers have increased in the recent years. Figure 3 is a picture showing the erosion situation at Thuong Phuoc village, Hong Ngu district, Dong Thap province (Mekong River).

Floods in the tributaries, upper Se San and Srepok rivers

Flood in the Central Highlands is normally classified as flash flood, especially in the tributaries of the Srepok and Se San rivers where tributary lengths are short, but steep channels and riverside mountains occur, while high intensity and long duration rains cause flash floods in a short time. Figure 4 shows the locations where flash floods and tributary floods occurred in the

Central Highlands during the flood season of 2007.

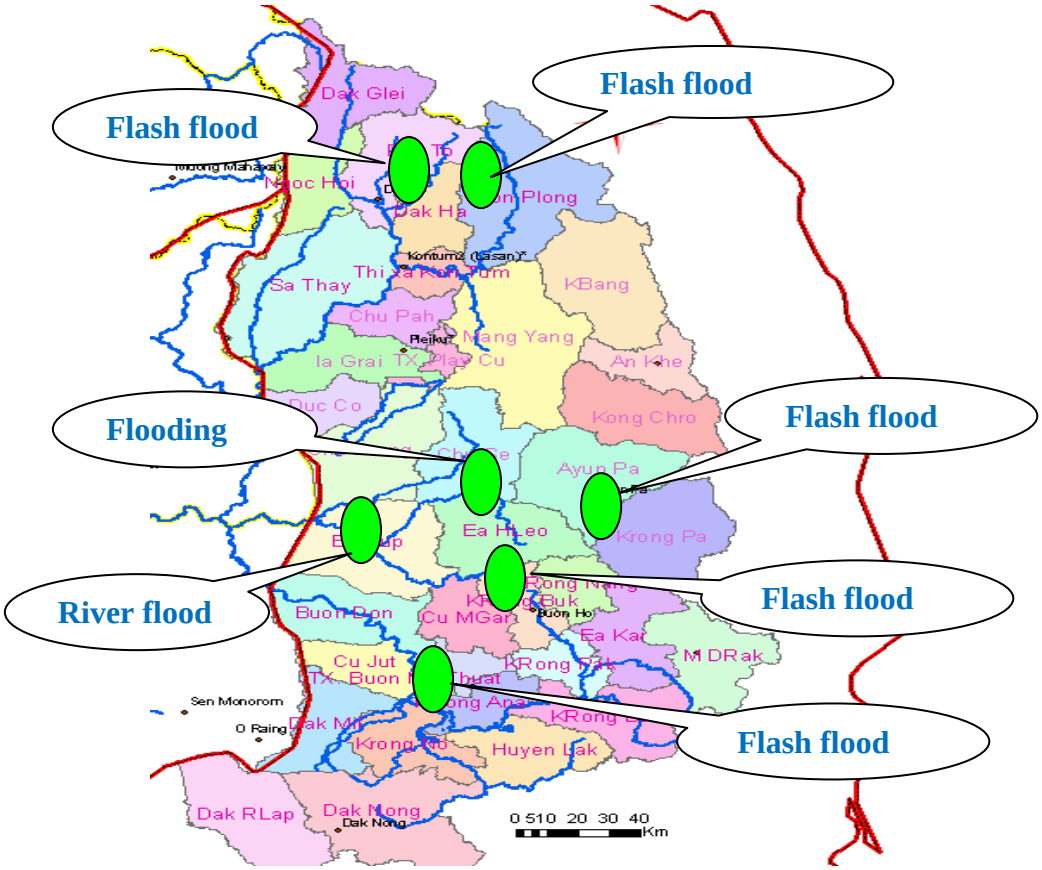


Figure 4. Floods and flooding in the Central Highlands during the flood season of 2007

There were six flood periods during the rainy season of 2007: (i) early week of August from 1 to 7; (ii) from 19 - 24 September; (iii) from 27 September to 4 October; (iv) from 15 - 19 October; (v) from 2 - 4 November; and (vi) from 9 - 11 November, in which the first one had big flash floods, mainly appearing in upper Srepok River, including Krong Buk tributary at Krong Buk station (2.08 m higher than alarm level 3), Ea Krong branch at Cau 14 station (4.41 m higher than alarm level 3); and Krong No stream at Duc Xuyen station (1.3 m higher than alarm level 3). Flash floods caused damages and deaths in the whole Dak Lak province and partly in Dak Nong province (Dak Nong district), especially in Ea Shoup district where the Ea Shoup reservoir received an inflow of 30% larger than the critical flood flow, causing cracks along the crest surface of the earthfill dam. Figure 5 shows a picture taken after the flood at the provincial road No.8, rubber farm 19/5, Ea Ding village, Cu Mgar district, Dak Lak province.

As resulted by typhoon No. 6 Paipath 0721 (5 November 2007) brought heavy rainfall over the central provinces of Viet Nam including Central Highlands where floods and flooding appeared after that from 9 - 11 November 2007. This was the second considerable flood event in 2007, mainly occurring in Dak Bla and Po Ko tributaries of Se San River where flash flood happened in the Kon Plong district, Kon Tum province, having 3 bridges moved out (Figure 6). There are no data and information concerning flood events in the SA - 1V, SA - 4V and SA-8V.

Hydrometeorological characteristics of the floods and flooding

The hydrometeorological characteristics of the 2007 floods and flooding in Viet Nam were dominated by tropical depressions/typhoons. During the rainy season, there were 7 typhoons and 3 tropical depressions on the East Sea, of which 6 typhoons affected Viet Nam (Table 1 and

Figure 7). Two of these typhoons (No.2 Noname and No.6 Paipath - 0721) directly caused serious damages and deaths in the Central Highlands.

Figure 5. Road and irrigation canasl were damaged by flash flood during Typhoon No.2, early August 2007

Figure 6. A bridge crossing Dak Bla River was moved by flash flood, 9 November 2007

Table 1. List of tropical typhoons affecting Viet Nam in the flood season of 2007

Storm no.	Name of typhoon	Approaching date	Beaufort scale	Affected areas
1	Toraji - 0703	3 - 5/7/2007	Scale 6 gusting over scale 7	Northern region from Quang Ninh to Hai Phong
2	Noname	1 - 6/8/2007	Scale 6,7, gusting over scale 8	Central Highland and Middle Viet Nam
3	Pabuk 0706	7 - 10/8/2007	Grade 11	Did not affect Viet Nam
4	Francisco - 713	22 - 25/9/2007	Tropical depression	North Viet Nam from Thai Binh to Thanh Hoa
5	Lekima - 0714	3/10/2007	Grade 12, gusting over scale 12	North and North Central provinces
6	Paipath - 0721	5/11/2007	Grade 10	Central region provinces
7	Hagibis - 0724	22 - 24/11/2007	Scale 6,7, gusting over scale 9	South region from Binh Dinh to Ninh Thuan prov.

Tropical storm No. 2 Noname

In the early morning of 1 August, a low depression originated in the south area of the East Sea developed to be the storm No.2 on 4 August 2007 with intensity of grade 6 to 7 and then reaching scale 8, gusting over grade 8 at the near storm centre. The storm moved quite rapidly in West-Northwest direction with a speed of 12 km/hr. In the afternoon of 6 August, it moved more slowly again and weakened into a tropical low depression. In the early morning of 8 August, after landing in the area of Ha Tinh province it declined into a low depression area. The storm directly affected to offshore territorial waters from Nghe An to Quang Ngai provinces; and brought torrential rains to the large areas of the Central Region and Central Highlands (see Figure 8).

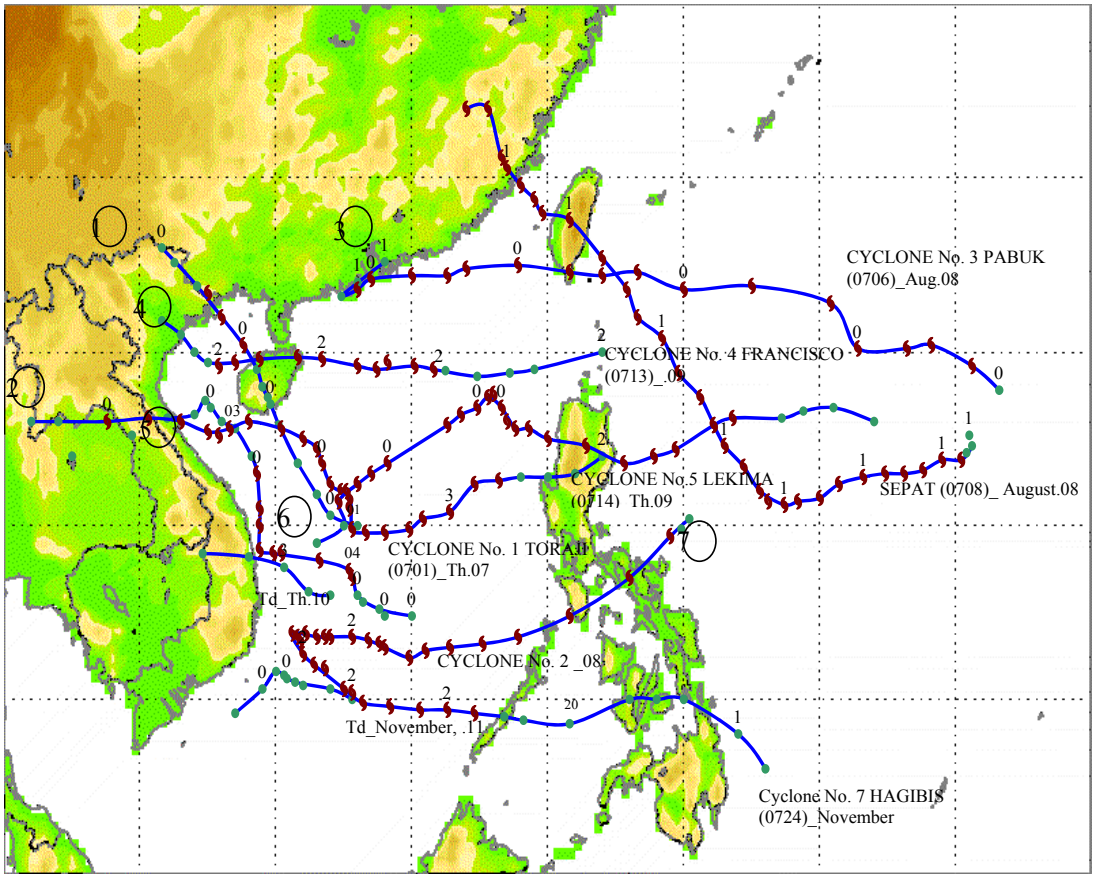


Figure 7. Tropical cyclone tracks affecting Viet Nam territory and LMB in 2007

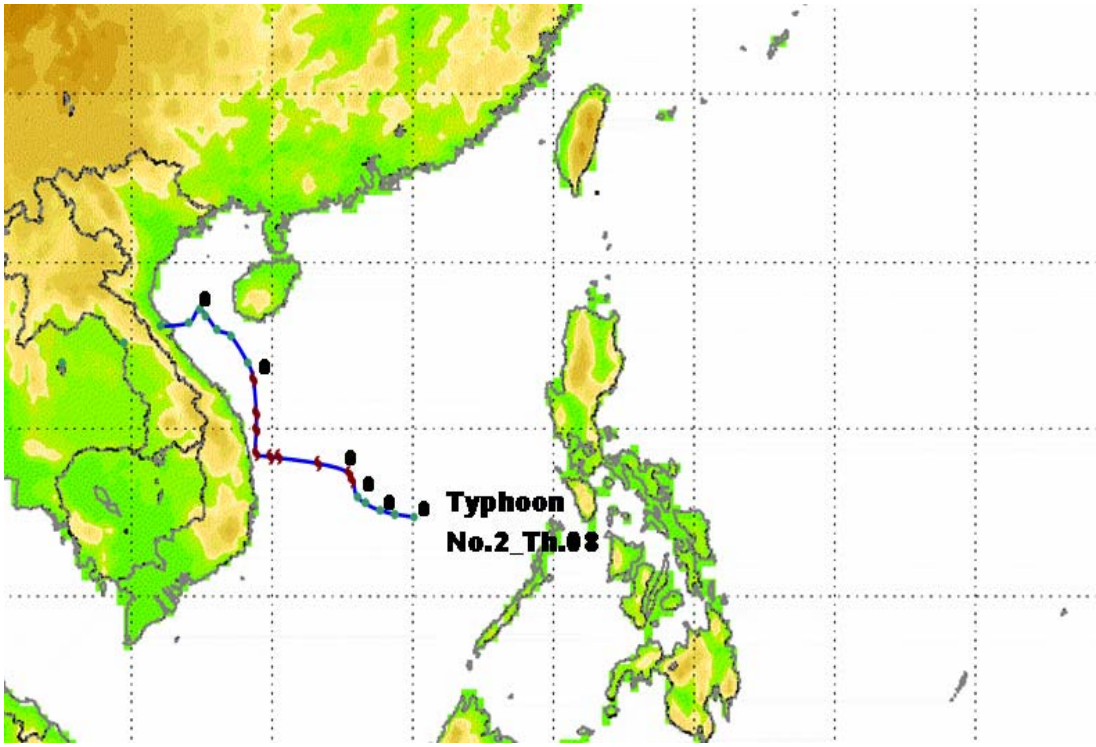


Figure 8. Typhoon track No.2 Noname

Typhoon No.5 (Lekima - 0714)

On 29 September, a low pressure in Luzon Island area (Philippines) strengthened to a tropical depression. On early morning of 30 September, the depression strengthened to a tropical level storm and hit Ngang Hill, then passed the area between Ha Tinh and Quang Binh provinces, resulting in strong wind at beaufort scale 12 and gusts reaching above grade 12. The strong storm had complicated tracks and changed its direction many times. After hitting Viet Nam, it moved to Laos PDR bringing heavy to very heavy rains in the central regions of both Viet Nam and Laos PDR (Figure 9).

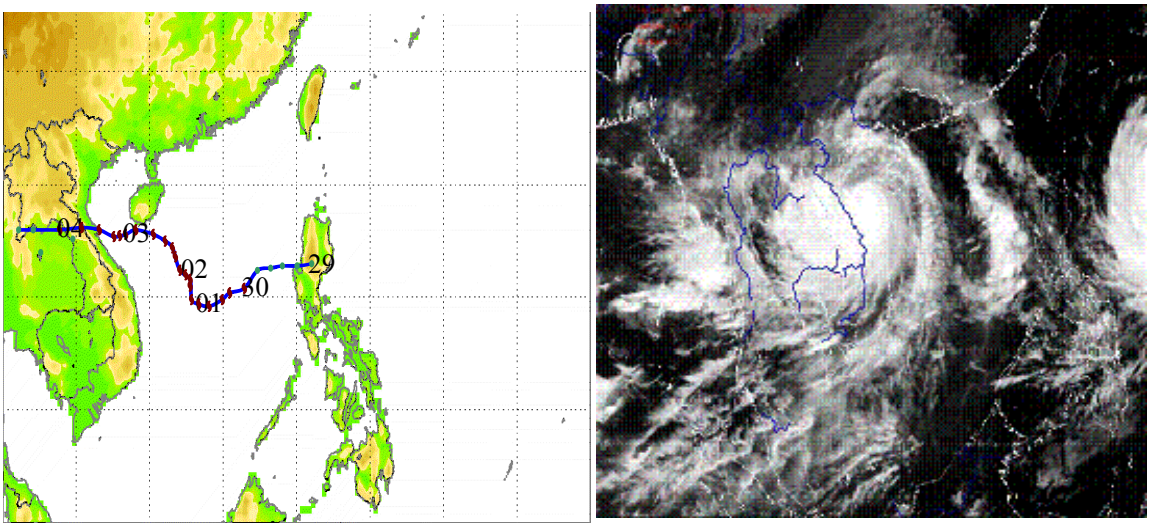


Figure 9 Severe tropical cyclone track N.5 Lekima (0714) crossing Viet Nam and Lower Mekong River Basin countries on 3 October 2007

Hydrometeorological characteristics of floods and flooding in the Mekong Delta (SA-10V)

Rainfall distribution in the Delta

At the beginning of the rainy season the rainfall distribution over the Delta was recorded positive normally; heavy rains occurred at large areas and almost all stations observed positive normally rainfall in the rainy season between May to November. There were one to three heavy rainfall periods at large-scale every month. Especially, the heavy rainfall periods during three months from August to October combined with spring tides caused inundation of large areas of the floodplain. Comparison with the normal flood year 2005 clearly shows that the distribution of rainfall in 2007 was 10 - 20% higher than the average annual rainfall, but much lower than the historical flood year 2000. Monthly rainfall in the flood season of 2007 and mean monthly rainfall at the main stations in the SA-10V is presented in Figure 10. Figure 11 shows the isolated rainfall map of the most southern Viet Nam. Daily rainfall at Chau Doc and Can Tho stations are indicated in Figures 12 and 13.

Floods in the mainstreams and flooding in the floodplain

Floods occurred in the Mekong and Bassac rivers in early July and August. The first flood peak reached 1,80 m+MSL at Tan Chau station on 6 July while it was 1,55 m+MSL at Chau Đoc station on 7 July. The second flood peak was 3.00 m+MSL at Tan Chau station on 31 August; it was 2,5 m+MSL (equal to alarm level I) at Chau Đoc station on 31 August. Water levels increased slowly reaching alarm level II at the end of September at both Tan Chau (3.6 m+MSL) and Chau Doc (3.0 m+MSL) stations. The highest water levels were at 4.08 m+MSL

at Tan Chau station (24 October) and 3,56 m+MSL at Chau Doc station (24 October) that was 0.10- 0.22 m lower than the long-term average flood water levels (4.20 - 3.78 m+MSL at Tan Chau and Chau Doc stations). Table 2 lists the maximum flood water levels at the hydrological stations along the main rivers and the on-farm areas in 2000, 2006 and 2007.

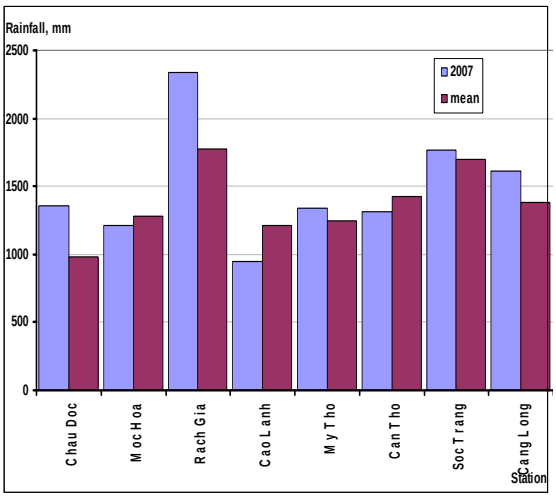


Figure 10. Comparison of 2007 monthly rainfall and mean monthly rainfall at the main stations

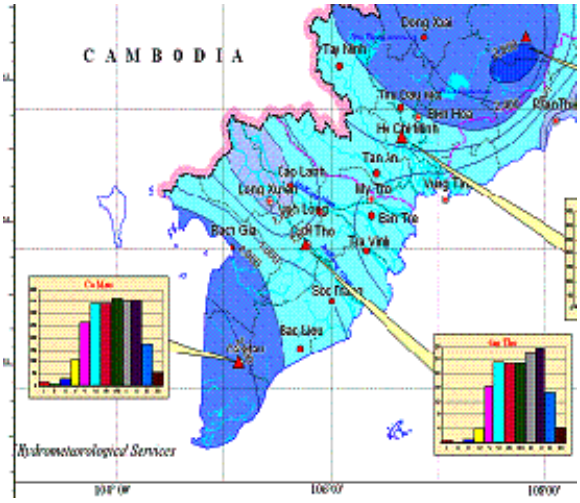


Figure 11. Isolated rainfall map in South VN

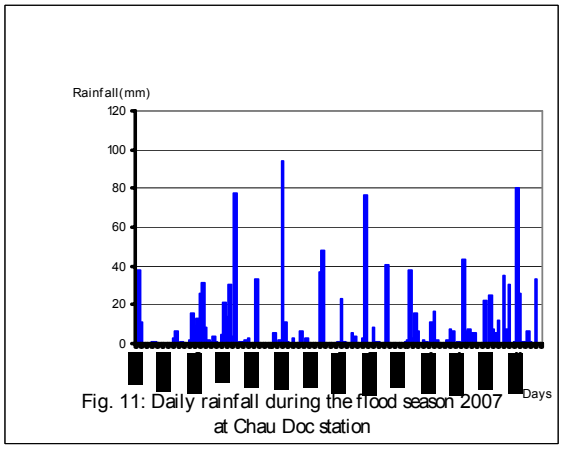


Figure 12. Daily rainfall at Chau Doc station

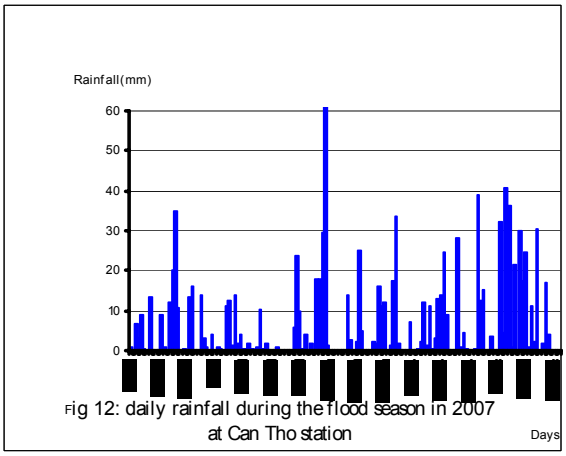


Figure 13. Daily rainfall at Can Tho station

Table 2. Maximum water level at hydrological stations on the mainstream and on-farm

Station	2007		2006		2000	
	H_{max} (cm)	Date	H_{max} (cm)	Date	H_{max} (cm)	Date
Tan Chau	408	23 October	417	17 - 19 October	5.23	23 September
Chau Đoc	356	24 October	371	21 October	4.90	24 September
My Thuan	185	26 October	184	6 November	180	30 September
My Tho	167	27 October	162	4 November	163	14 November
Long Xuyen	246	6 November	234	23 October	263	27 September
Can Tho	203	26 October	199	6 November	179	30 September
Moc Hoa	199	31 October	217	28 October	327	25 September
Tan Hiep	131	3 November	128	26 October	185	8 October
Cao Lanh	229	26 October	222	24 October	261	27 October

The historical flood hydrographs of the Mekong and Bassac rivers at Tan Chau and Chau Doc stations are indicated in the Figures 14 and 15, while Figures 16 and 17 illustrate the 2007 flood hydrographs at Tan Chau and Chau Doc stations.

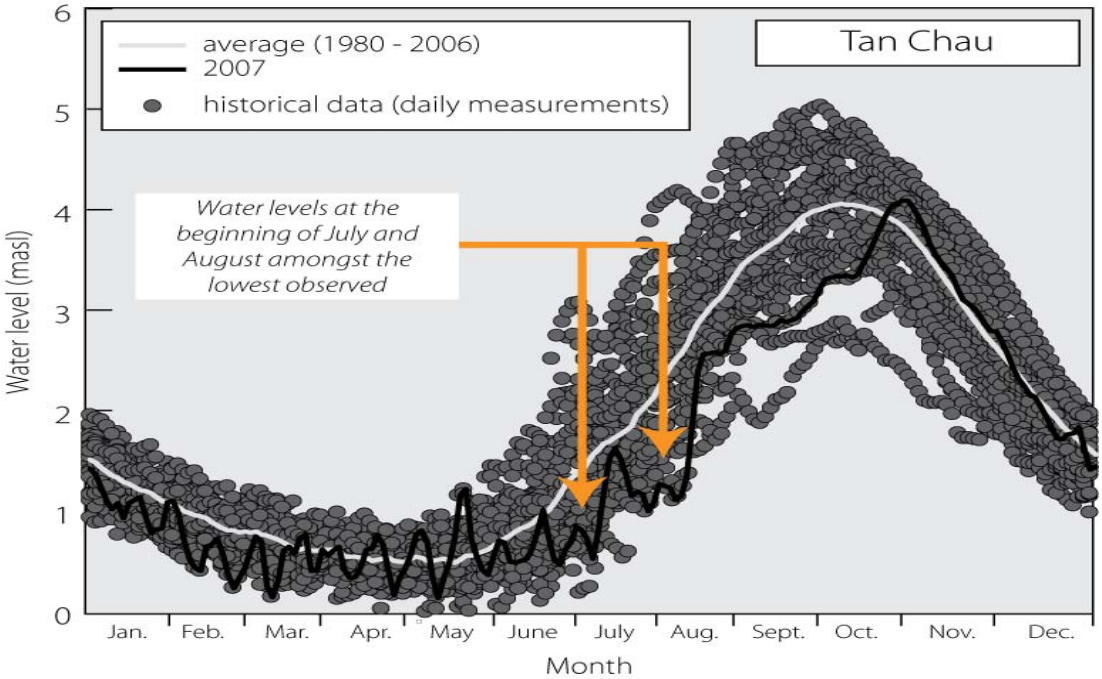


Figure 14. Historical flood hydrograph of Mekong River at Tan Chau station (Source: MRC, RFC, Presentaton on Annual Mekong Report 2007, Phnom Penh, 5 March 2008)

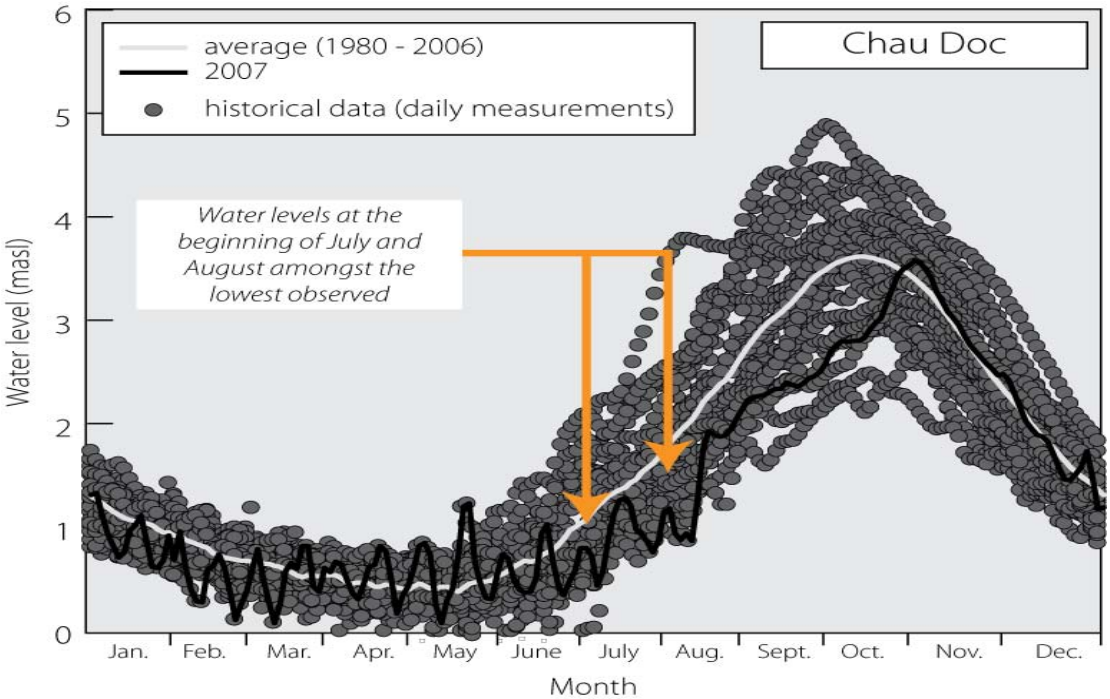


Figure 15. Historical flood hydrograph on Bassac River at Chau Doc station (Source: MRC, RFC, Presentaton on Annual Mekong Report 2007, Phnom Penh, 5 March 2008)

The 2007 inundation duration (water level over 3.6 m) in the on-farm areas (Plain of Reed) lasted nearly one month (25 days), shorter than last year (33 days) but the maximum

water level at the further inland stations of the Plain of Reed occurred half a month later than the long-term average water level and were some 9 - 21 cm lower than the water level last year. In late October a spring tide period appeared causing serious inundation in many provinces of the Delta, especially in Can Tho City where the water level reached 2.03 m+MSL at Can Tho station on Bassac River (Figure 18), a record value in the recent years. Figure 19 shows the inundation level at Moc Hoa station on Vaico River.

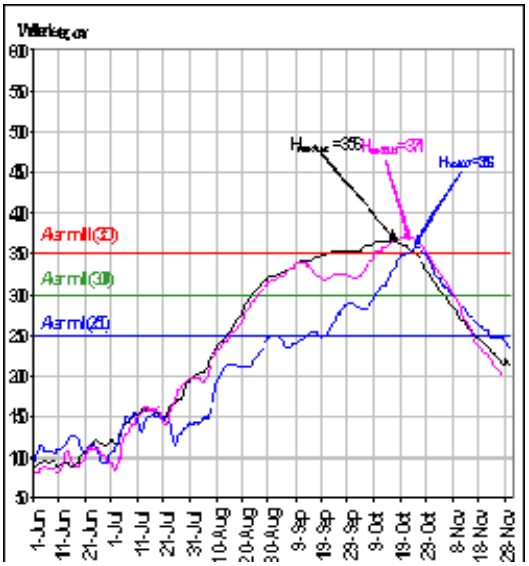


Figure 16. Flood hydrographs at Tan Chau Doc station, Mekong (Tien) River in 2006, 2007 and average

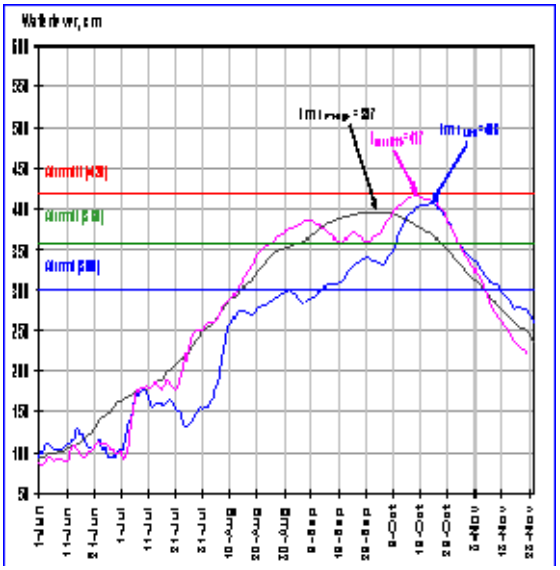


Figure 17. Flood hydrographs at Chau station, Bassac (Hau) River in 2006, 2007 and average

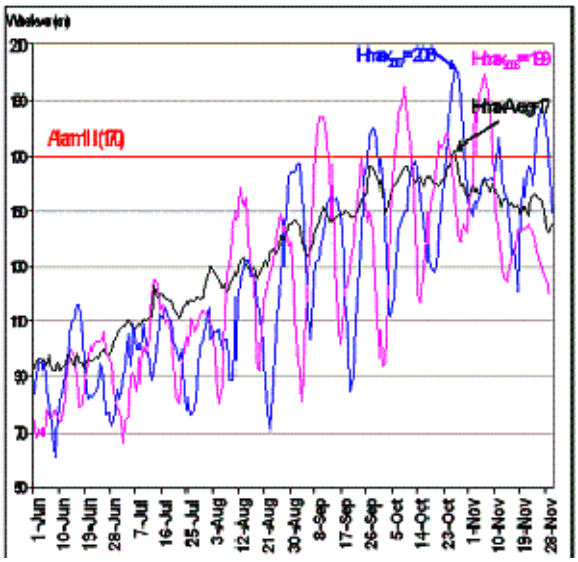


Figure 18. Flood hydrographs at Can Tho station on Bassac River in 2006, 2007 and average

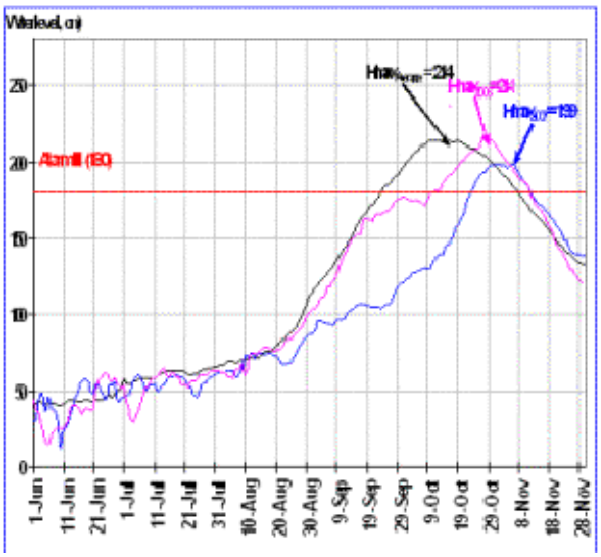


Figure 19. Flood hydrographs at Moc Hoa station on Van Co Tay River in 2006, 2007 and average

Table 3 presents the starting and ending dates of the 2007 flood season as well as the standard deviation at the main hydrological stations in the Cambodian plain and the delta in Viet Nam.

Table 3. Starting and ending dates of the 2007 flood season in the Mekong Delta (Source: MRC, RFC, Presentaton on Annual Mekong Report 2007, Phnom Penh, 5/3/2008)

Site	Onset of flood season			End of flood season		
	Historical average	Standard deviation	2007	Historical average	Standard deviation	2007
P. Penh Port	10 July	14 days	4 August	14 November	14 days	15 December
Prek Kdam	11 July	16 days	5 August	20 December	17 days	29 December
Tan Chau	19 July	20 days	8 August	17 December	12 days	14 December
Chau Doc	23 July	17 days	9 August	19 December	12 days	27 December

Hydrometeorological characteristics of floods and flooding in the tributaries of upper Se San and Srepok rivers in the Central Highlands (SA-7V)

Rainfall distribution

Total rainfall during the rainy season was the same as the long-term mean rainfall value. Statistically, in the rainy season, there were 12 heavy rainfall periods lasting normally 3 - 5 days, a special 7 days (early August); of which 6 periods of very heavy rains caused flash floods and flooding in the Central Highlands, in which the period from 2 - 5 August was the maximum rainfall distribution (Table 4) that flash floods occurred causing the most serious damages and deaths in Dak Lak province.

Table 4. Recorded rainfalls at the specific stations in the Central Highlands

No.	Name of station	River basin	Rainfall (mm)	Floods occurred
1	Buon Ma Thuot	Srepok	323	Local flash flood
2	Buon Ho	Srepok	575	Local flash flood
3	Giang Son	Srepok	307	Local flash flood
4	Duc Xuyen	Srepok	201	Local flash flood
5	Bridge 14	Srepok	172	River flood
6	Ban Don	Srepok	220	River flood
7	Dak Lei	Se San	264	River flood
8	Dak Mot	Se San	77	Small river flood
9	Kon Plong	Se San	77	Local flash flood
10	Kon Tum	Se San	171	River flood

Daily rainfall at Buon Me Thuot and Ban Don stations is presented in Figures 20 and 21. Figures 22 and 23 show the accumulated rainfalls at two critical periods in the rainy season: 1 - 5 August and from 27 September - 18 October.

Flood hydrology of the tributaries, upper Se San and Srepok rivers

There were six very heavy rainfall periods over the Central Highlands, of which the first (early August) and second (early November) periods were the most significant events causing floods and flooding on the upper Se San and Srepok rivers. Table 5 summaries the recorded data regarding the flood events occurring in this area. Figure 24 describes the flood hydrographs of Srepok River during the flood season of 2007 while Figure 25 indicates the flood hydrographs of the tributaries of Srepok River.

Table 6 summarises the recorded data regarding the flood events that occurred in the river basin area of upper Se San River. The rather big floods (equal to flood alarm level III) occurred in the tributaries of Se San River during the heavy rainfall period as result of Typhoon No.6 Paipath-0721, early November. Figure 26 illustrates the flood hydrographs of Dak Bla tributary at Kon Tum station during the occurrence of Typhoon No.6 Paipath-0721, early November. Figure 27 shows yearly flood hydrographs of the tributaries of Se San River.

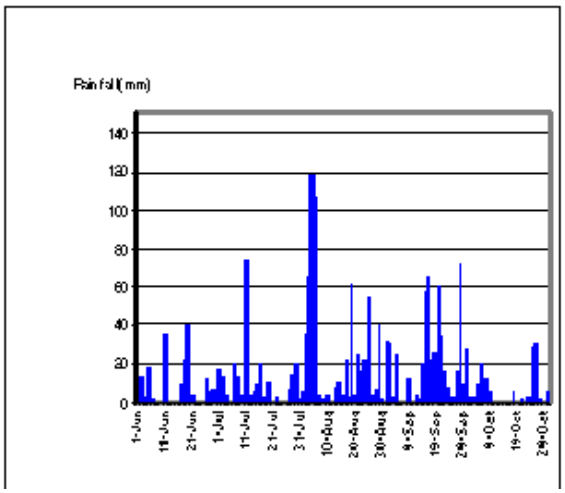


Figure 20 Accumulated rainfall at Buon Me Thuot station

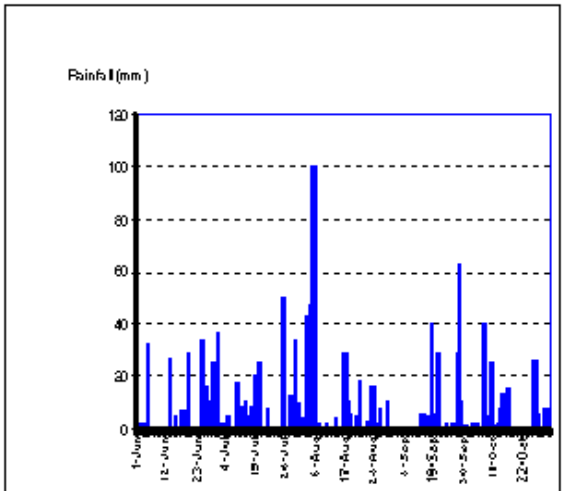


Figure 21 Accumulated rainfall at Ban Don station

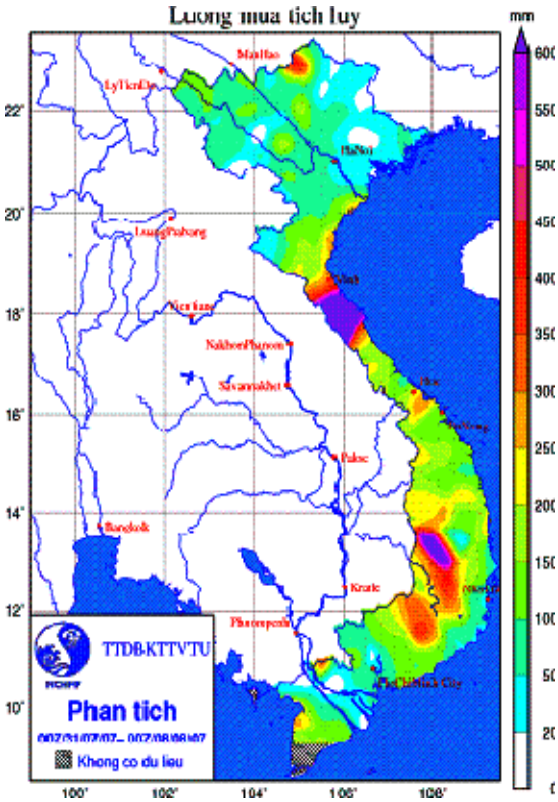


Figure 22. Accumulated rainfall 1-5 August

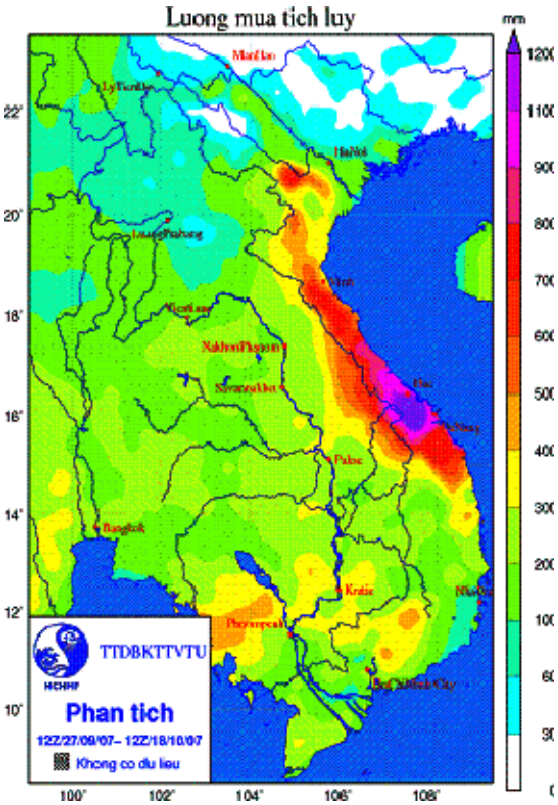


Figure 23. Accumulated rainfall in October

Table 5. Water level at hydrological stations along Srepok River and its tributaries during occurrence of typhoon No.2 Noname, early August 2007

River	Station	Hmax (2007)	Hmax (2006)	Recorded time	Date	Alarm level	Hmax/ha
Krg Buk	Krg Buk	458.39	-	10:00	5 August 2007	III	> 2.08 m
Ea Krong	Bridge 14	303.41	300.83	9:00	7 August 2007	III	> 2.41m
Srepok	Ban Don	176.11	172.35	21:00	5 August 2007	III	> 2.60 m
Krong No	Duc Xuyen	431.80	-	22:00	5 August 2007	III	> 1.30 m

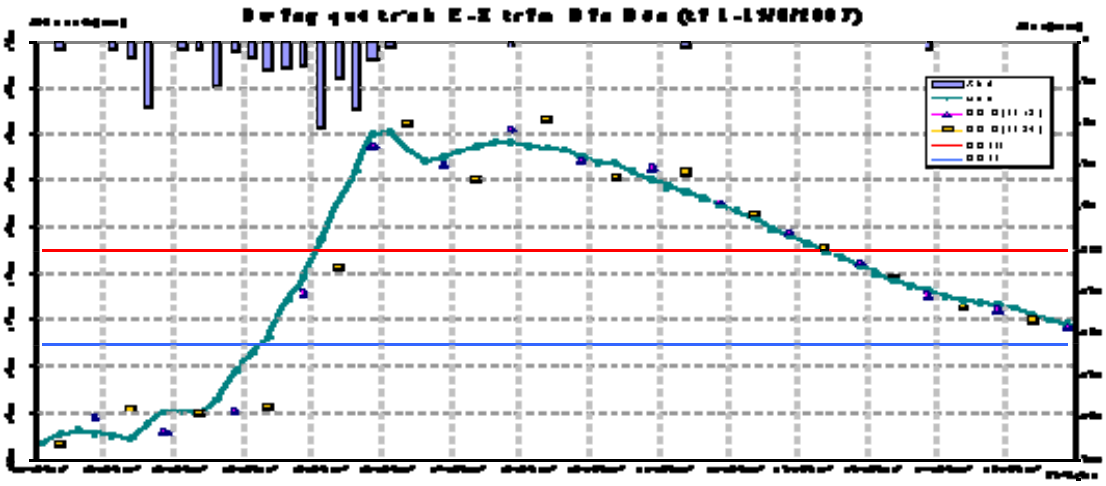


Figure 24. Flood hydrograph at Ban Don station, Srepok River, during 1 - 15 August 2007

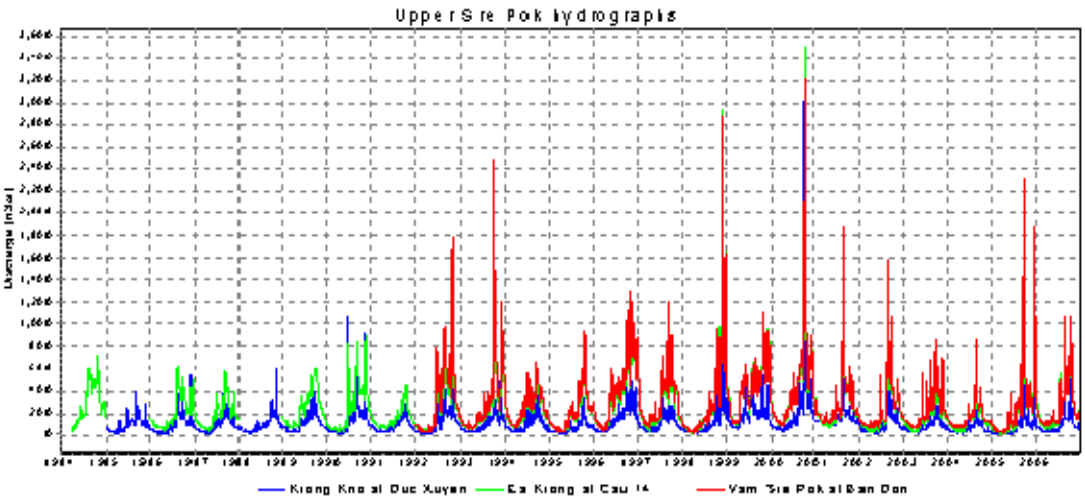


Figure 25. Flood hydrographs of the tributaries, upper Srepok River

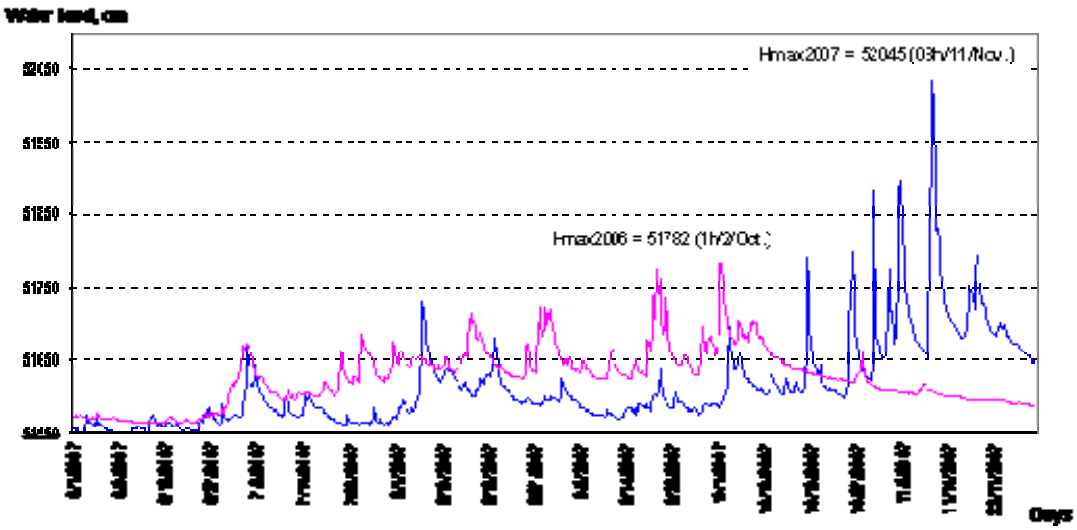


Figure 26. Flood hydrographs at Kon Tum station (Dakbla Tributary) in 2006 and 2007

Table 6. Water level at the hydrological stations in Se San tributaries during the occurrence of Typhoon No.6 Paipath-0721, early November 2007

River	Station	Hmax 2007	Hmax 2006	Recorded time	Date	Alarm level	Comparison to alarm level
Dak Bla	Kon Plong	594.05	592.65	1:00	7 November 2007	III	Equal
Dak Bla	Kon Tum	520.45	517.99	18:00	4 November 2007	III	Equal
Krong Poko	Dak Mot	583.36	458.39	5:00	11 November 2007	II	> 0.86m

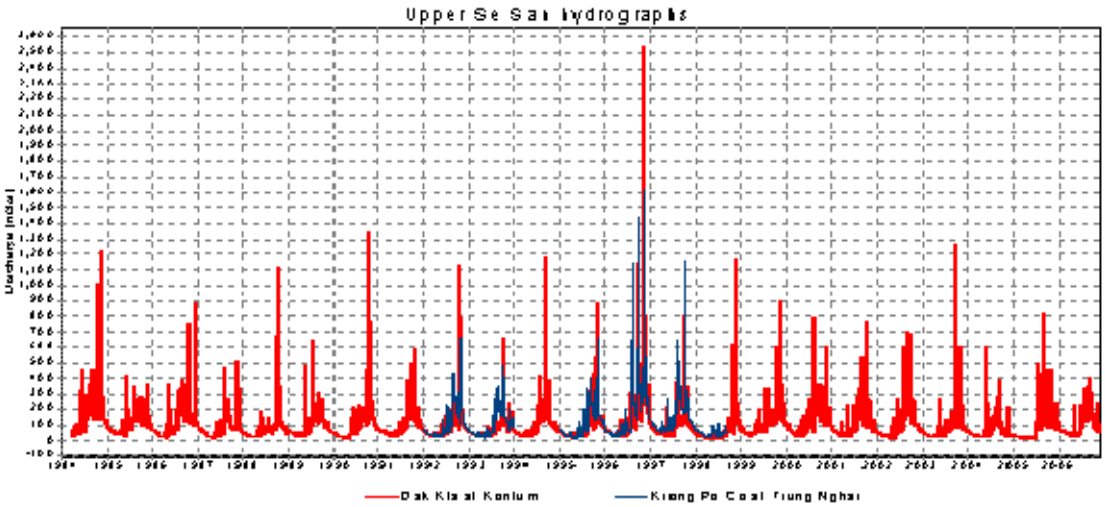


Figure 27. Flood hydrographs of the tributaries, upper Se San River

Summary of positive and negative effects of the floods

Generally, flood in Viet Nam is considered as disaster, affecting peoples life and country economy, especially floods occurring in the North and the Middle of Viet Nam, including the Central Highlands where the flash floods have dominated in remote areas, but flood in the MDV is still different from people to people on their viewpoints.

Floods and flooding phenomena are a natural hazard, which affects peoples life not only positive but also negative. Suffering from floods, the Viet Namese people in the flooded areas have learned how to live with floods. However, floods at big scales or the extraordinary floods sometimes cause loss of lives and properties as well as damage to the technical and social infrastructure. Clearly, floods at small to medium magnitude do not always cause negative impacts to people living in the flood-affected areas, they also can get benefits from flood flow.

It is considered as favourable conditions for the people living in the MDV where flood flow brings huge amounts of silt for farm sedimentation containing alluvial soils, naturally fertile for agriculture production. Yearly, flood flow brings fresh water for irrigation, domestic water supply, land reclamation as well as pushes the salinity intrusion boundary down to the river mouth and flushes acid water from acid sulphate soil areas. Naturally, flood flow has functioned to clean farmlands; dissolves chemical toxic; kill mice and insects. Furthermore, flood flow also supplies fishery resources to the people living in or out of the Delta. A more important role of flood flow is to reserve the wetland ecosystem. Besides, the Mekong Delta receives some hundred million tons of silts accreting to the seas (some 50 - 100 m, respectively) annually.

The 2007 flood was considered as a nice flood season supporting the farmers having a successful year for agriculture production with some 17.0 million tones of paddy keeping Viet Nam as the second country exporting rice in the world.

The above positive impacts are clear. However, floods and flooding in the MDV cause

deep (1 - 4 m) and long inundation (2 - 5 months) in a large area (some 1.4 - 2.0 million ha) affecting socio-economic development for production, settlement, technical and social infrastructure as well as people's lives. Especially, the big flood events such as the 2000 flood causing the death of some 500 people and losses of US$ 250 million for the MDV economy.

The 2007 flood in the Central Highlands, especially in Dak Lak province, considered as a disaster year having 29 people dead and 4 persons missing as well as losses of some US$ 50.8 million for the provincial economy during the flood period in early August, caused by typhoon No.2 Noname.

Impacts of floods and flooding in 2007

Based on data collected from Central Steering Committee for Flood and Storm Control (CCFSC), Department for Dyke Management and Flood Control and Storm Preparedness (DDMFCSP), Provincial Committee for Flood and Storm Control (PCFSC) and other sources, the flowing tables present the key issues of damages and deaths caused by natural disasters in 2007, of which Table 7 indicates damages and deaths caused by natural disasters in 2007, including the whole Viet Nam, Mekong Delta and Central Highlands while Table 8 shows comparison of damages and deaths in the Mekong Delta in Viet Nam during three years: 2007, 2006 and 2000.

Table 7. Summary of damages and deaths caused by natural disaster in 2007

No.	Type of losses	Viet Nam	Mekong Delta	Central Highlands
1	Human	462 died, 33 missing, 856 injured people	30 people died	29 people died, 4 persons missing
2	Assets	9,908 houses collapsed and drifted; 718,270 houses inundated and damaged; 4,811 class rooms and over 1,160 health care centres broken, drifted and damaged	1,400 houses destroyed; 23,864 houses inundated; 164 education rooms damaged and 101 classrooms moved.	166 houses destroyed, 12,447 house inundated
3	Agriculture	173,830 ha paddy fields inundated, in which 33,064 ha completely lost; 215,059 ha short-term crops submerged and damaged, of these, over 37,768 completely lost	33,700 ha of paddy 4,422 ha of upland crops damaged; 8328 ha of fruit tree damaged	20,344 ha of paddy damaged; 24,393 ha of short-term crop inundated 252 tonnes food production lost
4	Fishery	19,765 ha of aquaculture areas were flooded; more than 3,308 vessels were sunk and damaged	1,100 ha fish and shrimp ponds damaged; 852 fish cases damaged and 29 tones of fishery lost	593 fish ponds damaged
5	Transportation	Above 8,560,747 m^3 were eroded; more than 3,085 bridges and sluices were collapsed, drifted and damaged	19 km National roads, 705 km rural roads, 140 bridges, 126 km long eroded and 49,000 m^3	59 bridges destroyed; 14 bridges damaged
6	Water control structures	5,114,573 m^3 of soils were eroded and filled up; some 1,968 small structures were drifted and damaged eroded	185 units damaged, 104 km embankment eroded	331,837 m^3 eroded; 13 water control structures drifted; 24 small structures damaged
7	Other	40 provinces affected	5 provinces	4 provinces
8	Total cost	US$ 720 million	US$ 1.5 million	US$ 50.8 million

Table 8. Comparison of impact from disaster in the Delta during the years: 2007, 2006 and 2000 (Sources: Data collected from CSCFSC, MARD and MONRE, 2007, 2006 and 2000)

Description	Flood damage in 2007	Flood damage in 2006	Flood damage in 2000
Provinces affected	5	5	13
Families affected	13,500	15,530	800,000
People affected	67,500	77,650	10 million
People killed	30	42	453
Hectares of rice and crop damaged	14,688 ha	15,223 ha	2.0 million ha
Total estimated cost damages	US$ 1.5 million	US$ 2.0 million	US$ 250 million

Table 7 shows the losses in the whole Vietnam, Mekong Delta and Central Highlands caused by natural disasters in 2007, of which the losses of properties and people in the Central Highlands are the main figures of Dak Lak province only. No data and information were collected from the Kon Tum, Gia Rai and Dak Nong provinces.

Table 8 indicates that the losses of 2006 and 2000 caused by floods and flooding in the MDV were very small compared to the economic and people losses caused by floods and flooding that occurred in 2000. Although the floods on the Mekong River during the recent years (2006 - 2007) were normal but the result of precise forecast and early warning provided by National Centre for Hydrometeorology Forecast was helpful for making arrangements and preparedness measures from the government to provincial levels including stakeholders and affected people.

Figures 28 and 29 show comparison of the human loss graphs and property loss graphs of the Mekong Delta in Viet Nam and the whole country from 1990 to 2007.

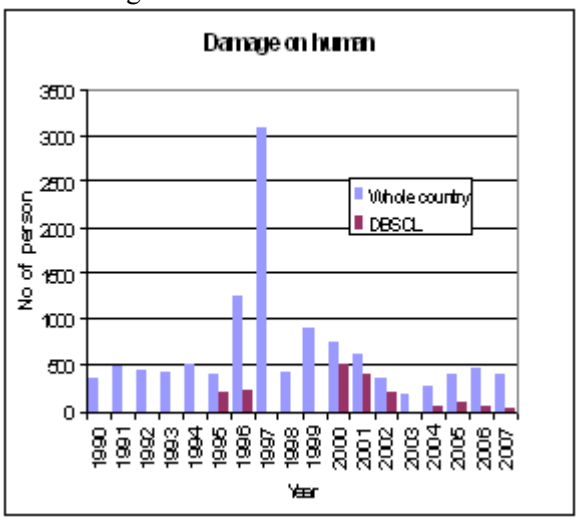


Figure 28. Human loss graph in Mekong Delta and whole Viet Nam

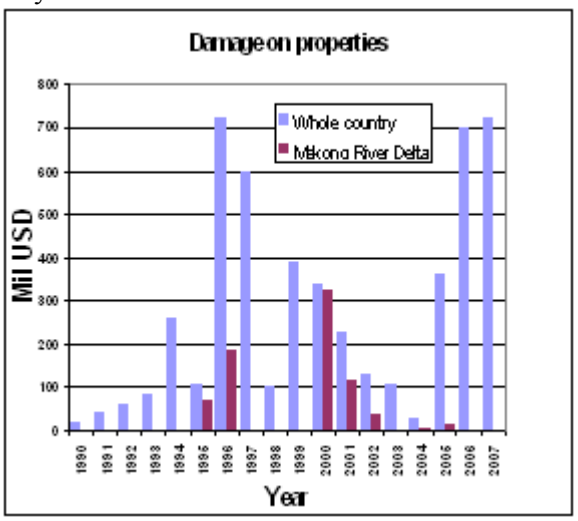


Figure 29. Property loss graph in Mekong Delta and whole Viet Nam

UPDATE ON THE NATIONAL FORECASTING AND WARNING CENTRES

Current status of national centres

At present, the National Centre for Hydrometeorological Forecasting (NCHMF), under the lead of the Ministry of Natural Resources and Environment (MONRE), is a legal agency performing both forecasting and warning at the national level. Besides, other agencies are concerned with warning activities, including the Central Steering Committee for Flood and Storm Control (CSCFSC), the National Committee for Search and Rescue (NCSAR) and the Department for

Dyke Management and Flood Control and Storm Preparedness (DDMFCSP) that are responsible for providing indicative/instructed warnings for implementation. More details regarding duties and responsibilities of major agencies are presented hereafter.

Central Steering Committee for Flood and Storm Control (CSCFSC)

The CSCFSC is responsible for emergency response to disastrous floods and storms. It has the comprehensive system of organizations spanning from the central to the local levels. The budget for their activities comes from three sources: Government, Local community's participation and external assistance. Figures 30, 31 and 32 show the updated organization chart of CSCSFSC, provincial and district levels.

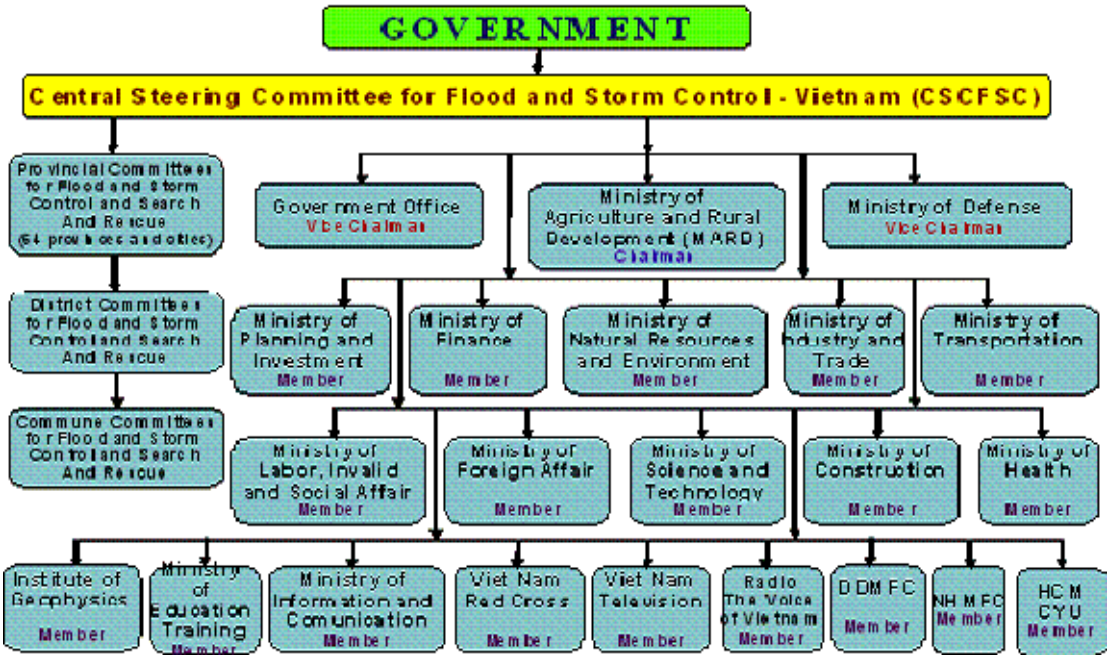


Figure 30. Indicative organization chart for responding to disastrous floods and storms

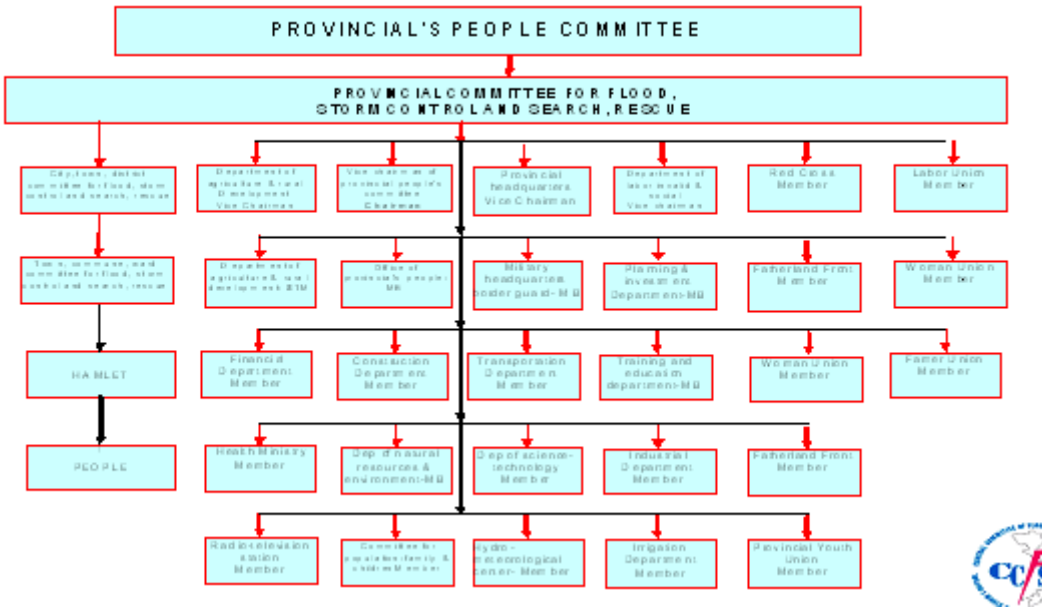


Figure 31. Implementing organization chart at provincial level

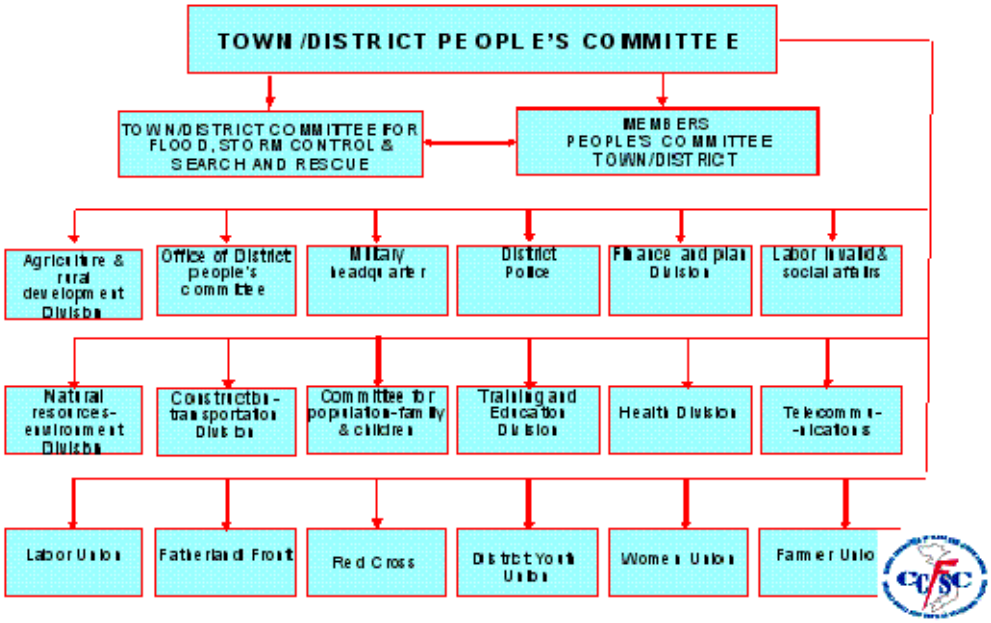


Figure 32. Implementing organization chart at district level

The chairmen of Provincial, District and commune people's committee issue the decision to establish the Provincial, District and commune committee for Flood and Storm control. The members of the Committee include: the chairman of people's committee is the chairman, Chief of the water sector is the vice chairman and the members are the chief or vice chief of sectors related to the flood and storm control work of local nature. The office of the committee is located at the water sector office. The expenditure for the operation of the committee is provided by the provincial budget, in the budget provided for the water sector.

Committees for flood and storm control at local levels have the responsibility to assist the provincial people's committee at this level to develop and directly implement the flood and storm control measures in this area; to protect dike and the economic and resident areas; overcome the aftermaths of flood and storm; as well as to prepare planning for flood and storm preparedness and prevention.

The Standing Office for flood and storm control at the provincial level operates in close collaboration with the Central Committee for flood and storm control, the National Committee for Research and Rescue, the Southern Centre for Hydrometeorological Services in order to monitor the hydrometeorological situations, and issues timely information on the flooding and raining situation, directives from the Central and provincial people committees towards respective departments, provincial authorities and agencies in districts, towns and the people.
The Standing Office of Flood and Storm Control provides the specific duties to its members in their locations and frequently conducting the monitoring supervise and solve difficulties.

National Committee for Search and Rescue (NCASR)

NCSAR (Figure 33) is responsible for coordinating, controlling, implementing the national warning system and equipment for providing the technical assisstance/expertice to search and rescue the victims caused by natural disasters. This agency was formed based on a Strategy and Action Plan for Mitigating Water Disaster in Viet Nam prepared by the International Consultants and Former Ministry of the Water Resources since the 1990s decade of the 20th Century. It's tasks and responsibilities were upgraded and increased since 2002 covering activities with respect to not only water disasters but also for other sectors, including space and marine areas.

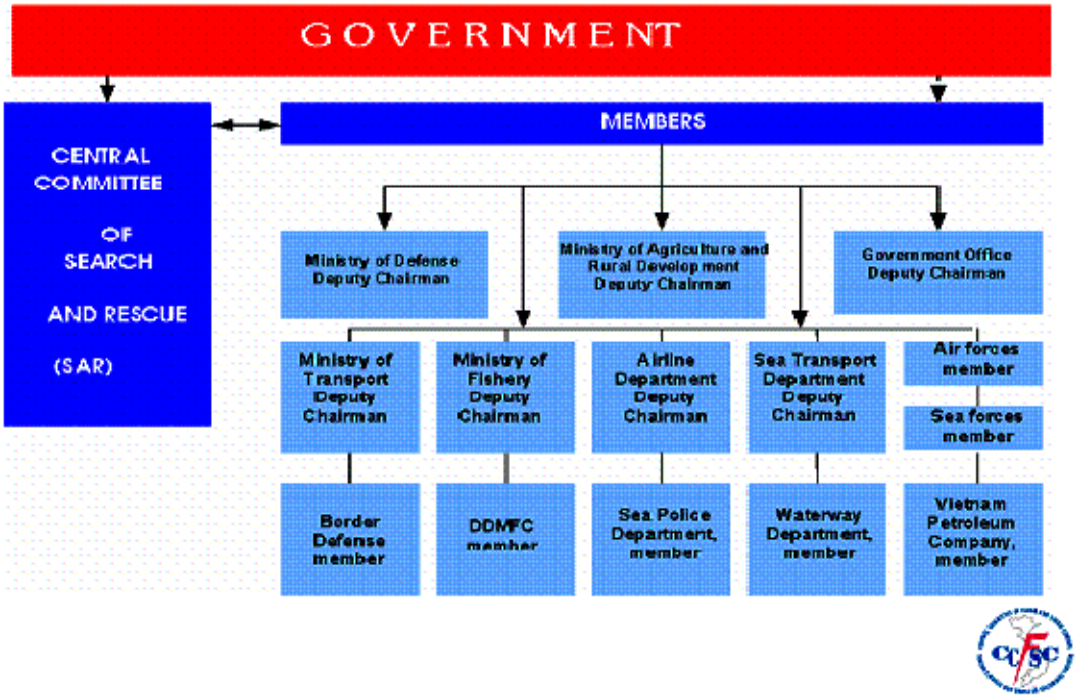


Figure 33. Organization of National Committee for Search and Rescue in Viet Nam

After a long time for preparation, the Government approved the National Strategy for Natural Disaster Prevention, Response and Mitigation until 2020, dated on 19 November 2007. This will promote and creates a solid foundation in support of the National FMMP as well as Regional FMMP. A natural disaster classification map (Figure 34) in Viet Nam is also attached in the National Strategy for Natural Disaster Prevention, Response and Mitigation until 2020. In addition, the Dike Law was approved by the Parliament in November 2006.

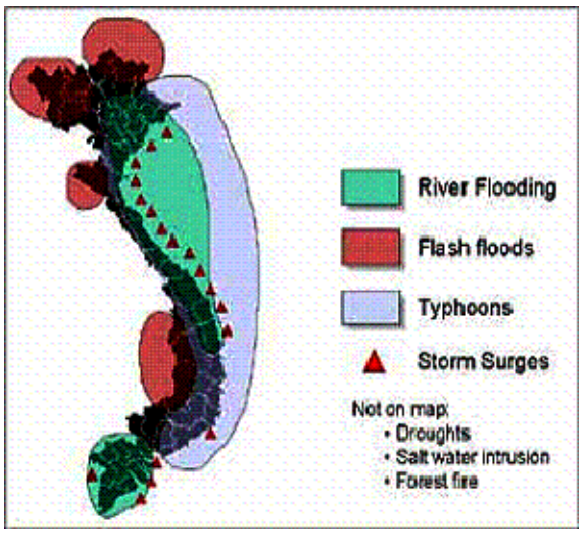


Figure 34. Nature disaster map in Viet Nam

Department for Dyke Management, Flood Control and Storm Preparedness (DDMFCSP)

The Statute on Flood and Typhoon Mitigation was promulgated 8 March 1993, establishing the responsibilities and powers of the Department for Dyke Management, Flood Control and Storm Preparedness (DDMFCSP) and for the Provincial and District Agriculture and Rural

Development Services, as well as defining the control of development in flood prone land areas. This statute also empowers authority's officers to take the necessary steps to prepare for floods and typhoons, and to participate in emergency repairs and protective works.

The DDMFCSP approves the Disaster Management Plans. Typhoons and floods are relatively rare in the South of Viet Nam and the emergency information system is not developed as in the Northern and Central Parts of Viet Nam. However, when a disaster occurs, it can inflict massive damage. Recent examples of the big floods in the Mekong Delta (2000, 2001 and 2002) as well as the typhoons (Durian in 2006 and Noname 2007) caused serious losses of people and properties.

During the pre-disaster, DDMFCSC regularly receives information updates from the Hydrometeor Logical Services. It keeps the Ministry of Agriculture and Rural Development (MARD), Office of the Government (OOG), Ministerial Committee for Flood and Storm Control (MCFSC), the Provincial Committee for Flood and Storm Control (PCFSC) and also the mass media, i.e. TV, radio and newspapers informed.

When a disaster actually occurs, and if emergency relief is needed, a joint mission of the members of CSCFSC visits the affected areas to assess the damages. DDMFCSP reports directly to the OOG, and a meeting of CSCFSC is held, the Ministry of Planning and Investment (MPI) and the Ministry of Finance (MOF) will submit to the OOG a plan for emergency relief, using domestic resources. In the event that international assistance is required, OOG will authorize the Ministry of Foreign Affairs (MOFA) to issue an appeal. MOFA coordinates with other agencies concerned to organize a field visit for staff of the international community within and outside Viet Nam. The Committee for Coordination and Reception of Foreign Aid (AIDRECEP) of MOFA and/or Viet Nam Red Cross are responsible for the delivery of relief goods received from the international community.

It is the fact that sometimes the local and provincial governments send their request for international assistance directly to NGOs, UN-agencies or embassies in Hanoi and in Ho Chi Minh City. MOFA should be consulted before any action is taken with regard to such requests.

Hydro-meteorological forecasting agencies

The hydrometeorological forecasting system includes 3 levels as follows:

- Central level is performed by the National Centre for Hydrometeorological Forecasting;
- Regional level is implemented by 9 Regional Hydrometeorological Centres;
- Provincial level is executed by 54 Provincial Hydrometeorological Centres.

The above system is operated during the whole year, especially during the storm and flood seasons. Detailed task and responsibilities of these agencies are presented in the following sections.

Two projects are under implementation, of which the local funded project mainly concentrates on building capacity while the World Bank funded project is to improve and upgrade facilities of the forecasting network.

National Centre for Hydrometeorological Forecasting (NCHMF)

The National Centre for Hydrometeorological Forecasting (NCHMF) is responsible to collect and exchange domestic and international hydrometeorological information. The domestic hydromet telecommunication system is used by radio, telephone, computerised wide area network (WAN) and MetTV to ensure received data from hydrometeorological observation network to NCHMF and transmit forecast information from NCHMF to the regional hydrometeorological centres (RHMC) and the provincial hydrometeorological forecasting Centres (PHMFC). There are three kinds of forecasting as below:

- short-term predictions (1 - 5 days);

- medium-term predictions (6 - 15 days);
- long-term predictions (months to seasonal).

i. Short-term forecasts:
The forecasting results are issued based on analysing synoptic charts, numerical weather prediction products, satellite images, and radar observations. The weather forecast products of other meteorological centres in the region as well as the worldwide network are also taken into consideration. During the flood season, water level forecasts are implemented in the main river systems. The flood forecasts are issued by application of the models: Streamflow Simulation and Reservoir Regulation (SSARR), Nedbør-Afstrømnings-Mode (NAM), regression and hydraulic models. The Hydrometeorological forecasts are broadcasted via national and local radio, television networks and published in the various daily newspapers;

ii. Medium-term predictions:
Daily rainfall and flow data are needed. The forecasting methods are applied including: the Rainfall-Runoff TANK model and regression method;

iii. Long-term predictions (month to season):
Series of flow data, meteorological data, and monthly seawater temperature at the El-Nino regions: A, B, C and D, ENSO, etc.

Forecasting methods are applied in historical flow process analysis, regression and an objective statistical identification method.

For the mainstream of the Mekong River the NCHMF is responsible for forecasting at two main stations namely Tan Chau and Chau Doc in the SA-10V. The forecasting results are posted on the website/internet and delivered to the concerned agencies.

Southern Region Hydrometeorological Centre (SRHMC)

Locating in Ho Chi Minh City, SRHMC is responsible for the management of activities regarding the hydrometeorological field in the South of Viet Nam including the Mekong Delta. The tasks and responsibilities are:

- to collect hydrometeorological data from international and national network stations from the NCHMF and the field station network. Data is processed to prepare forecasts and to transmit hydrometeorological forecasting information towards provincial stations;
- to manage the hydrometeorological network in the South of Viet Nam, including 19 provinces and cities;
- to manage, measure and survey hydrometeorological elements, and to process data on meteorology, hydrology, oceanography, environment, radar, radiation and ozone;
- to provide meteo-hydrological and oceanographic forecasts (short, medium and long-term);
- to carry out the warning of severe weather and hydrological phenomena as well as tropical storms, floods, flash floods, drought, salinity intrusion, serious thunderstorm and heavy rain, etc. to satisfy the requirements of socio-economic activities and prevent the natural disasters;
- to research and conduct meteorology, hydrology, oceanography, and environment services.

Central Region Hydrometeorological Centre (CRHMC)

Located in Gia Rai province, the Central Region Hydrometeorological Centre (CRHMC) is responsible for management of activities regarding hydrometeorological field in the Central provinces of Viet Nam including the Central Highlands (SA-7V). The tasks and responsibilities

are the same as SRHMC.

Provincial Centres for Hydrometeorological Forecasting (PCHMF)

The functions and responsibilities of the Provincial Centres for Hydrometeorological Forecasting (PCHMF) are to collect data from regional stations and provincial stations within its area. Collected data are processed and forecasted internally within the region. In addition, every province has the local network operated with funds from the Provincial people committee; most of the stations of the local network are located in the irrigation canals. Based on the forecast results issued by the Regional Centre, the PCHMFs shall also forecast the hydrometeorological factors in their local networks.

Flood forecasting and warning system

Scheme of the flood forecasting system

Flood forecasting and warning is closely integrating the data collection, communication, management system and computer modelling system to exactly forecast floods and flooding that may happen in an affected area. This system consists of real-time rainfall and water level data to be collected at the selected stations in the basin. The collected data is transferred to the master computer at the control station by radio links, lease lines, satellite. All collected data at the control centre computer is then input into a modelling software system to simulate flood events including peak water levels, flooding area and duration of inundation as well as flood extent. Figure 35 describes the scheme of the flood warning system in Viet Nam.

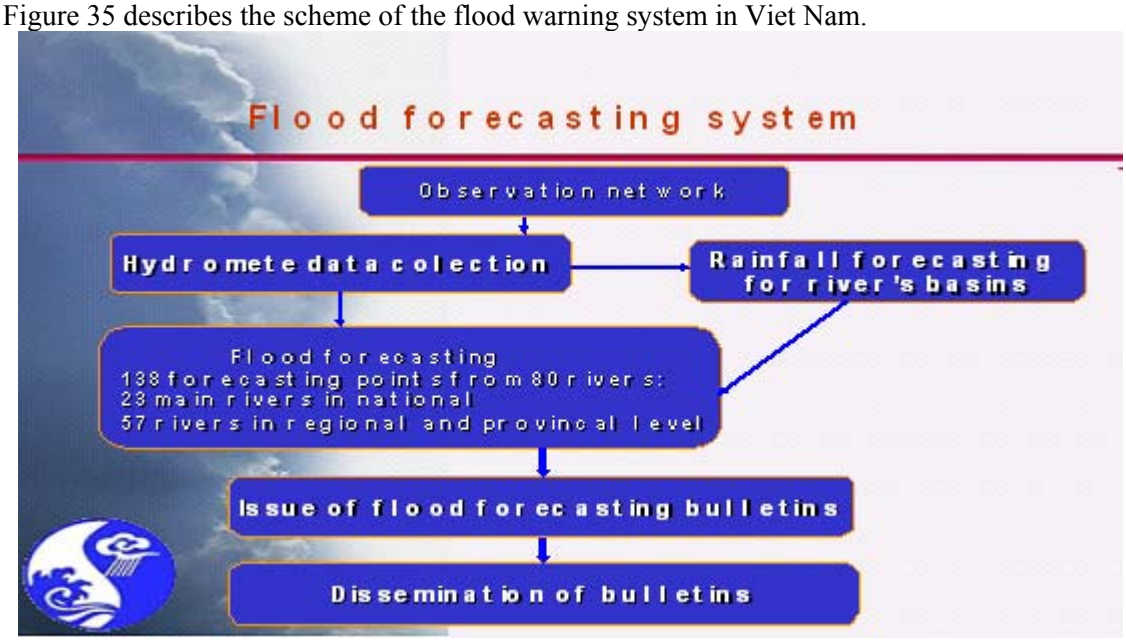


Figure 35. Scheme of the flood forecasting system in Viet Nam

Flood warning activities shall be carried out when the weather pattern brings heavy rainfall in the Lower Mekong River Basin, resulting by Southwest monsoon or typhoons from the East Sea, is detected and then adjusted based on the rainfall distribution.

Process of dissemination of flood forecasting and warning products

There are two warning systems: (i) the information warning system and (ii) the indicative warning system. The first system is mainly responsible for conducting weather and flood forecasts representing for the hydrometeorological forecasting network of MONRE while the

second system is responsible for conducting guidance and instructions for implementation of the warnings from the natural disaster mitigation and management offices representing for the Prime Minister (CSCFSC) and MARD (DDMFCSP). These two systems are in close coordination and collaboration for the same purposes of reducing damages and deaths caused by storm and flood hazard.

The national television, radio broadcasting, telephone, facsimile, e-mail, website and newspaper network is used for delivering the weather, flood and storm massages to the public. The flood warning based on the alarm water levels system that is divided into 3 stages:

- the *water rising warning stage* that will be issued in case of the highest flood water level forecasted is lower than level III, such as less than 4.2 m+MSL at Tan Chau station on the Mekong River;
- the *flood warning stage* that will be issued in case the water level can rise up to alarm level III, such as equal to 4.2 m+MSL at Tan Chau station on the Mekong River;
- the *urgent flood warning stage* that will be issued in case the flood water level can be reached at 4.2 m+MSL and then continuously rises up at Tan Chau station on the Mekong River.

There are two steps of flood warning (normal and urgent warning) being applied in Viet Nam. Of which the normal step will be started at the beginning of the rainy season. The hydrometeorological forecasting bulletins shall be delivered for the users as below:

- CSCFSC, MARD and MRC;
- Mass-media;
- Television, broadcasting network during daily program.

The urgent step starts in case the water level exceeds alarm level III, especially when it is over 4.5 m+MSL at Tan Chau station. The flood forecasting bulletins shall be delivered to the following agencies:

- CSCFSC, MARD and MRC;
- Mass-media, daily newspapers;
- Television, broadcasting network informing with many programs per day frequency.

CSCFSC will inform and deliver the warning massages to the offices concerned in the framework of the warning organization for disastrous floods and storms. At the same time CSCFSC will instruct the local network for implementation of the indicative plan as flood emergency response during the urgent step.

Update of the flood warning system

The flood warning system applied for the river network in Viet Nam is under review and evaluation by the Science Institute for Hydrometeorology and Environment through a specific study on the existing flood warning water levels. This study has been carried out for three years from 2006-2008. As planned, a new flood warning system will be issued after approving by the Government of Viet Nam (GOV) in the near future.

Unmet needs for forecasting and warning product dissemination to flood-at-risk communities

The flood forecasting and warning products have been more and more developed by many offices including MRC and published on websites, newspapers and public media networks but access to these data and information is limited only to the concerned agencies and people who are able to reach internet connection. For the remote areas such as the SA-1V, SA-4V, SA-7V and SA-8V, where a large-scale of inhabitants are the ethnic people who are poor and have a

low education, it is not easy to receive the flood forecasting and warning information for responding to flood, storm risks and hazards.

Aspects of the centre-community relationship that must be strengthened

The following aspects should be strengthened:

- at present there is no coordination and relation between the country member centres for flood forecasting and warning at the time of occurrence of flood events or other natural disasters. MRC-RFMMC should arrange meetings and workshops for sharing and exchanging knowledge and experiences among the country member agencies concerned;
- flood preparedness programmes involving the local communities and the Governmental centres can be useful to manage and mitigate flood risk and hazard;
- a community communication centre together with capacity building to the community should be made.

ACTIVITIES AND ISSUES WITH RESPECT TO THE THEME AND THE TOPICS OF THE 6th FORUM

Theme: Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin

The Theme includes 4 topics regarding the new developments, land use requirements and benefits from flood forecasting and early warning systems as well as the lessons learned from the floods in the past that will be discussed in the following sections.

Topic I: New developments with respect to flood forecasting and early warning

As planned up to 2020, to improve the flood forecasting services in the national meteorological network, some 400 new meteorological stations will be installed to increase it up to 2,000 stations in total, of which the automatic stations will represent 50% of the total network.

New software has been applied such as Marine software developed by French experts and Vespa software developed by Belgian Consultants, etc.. The French software is being applied for simulation of flood flow on the river system affected by tide at Hue province, while the Vespa software is used for the Central provinces. In addition, Mike 11 is applied for flood forecasting now.

Rainfall satellite imageries and rainfall forecast products from the international network have been used for flood forecasting and warning. The 72 hours rainfall forecast products, produced by Fifth Generation Mesoscale Model (MM5) and High Resolution Model (HRM) etc., are used as input data for the flood forecast models now. Two projects, the one funded by the World Bank for upgrading and improving the national meteorological network while the local project mainly focuses on capacity building for official staff, have been implemented since 2007. HYDMET software has been applied at the forecast centres for receiving data.

Topic II Land use based requirements for flood forecasting and early warning systems

The rapid population growth in Viet Nam as well as in the region, urbanisation and intensification of agriculture, changes in land use and river morphology, and rapid technology development require present forecasting to be improved, with better accuracy and lead-time. Related to differences in land use, the occurrence of land use changes there will be different requirements to flood forecasting and early warning. For densely populated areas as the Mekong Delta in Viet Nam (17.2 million people) with limited possibilities for a timely evacuation early

warning is very important. Therefore a seasonal forecast of the expected flood is more relevant in the Mekong Delta in Viet Nam.

At present time, for agriculture production, the seasonal forecast is mainly based on analysing expected floods that may occur in the year, including starting date and scale of floods. This activity normally starts at the end of March or early April yearly. In addition, forecast and warning activities on drought, salinity intrusion, and shortage of water have been carried out as medium-term (ten days or a month).

Topic III Costs and benefits of flood forecasting and early warning

Flood forecasting and early warning is provided for more than 30 years in the MRC Member States. Systems are improved and more people are aware of the systems. There is limited insight in the extent to which flood forecasting and early warning may reduce casualties and/or damage. However, the perception is that this is undoubtedly the case. Analyses under different conditions in flood prone areas may give insight in the various relations and interactions. Based on relevant indicators justification can generally be found for the investments in the development, operation and maintenance of flood forecasting and early warning systems.

Topic IV Lessons learned from past flood events

Flood is one of the natural hazards involving serious disruption of functioning of a society but flood is not always a disaster based on the scale of floods and flooding as well as benefits gained by flood flow. The question is raised how to use the advantage of flood flow and how to reduce the disadvantage of flood.

Flood, drought, acid sulphate soils and salinity intrusion are the main interrelated factors creating constraints for socio-economic development in the Delta. However, people living in the MDV have recognized that flood flow is a potential resource for solving those constraints for development and that an optimal plan to exploit flood flow should be made. A good flood preparedness plan, responding to flood emergency, will help the flood affected people reducing damages and deaths.

In general, knowledge and experiences on flood management and mitigation have been step by step improved in Viet Nam, but the experiences and methods responding to flash flood risk and hazard in the mountain areas are still lacking, including a forecasting and communication network as well as dissemination among the affected people in the remote areas.

Flood warning benchmarks have been installed at areas where flash floods frequently occur, such as Duc Xuyen station, Krong No Tributary, Upper Srepok River, Dak Nong province (Figure 36).

Figure 36. A new flood warning benchmark system has been installed along Krong No Tributary, downstream Duc Xuyen station

Based on analysis of the water levels at Tan Chau station (as experienced by the farmers), floods and flooding in the Mekong Delta in Viet Nam can be classified in 4 levels as presented in Figure 37 and 38. The concept *'Living with flood'* has been successfully applied in the Mekong Delta in Viet Nam (Figure 39). The measures for living with flood include: building residential clusters; flood proof housing; embankments; shifting of the cropping calendar; improvement of flood release capacity; establishment of child care centres; children safety training; and water born disease prevention.

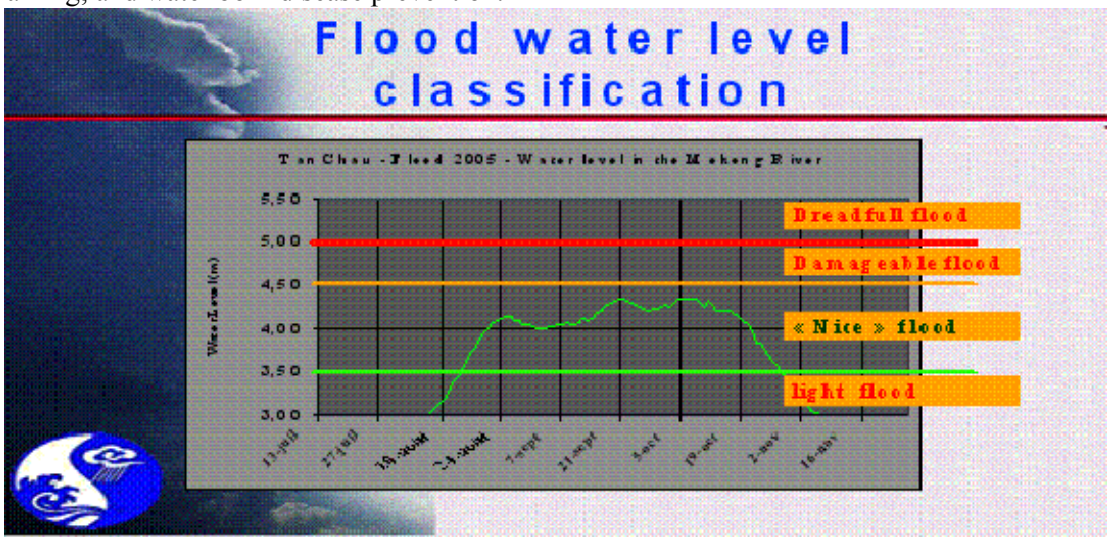


Figure 37. Flood classification on the Mekong River in the Delta of Viet Nam

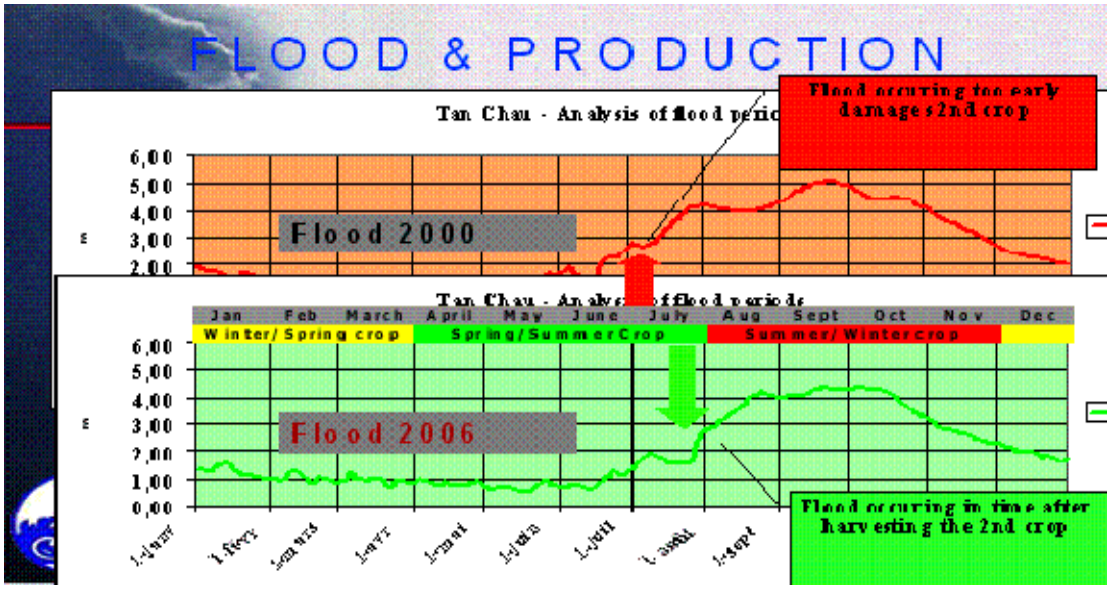


Figure 38. Flood analysis for agriculture production in the Mekong Delta in Viet Nam

RECOMMENDED PRAGMATIC WORKING ARRANGEMENTS BETWEEN NATIONAL CENTRES AND THE MRC-RFMMC

Meetings should be held before flood (April or May) and after flood (December or January) including participants from MRC-RFMMC and riparian counties. The objectives of the meetings would be concerning: exchanging and sharing knowledge, experiences and technology in forecasting flood, disaster assessment, emergency response, preparedness land use planning in the floodplain, etc. between MRC-RFMMC and country members.

Figure 39. Living with flood in the Mekong Delta in Viet Nam

OTHER NATIONAL SUGGESTIONS ON FLOOD FORECASTING AND EARLY WARNING AT MEDIUM-TERM

The following suggestions on flood forecasting and early warning at medium-term can be made:

- MRC should publish the forecasting news on rainfall, floods, especially early flood forecasting in early April every year so that the riparian countries line agencies will prepare action plans responding to the hydrological circumstance;
- MRC daily forecasting news should be broadcasted before 10:00 hr, in order that it can be referred by the riparian countries;
- additional water level and rainfall data at 19:00 hr daily should be provided;
- the new technology on forecasting and warning should be frequently exchanged between MRC-RFMMC and the riparian line agencies;
- training courses for riparian forecasters should be conducted by MRC-RFMMC every two years.

OBSERVATIONS AND FINDINGS

Recorded data during 82 years (1926 - 2007) indicate that there were 28 big floods (H > 4.5 m+MSL), of which 4 historical flood events (H > 5.00 m+MSL) in the Mekong Delta in 1936, 1961, 1966 and 2000 (Figure 40). Of these 4 historical flood events, the 1961 flood event was a local flood while the others were basin floods caused by snowmelt in the Upper Mekong River Basin combined with rainfall resulting from Southwest monsoon and typhoons occurring in the Lower Mekong River Basin.

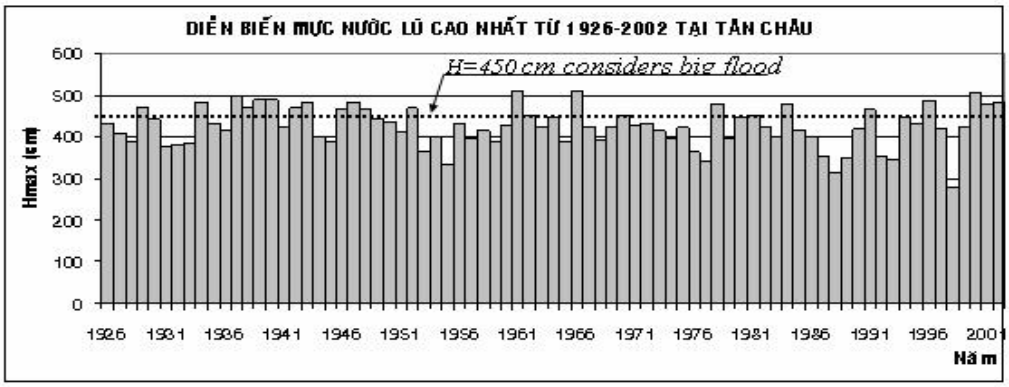


Figure 40. Maximum water levels at Tan Chau station, Mekong River 1926 to 2002

USEFUL REFERENCES, WEB SITES AND CONTACT ADDRESSES

UN, United Nations Disaster Management Team, 1995. Information Note, *Emergency Relief and Disaster Mitigation in Viet Nam.*

Bui Duc Long, 2007. *Collected Data and Information on the 2007 Flood*.

Central Steering Committee for Flood and Storm Control (CSCFSC)/Natural Disaster Partnership, 2007.Newsletter, Volumes 1 to Volume 12.

Mekong River Commission (MRC), 2001. *Consultation workshop on formulation of a regional strategy for flood management and mitigation in the Mekong River Basin*, Phnom Penh, Cambodia.

Mekong River Commission (MRC), 2005. *Overview Mekong Hydrology.*

Mekong River Commission (MRC), 2006. *Annual Flood Report 2005* (draft version).

Mekong River Commission (MRC)/European Commission Humanitarian Aid Fepartment (ECHO)/Asian Disaster Preparedness Center (ADPC), 2006. *Capacity Building for Flood Preparedness Planning and Implementation at Provincial and District Levels Project*, Courses Material.

Mekong River Commission (MRC)/Haskoning, Delft Hydraulics, UNESCO-IHE, 2007. Flood Management and Mitigation Programme (FMMP), Component 2: Structural Measures and flood Proofing, *Draft Inception Report, December, 2007*

Mekong River Commission Secretariat (MRCS), Flood Management and Mitigation Strategy Formulation for the Mekong Basin, *Proceeding of First Annual Mekong Flood Forum*, Phnom Penh, 2002.

MRC, Regional Flood Management and Mitigation Centre (RFMMC), Fourth Annual Mekong Flood Forum '*Improving Flood Forecasting and warning System for Flood Management and Mitigation in the Lower Mekong Basin*', Country Report and Papers, Siem Reap, Cambodia, 17-18 May 2006

Trinh Hoang Ngan, Thesis for Doctor Level, *Review of the Flood Control Studies for the Cuu Long Delta*, February, 2006

MRC, Regional Flood Management and Mitigation Centre (RFMMC), Annual Mekong Flood Forum 2006; March 2007

MRC, Regional Flood Management and Mitigation Centre (RFMMC), 5th Annual Mekong Flood Forum '*Improving Inputs towards Medium-term Flood Forecasting and Early Warning in the Lower Mekong Basin*', Country Report and Papers, Hochiminh City, Viet Nam, 17-18 May 2007;

Ministry of Agriculture and Rural Development (MARD), Department for Dyke Management, Flood Control and Storm Preparedness (DDMFCSP), *National Strategy for Natural Disaster Prevention, Respond and Mitigation until 2020*, November, 2007;

Ministry of Natural Resources and Environment/Science Institute for Hydrometeorological and Environment, 10th Workshop on *Water Resources Hydrology and Environment*, Hanoi, March, 2007

Ministry of Agriculture and Rural Development (MARD)/Southern Institute for Water Resources Research (SIWRR), *Overview of sea diking system planning and upgrading and consolidation of the existing diking system from Quang Ngai to Kien Giang*, Summary Report, Ho Chi Minh City, March 2008

FLOOD DISASTERS AND FLOOD FORECASTING PROGRESS IN CHINA

GUOQING WANG[1,2] AND JIANYUN ZHANG[1,2]

[1]*State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering, Nanjing Hydraulic Research Institute, Nanjing, China*

[2]*Research Centre for Climate Change, Ministry of Water Resources, Nanjing, China*

ABSTRACT

Flood disasters have been recognised as the most severe natural hazard in China. Strenuous efforts have been made in flood control since 1949. The Chinese government has worked out a series of policies and measures for flood control and management. On the one hand, structural measures such as dike reinforcement, river regulation, construction of reservoirs, building flood detention, and storage basins have been reinforced. On the other hand, non-structural measures, such as empirical forecasting schemes, hydrological models, and national flood forecasting systems have been developed as well. Flood disasters in China and flood defence in the Yangtze River are introduced at first in the paper. Later on, the progress of flood forecasting technology is reviewed. Finally, the challenges in flood forecasting are addressed, based on the analysis of human disturbance to the hydrological regime.

INTRODUCTION

Due to the special geographical location and climate conditions, China has frequently been hit by floods and suffered from flood disasters. With the population growth and quickly socio-economic development, the economic losses due to flood disasters have increased rapidly since the 1990s, and have become one of the constraints for sustainable development. Strenuous efforts, including structural and non-structural measures, have been made in flood disaster prevention and mitigation since 1949. China has formed flood control engineering systems with the focus on dike reinforcement, river regulation, reservoir construction, flood detention and storage basin building. The engineering systems have provided basic guarantee for economic development, improvement of living standards, social stability and ecological and environmental improvement. Meanwhile, since the devastating flood of 1998, non-structural measures such as flood forecasting systems, pre-schemes of flood control operation, and flood risk management have been significantly strengthened as well. Among which, flood forecasting is a key important non-structural measure for flood control, which plays an very important role in flood control and management, especially in the case of over-standard flood in China. Floods and flood disasters in China will be introduced in the paper at first, and the experience of flood defence on the Yangtze River will be presented as well. Finally, the progress on flood

forecasting in China was reviewed.

FLOODS AND FLOOD DISASTERS IN CHINA

The vast area of East China and most of South China are dominated by the Eastern Asia monsoon, which results in dry winters and wet summers. Precipitation distributes quite unevenly temporally and spatially in China. Annual precipitation is over 1,600 mm in the Southeast, while this figure drops to only dozens of millimetres in the Northwest. In most parts of China, the rainfall is high in intensity and concentrated in time, about 60 ~ 80% of the annual precipitation falls during the rainy season, which normally lasts for about four months. All these features lead to the concurrent occurrence of flood and drought disasters with high severity.

According to the historical record, 1,092 large flood disaster events occurred since 206 BC in China during the period of 2,155 years, which means once in every two years on average. At the beginning of the twentieth century, the major rivers in China were struck by a number of disastrous floods. In 1931, disastrous floods hit the Huaihe River basin and the Yangtze River basin. Over 51 million people were affected, of which 400,000 died. However, after 1949 the life losses due to floods became less and less compared with those before that date, because of the flood control projects that were put in place and the efforts made in flood preparedness (Figure 1). Taking the Yangtze River as an example, the flood of 1998, which was close to the maximum one since 1949, only caused the death 1,320 of people, while the disastrous flood of 1954 caused 37,000 losses of life.

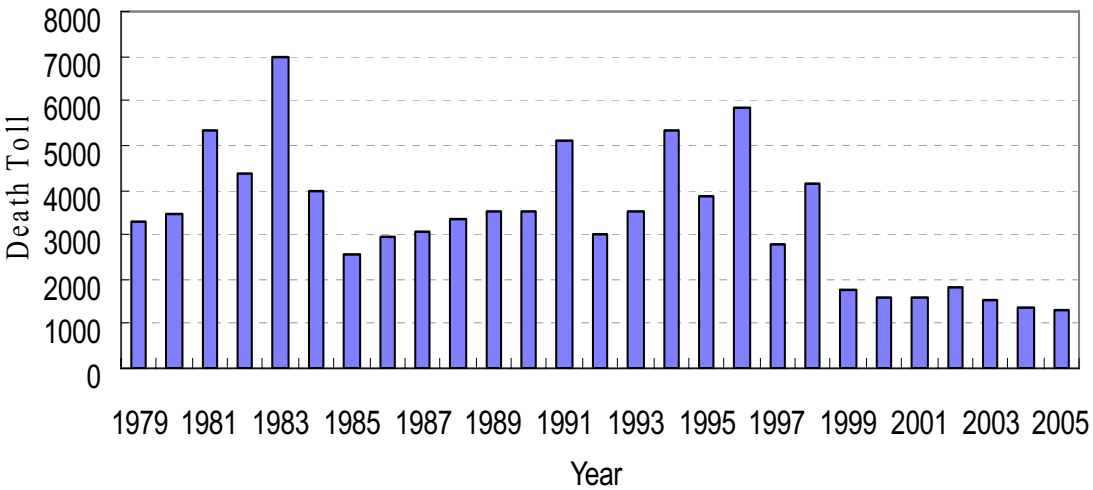


Figure 1. Life losses by flood disasters in China since 1979

However, with the population growth, rapid city expansion and economic development, the economic losses due to flood disasters have increased rapidly (Figure 2). Statistics show that since 1990s, national averaged economic loss directly caused by floods exceeds RMB[1] 110 billion every year, equivalent to 2% of the gross national product (GDP) in the same period. On

[1] RMB = Chinese Yuan

average, about 10 million ha, which accounts for about 10% of China's total farmland, was affected annually by floods during the period since 1949. Flood control and management are of vital importance of China for its social and economic development.

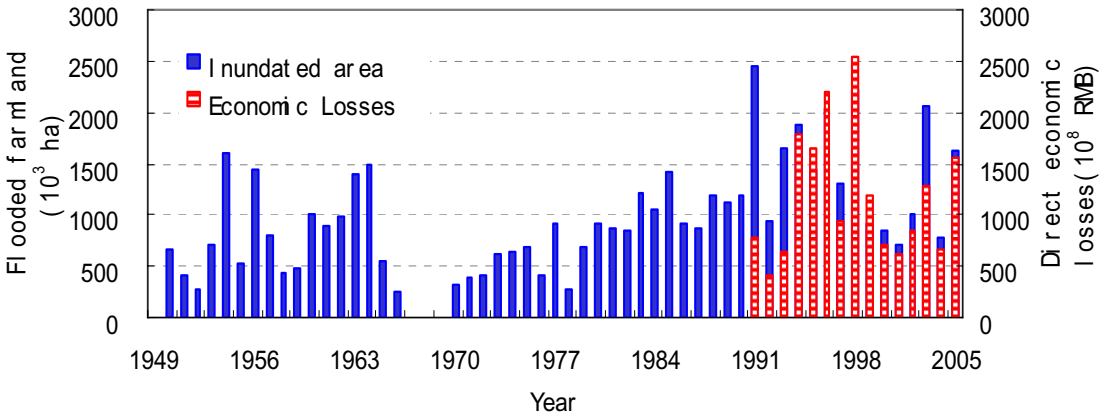


Figure 2. Damage of flood disasters in China since 1949

FLOOD DISASTERS AND FLOOD DEFENCE ON THE YANGTZE RIVER

The Yangtze River, being the longest river in China and the third longest river in the world, originates in the Qinghai-Tibet Plateau and flows about 6,300 km eastwards to the East China Sea. The Yangtze River Basin lies between 91 - 122°E and 25 - 35°N, and has a drainage area of 1.8 million km^2. The upstream of the Yichang gauge (near the Three Gorges Dam site) is called the upper Yangtze River, which has a drainage area of about 1.0 million km^2, and contains four major tributaries, named Yalongjiang River, Minjiang River, Jialingjiang River and Wujiang River. The region between the Yichang gauge and Jiujiang gauge is called the middle stream, which includes the Hanjiang tributary and two large lakes, named Dongting Lake and Poyang Lake. Below the Jiujiang gauge is the Lower Yangtze River. The hydrologic and hydraulic behaviour of the upper and middle reaches of the Yangtze River is quite complex and markedly different. The upper reach of the river has a stable channel with relatively minor local inflows. The middle reach is characterized by relatively flat hydraulic gradients, complex flow paths, significant local inflows and extensive lake systems.

The Yangtze River is a major source of surface water for China, accounting for 38% of all surface water discharges, mean annual discharge at Hankou station in the middle reaches is 23,400 m^3/s. Located in the East Asia subtropical zone, the Yangtze River Basin is climatically characterized by a subtropical monsoon climate with a mean annual precipitation of 1,090 mm. In the past decades, the Yangtze River Basin has suffered disastrous flooding events due to heavy monsoon rainfalls. The summer monsoons account for 40% of the total discharge, while winter discharge is mainly the result from snowmelt. Since 1877, at least 25 floods have exceeded the channel capacity of the Yangtze River. The most recent of these major floods occurred in 1998. Over 3,000 people lost their lives during the 1998 floods when some 15 million people were rendered homeless, 5 million houses were destroyed, 22 million hectares farmland was inundated and 1.8 million hectares of crops destroyed. The total damage bill was

estimated to exceed $ US 20 billion.

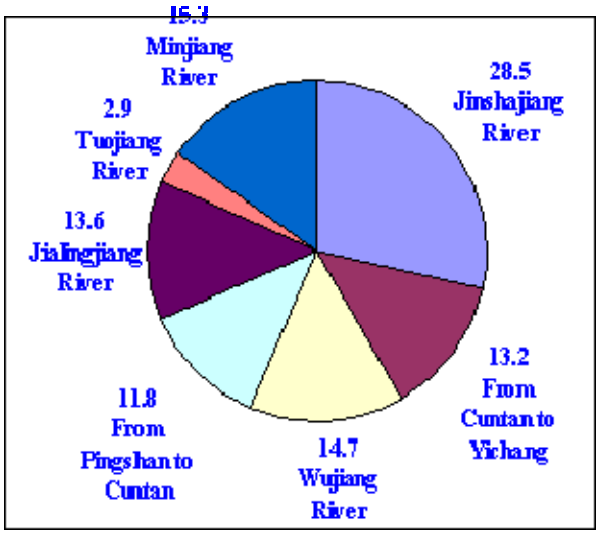


Figure 3. Composites of 15-day flood volume at Yichang station

The composites of 15-day flood volume at Yichang station are shown in Figure 3, which indicates that about 28.5% of flood comes from Jinshajiang River. Minjiang River is the second largest flood source, which can account for 15.3% of total 15-day flood volume.

In the middle and lower reaches, the floodplains of the Yangtze River are protected by more than 3,600 km of primary levees. A further 30,000 km of secondary levees provide flood protection along the tributaries and minor rivers and around the cities and towns of the middle and lower reaches. The middle reach also contains 35 of substantial detention basins used for flood management purposes. Over 50,000 reservoirs have been constructed with a total storage capacity of 170 billion m^3, among which, there are 142 large-size reservoirs with a capacity of more than 0.1 billion m^3, accounting for 70% of the total storage.

PROGRESS OF FLOOD FORECASTING IN CHINA

Generally, the progress of flood forecasting in China would be divided into three phases based on flood forecasting system development, (1) empirical forecasting schemes (EFS) adopted before 1970s, (2) Watershed hydrological models (WHM) employed in 1970s and 1980s, and (3) National flood forecasting system (NFFS) developed since 1990s.

Empirical correlation methods developed, before 1970s

Empirical Forecasting Schemes (EFS) were developed in 1950 - 1970s, such as correlation curves, P~R+UH, which were widely applied for operational flood forecasting in all of the main rivers with appropriate accuracy in application. The empirical correlation methods are effective for most cases, but only focus on the peak forecasting, no hydrograph. Chinese hydrologists have developed empirical forecasting schemes at more than 500 forecasting points for the seven major rivers.

Watershed hydrological models developed, in 1970s and 1980s

The hydrological modelling techniques for flood forecasting have been developed since early 1970s, on the basis of the conventional methods in runoff yield analysis and flood routing. Chinese Xin'anjiang Model and other models like antecedent precipitation index (API), Sacramento, Tank, Soil Moisture Accounting and Routing (SMAR) and synthetized constrained linear system (SCLS) are also employed in many river basins' forecasting systems.

Xin'anjiang Model was developed in Hohai University, China. The model consists of three components: (1) the generation of runoff, the model considers the pervious area and impervious area, and in the pervious area, one curve which reflects the feature of soil capacity to hold water is employed with a 3-layes evaporation model; (2) the generated runoff will be divided into surface runoff (RS), sub-surface runoff (RI), and underground water (RG) according of the geological feature of the basin and its infiltrating capacity; and (3) routing part, the RS can be routed into discharge into the river using unit hydrograph or Nash routing model, the RI and RG can be routed into discharge using Nash Linear Reservoirs model or other method. Currently, Xin'anjiang Model has been widely applied in China, particularly, for some middle-size or large-size river basins in humid regions.

The watershed hydrological models (WHM) can control water balance and get good simulation results in humid areas. The soil moisture accounting models such as traditional API model, Xin'anjiang Model, SMAR model and Sacramento model and so on are suitable for most areas in China. In arid and semi-arid areas, there are some difficulties in hydrological simulation and forecasting, mainly due to lack of flood-events data for model calibration, another important reason is that the model structure cannot be suitable for reflecting the practical situation of flow generation.

Hydrological forecasting systems developed, since 1990s

The 1st generation of the real time flood forecasting system (FFS) on VAX machine or single PC was developed in the early 1980s. In the 1990s, the 2nd generation of the FFS were developed in cooperating with America and European countries. After 1998s disastrous flood in Yangtze River, Songhua River and Pearl River the National Flood Forecasting System (NFFS) has been designed, developed, tested and implemented by the Bureau of Hydrology (BOH) of China's Ministry of Water Resources (MWR) associated with related universities and scientific research academies, and operation sectors.

A major objective of the NFFS was to develop a system structure, which faced to the demand of future flood forecasting. The basic design requirements for NFFS include the following: (1) establishing an advanced standard software and hardware configuration based on the uniform standard real-time database and client/server environment, (2) adopting modular structure, so that modules can be independent of system and components could be developed by a number of individuals; (3) allowing users to select models and the sequence of use, (4) possessing a model calibration system which can combine manual and automatic calibration methods, (5) permitting users to control real-time processing flexibly and use graphical and

tabular interface for interactive forecasting, (6) efficiently processing large amounts of data to produce forecasts at hundreds or thousands of locations, (7) having an integrated powerful flood forecasting management function.

CONLUSIONS AND DISCUSSION

China has frequently been hit by floods and suffered from flood disasters. With the population growth and quick socio-economic development, the economic losses due to flood disasters have increased rapidly since the 1990s. The Yangtze River is the first largest river in China, which is also a frequently flood hit river. The structural and non-structural measures for flood control have played an important role to guarantee economic development, improvement of living standards, social stability and ecological and environmental improvement.

Since the devastating flood of 1998, non-structural measures such as flood forecasting systems, pre-schemes of flood control operation have been significantly strengthened. However, the intensive human activities on land-use have destroyed the representativety of long time series of hydrological data, which as a result that the calibration of parameters with historical data cannot reflect the current practical situation, and many gauged basins have become ungauged areas. Thereby, study on prediction in ungauged basins (PUB) is the key to improve accuracy of flood forecasting.

For better management of water resources, it requires better prediction in the ungauged or poorly gauged basins. With strong requests from the applications, the most interesting PUB scientific problems include: (1) hydrological predicting approach for the large poorly-gauged basins; (2) prediction of hydrological responses to human activity and climate change in ungauged basins; and (3) prediction of eco-environmental responses to human activity, such as soil erosion and non-point source water pollution in ungauged basins.

REFERENCES

Intergovernmental Panel on Climate Change (IPCC), 2001a. Climate Change 2001:Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge.

Liu, J., Zhang, J., 2005. Development and Prospects of Hydrological Forecasting Technique in China. Journal of .Hydrology (in Chinese), 25(6), 1-5.

Pan, X.H., 2002. Changes in temperature and precipitation in China during the last 50 years. Mater Thesis, the Chinese Academy of Meteorological Sciences, Beijing, China.

Tan, B.Q., O'Connor, K.M. and Liu, Z.C., 1996. Application of a distributed form of the SMAR model. Proceedings of the 'International Conference on Water Resources & Environment Research: Towards the 21st Century', October 29 - 31, Kyoto, Japan (at Heian Kaikan), 1, 46-52.

Wang, J.M., 2000. The Flood Forecasting Model of SCLS. Yellow River Conservancy Press, Zhengzhou.

Yang, D., C. Li, B. Ye, H. Hu, H. Zhang, Z. Liu & J. Xia, 2005. Chinese Perspectives on PUB and the Working Group Initiative, IAHS publication, 301.

Zhang, J.Y., O'Connor, K.M. and Liang, G.C., 1994. A software package for river flow forecasting based on the SMAR model.' 5th International Conference on Hydraulic Eng. Software, Hydrosoft 94, Porto Carro, Greece (September 1994). Publ. in Hydraulic Engineering Software V, Vol. I, Water Resources and Distribution, eds. W.R. Blain & Katsifarakis, computational Mechanics Publications, Southhampton, 163-170.

Zhang, J.Y., Wang, G.W., Zhang, J.X., and Sun, C.P., 2005. Flood forecasting and regulating system based on Web: development and application. Water Resources and Hydropower Engineering, 36(2), 67-70.

Zhang, S.L., 2002. Design and Development of China National Flood Forecasting System. Journal of. Hydrology (in Chinese), 22(1), 28-32.

Zhao, R. J., 1992. Xinanjiang Model Applied in China. Journal of Hydrology, 135, 371-381.

Zhao, R. J., Zhuang, Y. L., Fang, L.R., Liu X.R., and Zhang Q.S., 1980. The Xinanjiang Model. In: Hydrological Forecasting (Proceedings Oxford Symposium), 351-356. IAHS publication, 129, IAHS Press, Wallingford, UK.

FLOODS, FORECASTING SYSTEM AND MANAGEMENT IN MYANMAR

[1]U HLA MYINT THEIN AND [2]U SEIN TUN

[1]Deputy Director General, Directorate of Water Resources and Improvement of River Systems, Ministry of Transport, Union of Myanmar
[2]Deputy Director, Directorate of Water Resources and Improvement of River Systems, Ministry of Transport, Union of Myanmar

ABSTRACT

The topography of Myanmar and the situation of the river system offer the country and its people several advantages. On the other hand the formation of the river system, especially in the delta area, which is crisscrossed with many rivers and creeks, results in flooding as disadvantage. Flood is one of the natural disasters that occur in the country every year. Whatever, flood or other kind of disaster, usually occuring or rare, serious event or not, it is essential to draw plans for prevention, relief and resettlement based on construction of preventive measures, public education and warning. This paper likes to highlight that during the peak monsoon period of 2007, moderate floods occurred along the major rivers of Myanmar. But this year was significant for the flash floods in some major city areas.

GENERAL DESCRIPTION OF MYANMAR'S RIVER SYSTEMS

Myanmar is well endowed with natural river resources, of which Ayeyarwady, Chindwin, Sittoung, Thanlwin, Kaladan, Leimyo, Mayu, Attaran, Gyaing and numerous small rivers. In the lower region of Myanmar, the delta is crisscrossed with many rivers and creeks. In an average year 8,60,000 million cubic metres of water is discharged by all Myanmar rivers into the sea. The North-South direction of the mountain ranges of Myanmar is reflected in course of major river systems.

Myanmar consists of a series of river valleys running form North to South divided from each other by mountain ranges and plateaus. The division of the country by drainage areas of river systems, expressed in percentage, is shown in Table 1.

Table 1. Division of Myanmar by drainage areas of river systems, expressed in percentage

River system	Percentage of total area
Ayeyarwady and Chindwin rivers	55.0
Thanlwin River and tributaries	15.3
Mekong River and tributaries	3.1
Sittoung River	5.4
Kaladan River and tributaries	3.8
Yangon River	3.0
Taninthayi River	2.7
Minor coastal rivers	11.8

Myanmar belongs to the Asian monsoon region. Two-third of the country lies in the tropical and one-third in the temperate zone. Thus, Myanmar's' rivers live primarily under the influence of monsoon winds. 90 to 95% of the rainfall is concentrated in the period of May to October, especially in the months of July, August and September. The extreme rainfall between seasons leads to mark differences in the reaction in the drainage areas. As a result Myanmar's rivers rise as from May/June and generally peak in July/August. The water level

starts to fall again by September and October.

Ayeyarwady delta is the typical example of a humid tropical zone delta in an early stage of hydraulic and agricultural development. It is obviously lowland and flat terrain and inundation can happen in many areas in the rainy season. This results in the formation of swamplands. In the coastal zone about 5,200 km^2 are below high spring tide level and are subject to flooding with more or less saline water. This is likely to occur in September/October when the river floods recede and south-westerly winds cause some piling up of the sea above the level of the high spring tides.

FLOOD AND FLOOD FORECASTING

Natural disasters such as floods, storms, earthquakes and landslides and man-made disasters such as fires occur in Myanmar. According to records of the 11 years period from 1996 to 2006, the occurrence of fire is about 70% and it results in the most frequent and high losses among the others. Floods cause 11%, storms 10% and the remaining 9% is caused by other types of disasters.

According to the cause of floods, they can be divided as follows:

- *flash floods.* In the central area of Myanmar, the annual rainfall is less than 1,000 mm and the drainage systems of these areas are enough for most of the years with normal rainfall. But, once for a long period, about 60 to 70 years, it rains heavily at a small area in a short time and the ditches and creeks of that area cannot receive the flowing water and flash floods occur for a short time. This type of flood is dangerous for the local people and some fatalities and losses of properties occur. Wuntho Township at Sagaing Division flood 1995 and Wundwin Township at Mandalay Division floods 2001 were recorded for flash floods;
- *river floods.* Southwest monsoon period is from June to October. In the mid of the monsoon, the rainfall is heavy in the northern and southern parts of Myanmar. When the heavy rains occasionally fall in the headwaters of the main river systems, they result in floods in the lower reaches. In Chindwin River Basin, floods occur every year at Hkamti Township in July or August. The town is situated on the hillside, the people are rich with flood experiences, and they can mitigate losses of floods. For Thanlwin River, Hpa-an and neighbouring townships have to face flood in the mid of the monsoon. These townships are near the sea and the inundation period is only for two or three days and the losses are not severe. Along Ayeyarwady River, the water level reaches to danger level at some townships in the mid of the monsoon period. But, because of the dams, dikes, reservoirs, diversion weirs and reserved lower land of the riversides, the water can be controlled and inundation of the towns and cities is very rare. The only reason of flood in these areas is weakness of the dikes and collapse under the pressure of water. In the past, the Sittoung River was very dangerous for flood in Shwe Kyin and Madauk townships and in the Bago division. After construction of Paung Laung Dam and local dams and weirs, the flood can be reduced in this region;
- *storm surges.* Cyclones form in the Bay of Bengal every year and some severe storm may cross the coast of Myanmar at Rakhine State or Ayeyarwady Division once every 3 to 4 years. Because of the severe storms, tidal waves of about 1.5 - 3 m (5 - 10 feet) inundate these coastal areas. In 1968 the Sittway Cyclone occurred and 1,037 people were killed by the storm surge.

The Directorate of Water Resources and Improvement of River Systems (DWIR) cooperates with the concerned agencies especially with the Department of Meteorology and Hydrology (DMH) in demarcation of danger water levels. DMH is also responsible for cyclone and flood warning and the forecasting system. Hence, broad disseminations of warnings are being made through the mass media such as television, radio, wireless and

newspapers. The block diagram in Figure 1 shows the operational procedure of early flood warning, which was developed by DMH.

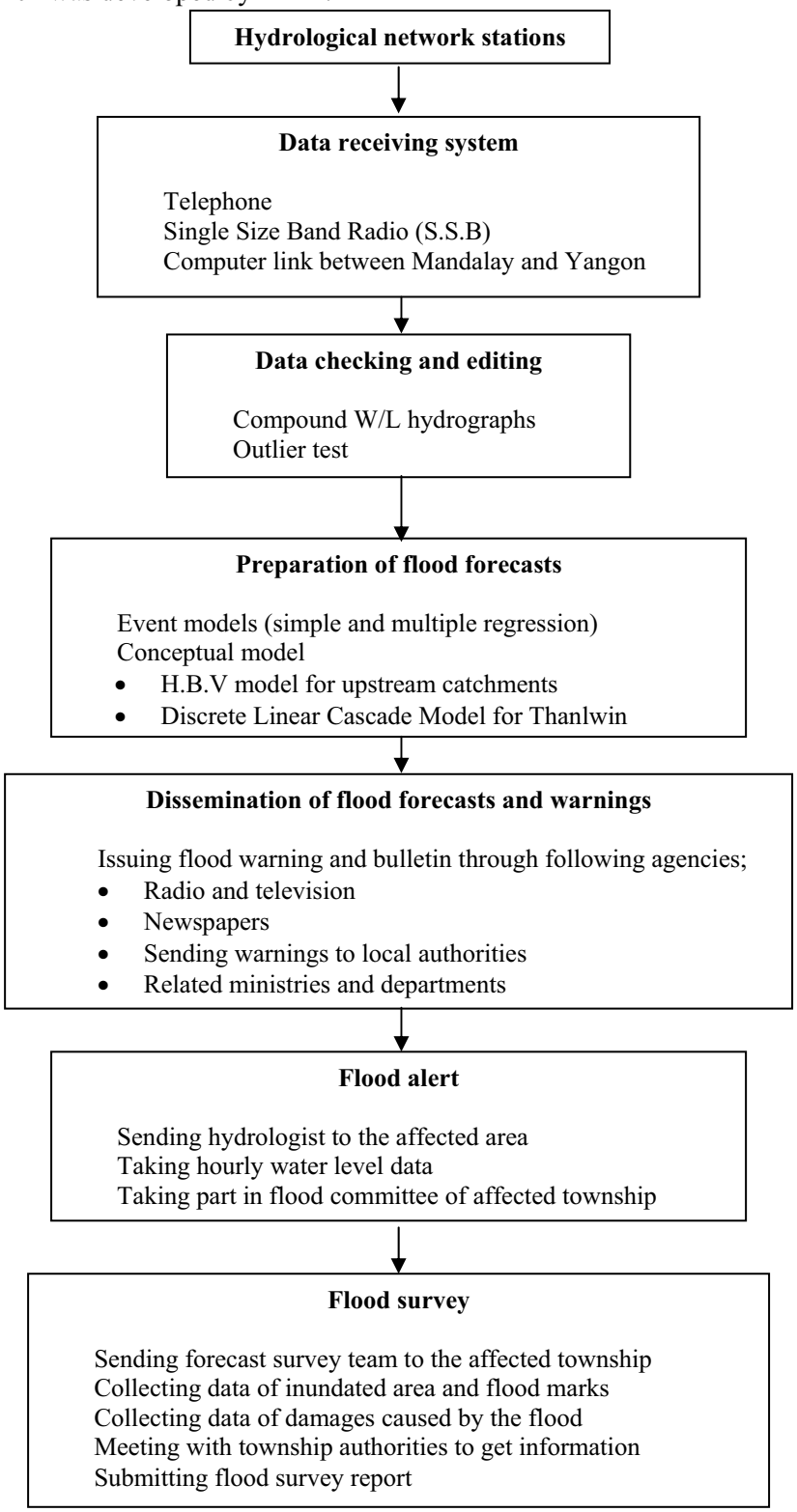


Figure 1. Block diagram showing the operational procedures of the early flood warning system

DISASTER MANAGEMENT IN MYANMAR

The principal aims to manage all types of disasters, including floods are as follows:

- to prevent or mitigate losses in human life among the people;
- to prevent or mitigate losses in settlements and property of the people;
- to prevent or mitigate losses in property of the State.

In order to carry out the principle aims, the Central Committee for National Disaster Prevention was formed under the Chairmanship of the Prime Minister of the State. The Secretary (1) of the State Peace and Development Council acts as Vice-Chairman and members are Ministers concerned, Chairmen of State/Division Peace and Development Councils and Mayors of Yangon and Mandalay and it comprises of (37) members. Under the Central Committee, the central working Committee for Disaster Prevention was formed and the Secretary (1) of State Peace and Development Council acts as Chairman, Minister for Social Welfare, Relief and Resettlement as Vice-Chairman and there are (36) members. To implement the preventive measures, relief and reconstruction tasks sector wise, ten sub-committees were formed under the Central Working Committee and District, Townships, Wards/Village Tracks Working Committees for Disaster Prevention were also organized. Sectoral and regional disaster management plans were drawn up and implemented by the Committees. The ultimate objective and systems of disaster management in Myanmar are to mobilize national strength, for disaster preparedness, prevention, relief, resettlement and reconstruction as an implementation of Total Disaster Risk Management. During a disaster, the committees at different levels and local authorities fulfil their respective duties, cooperation and coordination for an effective implementation.

Myanmar has its own system and practice for disaster preparedness and prevention based on its social, cultural, political and administrative system. As a preparedness measure, stock dumping centres of relief goods have been established in major towns of states and divisions in the country by the Relief and Resettlement Department under the Ministry of Social Welfare, Relief and Resettlement. One central warehouse, which can store six kinds of relief items enough for 10,000 families was opened in Yangon and 18 warehouses, enough for 1,000 to 2,000 families, were also opened in states and divisions. The six kinds of relief goods are clothing (male and female nether garment) cotton cloths or towels, blankets, enamel bowls and cooking pots. Supporting equipments such as tarpaulin tents, generator and water pumps are also kept in the central warehouse and respective warehouses. For emergency cases during disasters, the relief materials and supporting equipments are speedily dispatched to disaster striken areas from the nearest warehouse.

The conscientious community participation is very important for effective implementation of disaster prevention, preparedness, relief and rehabilitation. For that purpose the Department of Relief and Resettlement in collaboration with the Department of Meteorology and Hydrology, Fire Services Department, Department of Health, Department of Irrigation, Myanmar Police Force, Directorate of Water Resources and Improvement of River Systems and Myanmar Red Cross Society organizes disaster management courses in the states and divisions. The objectives of the training are to enhance disaster capacity of authorities concerned and members of Non Governmental Organisations (NGO), to conduct multiplier courses in their respective townships and to organize, educate and motivate people for cooperation in the field of disaster management. Since 1977, altogether (81) training courses were conducted and 3,550 participants were trained.

REVIEW OF FLOODS IN 2007

In 2007, during the peak monsoon period July and August, floods occurred along the major rivers of Myanmar, and also along the some border rivers (Figure 1). For instance, in Shweli

River in Muse Township. Most of them were moderate floods.

The year 2007 was significant for flash floods. The continuous heavy rain caused severe flash floods in some major city areas, i.e., Yangon, Mandalay, Bago and especially in Kyangin. Damages of crops, bridges and roads, etc. were reported by concerned agencies. Flood peaks and durations above town danger level and flood events are illustrated by photographs accordingly.

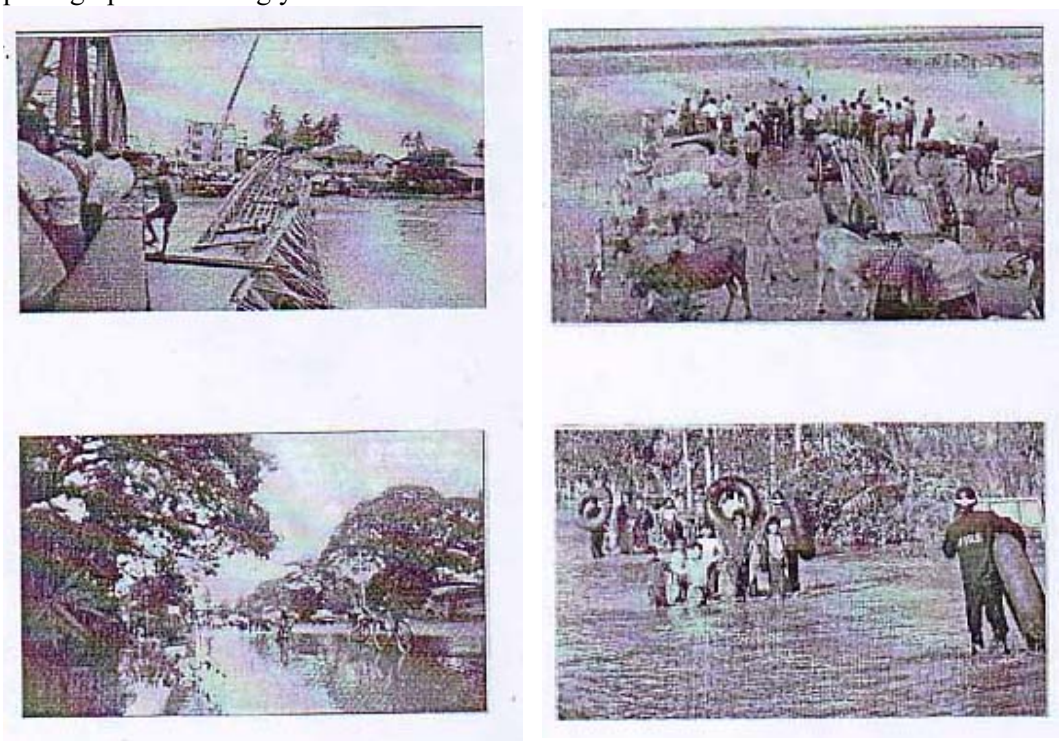


Figure 1. Flood events in Myanmar in 2007

REFERENCES

Daw Tin Yi and Daw Yin Min Latt, 2004. *Early flood warning system of DMH and Explanation to the Terminology,* Department of Meteorology and Hydrology (DMH), *Yangon*, Myanmar

Mg Mg Khin, 2004. *Material and Moral Support Activities for flood victims.* Department of Relief and Resettlement, *Yangon* , Myanmar

Sein Tun, 1996. *Myanma Rivers Reference.* Directorate of Water Resources and Improvement of River Systems (DWIR), *Yangon* , Myanmar

2007 MEKONG FLOOD REPORT - FLOOD HYDROLOGY OF THE MEKONG TRIBUTARIES

JANEJIRA TOSPORNSAMPAN[1] AND PETER ADAMSON[2]

[1]MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC)
Phnom Penh, Cambodia
[2]Mekong Mekong River Commission (MRC), Vientiane, Lao PDR

ABSTRACT

Following the accepted format and structure established during the preparation of the 2006 Annual Flood Report, the current document comprises three major sections:

- a thematic review, which this year focuses upon the flood hydrology of the major tributary systems, which provides a logical succession to that in the 2006 Report which addressed the flood hydrology of the mainstream of the Mekong River;
- a regional hydro-meteorological assessment of the 2007 flood season;
- a summary of the four Country Reports.

In terms of peak discharges and seasonal flood volumes, conditions during the 2007 flood season along the mainstream of the Mekong River were comparable to those that occurred during 2006. As then, both variables fell below their long-term average values, the degree to which they did so becoming more pronounced downstream, such that at Kratie both flood peak and volume were significantly below normal. In fact flood conditions at Kratie during 2006 and 2007 are amongst the eight lowest observed since 1924, seven of which have occurred during the last 20 years. This intensification of the shortfall in peak and volume downstream of Vientiane points to significantly reduced monsoonal rainfalls within the river basins of the large left bank tributaries that lie in Lao PDR over the last two seasons. Conditions in the mainstream reaches where the flood hydrology is dominated by flows from the Upper Mekong in China, that is those upstream of Vientiane, tended to be much less anomalous and closer to average.

These below average flood conditions were not, however, the definitive hydrological feature of the 2007 season. This lies with the fact that throughout the mainstream the start of the flood season was generally the latest observed over the last 80 to 90 years. Typically, the season begins in the last week of June or the first week of July in those reaches above Kratie and a week or two later at Phnom Penh and in the Delta in Vietnam. Regionally, flows by the end of July 2007 were amongst the lowest ever observed at that time of the year. At Kratie, for example, the 2007 flood onset was the latest observed over the 84 years since records began in 1924.

The review of the tributary hydrology is set out within the framework of the river systems along three mainstream reaches, namely Chiang Saen to Vientiane, Vientiane to Pakse and Pakse to Kratie. The subject matter specifically considers the incidence and severity of flash floods, particularly in Northern Thailand and Northern Lao PDR, the role of the Mun-Chi Basin and its contribution to the mainstream and the geographical pattern of flood flow contributions from the major tributaries to the extreme flood conditions that have been observed along the mainstream. A significant contribution within the review has been the development of a methodology for estimating flood magnitude and risk at ungauged locations, which assumes considerable relevance for the evaluation of design floods for the many hydropower schemes now under consideration within the Lower Mekong River Basin (LMB).

Finally, the four riparian National Flood Reports for 2007 have been condensed into a

consistent summary section, which sets out a more detailed appraisal of local flood conditions, causes and damage. A set of Appendices provide selected basic data consistent with the aim that over the years the Annual Flood Report will accumulate key reference material for future evaluations of the nature of floods and flooding in the LMB and the frequency and severity of the damage caused.

INTRODUCTION

As in 2006, the 2007 Annual Flood Report aims to fill two primary roles, (i) to provide a summary of flood conditions in the Mekong Region over the year, and (ii) to collate the relevant data and information. The Report also has an annual 'theme'. Having contributed significantly to the understanding of Mekong mainstream floods and flooding in the 2006 Report, this document has made the logical progression and taken the flood hydrology of the tributaries as its theme, with ash floods meriting particular attention.

THE FLOOD HYDROLOGY OF THE MAJOR TRIBUTARIES IN THE LOWER MEKONG RIVER BASIN

An introductory note on the impacts of land use change and deforestation on the flood regime of the Mekong tributary rivers

The belief that deforestation causes an increase in the frequency and severity of major floods and compounds the damage that they do appears to be widespread. This view is as widely held within the Mekong River Basin as it is throughout the tropical world. However, an authoritative Report from the UN's Food and Agriculture Organisation (FAO) and the Centre for International Forestry Research (CIFOR) says that the evidence shows no link. That flood damage is increasing is unquestioned; however this is not linked to the increasing magnitude of events but is due to the growing global population and the consequent expansion of human settlements into areas, which had once been marginal. As a result, each flood claims more lives than it would have done a century ago. In addition the human diversion of watercourses and the construction of flood protection works often moves the problem from upstream to downstream areas.

There are arguments and some evidence to suggest that the actual frequency of floods is beginning to increase, possibly in response to climate change, a major consequence of which, it is generally agreed, will be an increase in the incidence of extreme events.

The geography of the major tributary contributions to the flood hydrology of the Mekong

The physical geographical region defined by the Lower Mekong River Basin (LMB) is a variable one in terms of its topography, land cover, and rainfall. These three factors obviously have a major impact on regional hydrological response and its spatial variability, which is reflected in the contributions that the major tributaries make to the mainstream flows. These major tributaries are identified and, recognising the geographical distinctions in tributary hydrology, three reaches of the mainstream and their tributaries are considered: Chiang Saen to Vientiane, Vientiane to Pakse and Pakse to Kratie.

Chiang Saen to Vientiane - the regional history of tributary floods and flooding

In northern Thailand and northern Lao PDR ash floods have been much in the news in recent years with locally catastrophic events particularly in 2000 and 2001. Flash floods in these regions feature in the hydrological landscape to some extent virtually every year and there is a

long history of extreme events. For example, the years between 1918 and 1920 each featured devastating events, as did 1953. Even further back in time the original capital of the Lanna Kingdom had to be moved to Chiang Mai at the end of the 13th Century because of frequent flood inundation. These events obviously occurred long before the regional forests were reduced by logging, which has been blamed for a supposed increase in the frequency of the flood hazard since the 1960s. The logging of natural forests was banned in Thailand following the national flood emergency of 1988.

In the northern Lao PDR provinces of Huaphan, Pongsaly, Luang Namtha and Luang Prabang significant flooding has been similarly frequent, having occurred in 1991, 1995, 1996, 2000, 2002, 2005 and 2006. Prior to that the largest regional flood was in September 1966, which was associated with the incursion of cyclone Phyllis over the large northern tributaries.

Chiang Saen to Vientiane - the regional tributary systems

A schematic of the regional tributary rivers is presented along with summaries of their areas and the hydrological data that are available.

- the reach comprises a complex of right bank tributaries in North and Northeast Thailand, principally the Nam Mae Khan, Nam Mae Ing, Nam Mae Kok and Nam Loei and a number of generally larger left bank tributaries in northern Lao PDR. Of these the Nam Ou is by far the most significant in terms of drainage area and discharge;
- the total tributary area is 110,000 km^2, of which streamflow data are available for almost 60,000 km^2;
- annual tributary runoff is less than in other parts of the LMB to the South, particularly from the large left bank tributary systems downstream of Vientiane;
- the sub-reach between Luang Prabang and Vientiane is unique in the LMB in that there are no large left bank tributaries, a fact which largely explains the small contribution it makes to the overall flow of the Mekong;
- flash floods in this area of the LMB have been a key feature of its hydrological history. It has also been an area where deforestation and 'slash and burn' agriculture have been widespread, leading to arguments that the consequent landscape changes have been a major contributory factor to flooding.

Chiang Saen to Vientiane - are flash floods becoming more common?

The view that deforestation has increased the frequency and severity of ash floods is widely held, particularly in northern Thailand. There appears to be sufficient evidence on the basis of the analyses undertaken that extreme floods have become more frequent over the last 15 years or so. Whether this is a response to external influences such as climate change is arguable. It may simply be part of the natural periodicity of such processes - the fact that there were no significant events at all during the 1980s might be evidence in this regard. However, the timescale for which data are available is far too short to establish any such possible periodic patterns one way or the other. However, it seems reasonable to conclude that after the logging ban in Thailand during the late 1980s, deforestation appears not to be a factor to the increased frequency of events post 1990.

Chiang Saen to Vientiane - the hydrological assessment of extreme regional tributary flood events

It is proposed that there are two weather processes linked to the occurrence of floods, one that generates average and significant floods and one that generates floods that are far more extreme. This distinction may be linked to:

- typical monsoonal storms and average antecedent river basin conditions that result in the

more typical or basic events;

- more extreme weather systems, such as intense tropical depressions, severe tropical storms and typhoons, which combine with wet or saturated antecedent river basin conditions to generate extreme or outlier events.

The picture that emerges from the assessment of the most extreme historical regional flood events is that, except for the larger river basins in Lao PDR such as the Nam Ou, they are of short duration, typically three to four days. In addition:

- times to peak are extremely rapid, typically less than one day;
- antecedent flow conditions are often not linked in any significant way to the peak magnitude, though such is the rapid rate of recession of the flood hydrograph this may not of itself be a meaningful indication of the actual state of the river basin in terms of wetness and its ability to generate maximum rates of runoff during a storm.

Vientiane to Pakse - the regional tributary systems

In this reach the large left bank tributaries in Lao PDR begin to exert their dominant influence on the flood hydrology of the Mekong, starting with the entry of the Nam Ngum 50 km downstream of Vientiane. The combined mean annual flow of all tributaries between Vientiane and Pakse is 171 km^3, almost 40% of the total for the Mekong. The major contributions to this figure are made from the left bank by the Nam Ngum, Nam Kading/Nam Theun and the Se Bang Hieng, while the Mun-Chi Basin accounts for by far the greater part of the floodwater arising from the right bank in Thailand. Within this reach:

- the tributary river basin areas are generally very large, such that ash floods do not dominate the flood hydrology as they do in the tributaries upstream of Vientiane. They are locally important on some of the smaller, steeper, tributaries and in the upper reaches of the larger rivers, and on the larger tributaries conditions may arise where extremely rapid increases in discharges are followed by equally fast flood recessions;
- in their lower reaches backwater effects from the confluence with the mainstream of the Mekong can extend very considerable distances upstream and exacerbate the depth and duration of inundation during extreme events;
- the accelerating development of hydropower schemes in this sub-region of the LMB will in time significantly modify the flood regime of many of the major tributaries. The impact upon flood peaks and volumes will depend upon the scale of reservoir development and whether any such storages are operated in a way that mitigates the flood hazard, for example by the provision of operational flood storage during the flood season;
- it is anticipated that one of the major changes to the flood regime will be a delay in the start of the flood season and the onset of the higher discharges associated with it. Early season flood water will be withheld in the reservoirs, which will typically be drawn down at the end of the dry season;
- the cumulative impacts of the numerous proposed schemes will in time modify the flood regime of the Mekong mainstream itself.

Vientiane to Pakse - the hydrological assessment of extreme regional tributary flood events

Because the major tributaries in this Mekong hydrological sub-region are large, flood risk should be assessed both in terms of flood peak and volume, thereby acknowledging the importance of both the depth and duration of flood inundation. A highly variable flood hydrology both within and between years is characteristic of the large left bank tributaries and there is, in effect, nothing that can be defined the ‘typical’ flood season hydrograph. Extremely rapid increases and decreases in flood discharge, generally associated with severe tropical

storms can, even in very large river basins, cause ash flood conditions.

Due to the at landscape, the lower rainfall and to some extent the presence of large reservoirs, ash floods are not a feature of the hydrology of the Mun-Chi Basin, except in the far upstream reaches. In recent years the events of 2000, 2001 and 2002 were the largest both in terms of flood peak and volume. On the Nam Mun the highest peak discharge occurred in 1978, corresponding with the year that the largest flood peak was observed on the mainstream of the Mekong at Kratie since records began in 1924.

The evidence from the Nam Chi Basin suggests that below 'normal' flood years, when peak and volume are significantly less than average, tend to cluster. During the 13 years between 1967 and 1979, eight of the most extremely deficient annual floods were observed.

With a total basin area of 120,000 km^2, equivalent to 22% of the Mekong drainage area at Pakse, the Mun-Chi system contributes only 10% to the average flood volume at that point on the mainstream and 6% to the total at the Delta.

Vientiane to Pakse - the estimation of flood risk at ungauged locations

The accelerating pace of hydropower development in the LMB means that there is a growing need for the development of reliable procedures for the estimation of design flood risk at ungauged dam sites. Over recent years 'best practise' has involved the use of regional methods based upon the pooling of data in regions and sub-regions that might be considered to be homogenous with respect to their flood hydrology. The Mekong between Vientiane and Pakse can be considered to be one such, though the left and right bank tributaries require separate treatment. A statistical procedure is developed.

Pakse to Kratie - the regional tributary systems

This reach of the Mekong, which accounts for 18% of the total basin drainage area, the tributary contribution to the mean annual flood volume at the Delta is about 20%. At Kratie 90% of floodwater has already entered the system; downstream of there most of the balance is made up by the contribution of the Tonle Sap Basin in Cambodia. Of this 20% around 18% is accounted for by the combined Se Kong, Se San and Sre Pok Basins, which combined make the largest single contribution to the total Mekong flood in most years.

The major constraint to hydrological analysis in this sub-region is a lack of representative data, which are distributed amongst only seven sites. With the exception of the gauge on the Se Done at Kong Se Done, which records the flows from 65% of the basin, and the gauge on the Se Kong at Attapeu, the others on the Se Kong and Sre Prok are far upstream and only provide information about the hydrology of the headwaters. Meaningful estimates of the flood hydrology of these key regional river systems are therefore dependent upon hydrological modelling.

Pakse to Kratie - the hydrological assessment of extreme regional tributary flood events

This lack of representative data means that only a limited assessment of the tributary flood hydrology is possible, which is unsatisfactory given the pivotal role of the Se Kong, Se San and Sre Pok in the generation of extreme flood conditions across the Cambodian floodplain and in the Mekong Delta. Their contribution to the extreme regional flood of 2000 was a major one. This event was characterised by a peak flow at Kratie on the mainstream of the Mekong that was only marginally above average. It was the total flood volume over the flood season that was extreme, being the highest observed since 1924.

THE 2007 FLOOD SEASON

Hydrological aspects - the mainstream of the Mekong

In terms of peak discharges and seasonal flood volumes, conditions along the mainstream of the Mekong during the 2007 flood season were comparable to those that occurred during 2006. As then, both variables fell below their long-term average values; the degree to which they did so became more pronounced downstream, so that at Kratie both flood peak and volume were significantly below normal. In fact, flood conditions at Kratie during 2006 and 2007 are amongst the eight lowest observed since 1924.

These below average flood conditions were not, however, the definitive hydrological feature of the 2007 season. This lies with the fact that throughout the mainstream the start of the flood season was generally the latest observed over the last 80 to 90 years. Typically, the season begins in the last week of June or the first week of July in those reaches above Kratie and a week or two later at Phnom Penh and in the Delta in Vietnam. As a consequence of the three weeks to one month delay in 2007, water levels at the end of July were amongst the lowest ever observed.

Hydrological aspects - the Cambodian floodplain and Mekong Delta

Self evidently, hydrological conditions over the Cambodian floodplain and within the delta during the 2007 flood season - indicated in terms of water level rather than discharge - reflected those that prevailed upstream. Water levels were considerably below average throughout most of the years and amongst the lowest observed at the end of July. Only in October did they increase to anywhere near average.

The 2007 Flood season - meteorological aspects

With the exception of most of Cambodia and the Delta region, rainfall during the Southwest Monsoon of 2007 over the Mekong region was moderately below average, with only one extensive storm system that was large enough to bring the Mekong up to average discharges and water levels. This was severe tropical storm ‘Lekima’, which passed over the central regions of Lao PDR and Thailand during the first week of October.

LAO PDR 2007 COUNTRY REPORT

The central and southern parts of Lao PDR were the most affected by floods in 2007, which were mainly associated with impacts of tropical storm ‘Lekima’. The resultant national damage and loss exceeded that for 2006, particularly with respect to the rice crop. Elsewhere in the country the only events of note in 2007 were heavy rainfall during mid September in Luangnamtha Province and a local storm in Vientiane during April, which caused some damage. Two people were killed and over 600 villages were affected in some way by the floodwater. Almost 160,000 ha of rice crop were damaged to some extent by prolonged submergence along with 30% of the planted vegetable crop.

THAILAND 2007 COUNTRY REPORT

The southern parts of the Mun and Chi River Basins around Nakon Phanom, Kalasin Mukdahan, Roi-et Yasothon and Ubonrachatani were the most affected by the storm rainfall

associated with 'Lekima'. Most rainfall occurred on 4 and 5 October, by which time the event had been downgraded to a tropical depression. Rainfall decreased from in excess of 250 mm in the east of the Mun-Chi Basin to less that 150 mm in the west during the first week of October as the intensity of the system decreased as it tracked westwards. Flooding in Northeast and Central Thailand during October 2007 was described by the Bangkok Post as the worst in 40 years, with troops and rescue workers dispatched to assist stranded residents. A number of people died as a result of being swept away and thousands of hectares of crop lands were inundated to a depth of 1 m and more. There was widespread disruption of road links and many communities were cut off. Other reports suggest that the total number of people killed was as high as 67 and that 17,000 people had to be evacuated.

CAMBODIA 2007 COUNTRY REPORT

Events in Cambodia during 2007 centred around the flooding caused by Tropical Storm 'Pabuk' in the northern and coastal areas of the country on 4 and 5 August. Otherwise, the fact that the annual flood on the mainstream of the Mekong was a month late in starting and that water levels, once it had, remained significantly below average until October following 'Lekima', meant that levels in the Tonle Sap Great Lake were considerably lower than average. This delay in the increase in lake levels until early August and the fact that inundation of the riparian forest covered a much smaller area than usual resulted in a large fall in the annual fish catch. Reports from those provinces affected by 'Pabuk' during August indicate that more than 160,000 persons were affected, 5 people were killed, 37 km of rural roads were seriously eroded, along with some locally significant damage to public building, temples and residential areas. A number of dykes and irrigation canals filled with sediment or eroded. Over 8,000 ha of rice and other crops were damaged or altogether lost due to prolonged submergence.

VIET NAM 2007 COUNTRY REPORT

Seven typhoons and three tropical depressions, originating in the South China Sea, affected the Vietnamese regions of the LMB during 2007, of which those designated Numbers 2 ('Pabuk' in Cambodia) and 5 during August and November caused major ash floods in the Upper Se San and Sre Pok Basins. Flooding in the Mekong Delta was minimal, except during spring tides when areas of Can Tho City were inundated. Serious damage to infrastructure, agricultural production, and human settlements resulted from Typhoon No. 2 during early August. In Dak Lak Province 23 people died and losses to the provincial economy estimated at US$ 5 million. Over 10,000 properties were inundated, more than 41,000 ha of agricultural lands flooded and 70 water control projects destroyed or damaged. The ash floods, landslides and debris flows that took place in November as a result of Typhoon No. 5 caused extensive damage in the Upper Se San. In Kon Plong one person died, four bridges were either damaged or completely destroyed and several villages flooded and cut off. The remoteness of many of the villages was a challenge to rescue and repair.

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

In many ways the flood season of 2007 mirrored that of 2006, with below average peak discharges, water levels and flood volumes, which at Kratie were significantly so. The definitive feature of the year was the exceptionally late start to the flood season throughout the Lower Mekong region. It generally starts during the early weeks of July but in 2007 the onset was as late as early August in Cambodia and Viet Nam. This delay caused discharge and water levels towards the end of July to be some of the lowest observed since hydrological records began in

the early 20th Century. The major impact of a shorter flood season, significantly low water levels over most of the season and the fact that maximum water levels were unseasonably late, not occurring as that did until October, reduced the annual fish in the Tonle Sap Great Lake by a reported 35%.

The only major regional storm event to cause widespread flooding over the Central Areas in Lao PDR and Thailand was Tropical Storm 'Lekima', which occurred in October. This provided the only flood runoff during the year on a scale large enough to cause Mekong water levels to increase to anywhere near average.

Elsewhere, ash floods in Cambodia and Viet Nam during August and again in Viet Nam in November caused considerable damage and loss of life, particularly in the Upper Se San and Sre Pok Rivers.

The principal recommendations are:

- in 2007 the incidence of ash flooding and the death and damage that it causes once again drawn particular comment, particularly through the National Flood Reports. There is general consensus that they are not well understood and that reducing the number of people and their property that is exposed to them is amongst the priorities for regional flood management and mitigation;
- because storm rainfall is spatially very variable and the highest rainfall areas are in the remoter mountainous regions it is often not possible to find any storm data from ground observations to link to many extreme ash floods that have occurred. This seriously limits efforts to understand them in terms of cause and effect. Satellite and weather radar are the obvious means of gaining this better understanding and efforts should be made to pursue such studies, perhaps under the remit of the FMMP;
- unlike the mainstream data, those for the tributaries are not up to date so no analysis of conditions during 2007 is possible. Consideration should perhaps be given to the provision of current hydrological data for those rivers that contribute major volumes of floodwater to the Mekong. These have been identified as part of this Report. Such data would add substantially to understanding current flood conditions, particularly in the event of an extreme flood year;
- another data issue that drew comment is the lack of consistency between National water level datums and those held in the database at the Mekong River Commission Secretariat (MRCS). The latter should be audited in order to ensure that the water levels reported in documents such as this agree with the official National figures;
- finally, it has been recommended that consideration be given to the translation of the Annual Flood Report into the languages of the MRC Member States so that it can be more widely read and understood by the relevant stakeholders and line agencies and make a meaningful contribution to institutional strengthening and the available reference material.

THE MEKONG RIVER FLOOD FORECASTING SYSTEM AT THE REGIONAL FLOOD MANAGEMENT AND MITIGATION CENTRE

BOB PENGEL[1], JANEJIRA TOSPORNSAMPAN[1], TERRY MALONE[2], MARCO-HARTMAN[3] AND MS. ASTRID JANSSEN[4]

[1]*MRC Regional Flood Management and Mitigation Centre, Phnom Penh, Cambodia*
[2]*SunWater, Brisbane, Australia*
[3]*HKV consultants, Lelystad, the Netherlands*
[4]*Deltares, Delft, the Netherlands*

ABSTRACT

The Regional Flood Management and Mitigation Centre of the Mekong River Commission (MRC-RFMMC) in Phnom Penh currently produces short-term one- to five-day flood forecasts for 23 locations along the Lower Mekong River, using a time-tested but by now outdated implementation of the Streamflow Simulation and Reservoir Regulation model. The May 2006 Road Map Mission (Malone, 2006) recognised that extension of the forecasts to medium-term (ten days) and the introduction and development of improved hydrological models was a major step towards the improvement of the MRC-RFMMC flood forecasting services.

In order to have a first version of the system operational by the flood season of 2008 the Australian URBS hydrological model was selected as trial model for the MRC-RFMMC. The URBS (actually not an acronym, but sometimes rendered as 'Unified Run-off Basin Simulation') model is a semi-distributed non-linear model with build-in flood routing capability, used extensively for flood forecasting by the Australian Bureau of Meteorology and by the Yangtze (Chiangjiang) Water Resources Commission in China. To enable the flood forecaster to focus on major tasks, the implementation of the Flood Early Warning System (FEWS) is now planned. FEWS will take care of all data capturing, pre-validation and processing, model runs and output post processing. It will also enable easy access to graphs, maps and tables of input and output data, both for recent and historical situations, so comparisons can be made.

As a complementary exercise to these improvements, attention should be paid to data availability. The input for the new hydrological models is primarily rainfall data, from both point and grid-based products. Analysis of the near real time rainfall network for Cambodia and the Lao PDR shows that limited and relatively low-tech support will substantially increase the availability and spatial distribution of rainfall data, both for direct input and for bias reduction of grid rainfall products.

INTRODUCTION

The Mekong River Commission was formed on 5 April 1995 by an agreement between the governments of Cambodia, the Lao PDR, Thailand and Viet Nam. The four countries agreed on joint management of their shared water resources and development of the economic potential of the river. The MRC has been built on a foundation of 50 years of knowledge and experience in the region, starting from 1957 when it began life as the UN-founded Mekong Committee. In 1996 China and Myanmar became Dialogue Partners of the MRC.

The MRC serves its Member States by supporting decisions and promoting action on sustainable development and poverty alleviation as a contribution to the UN Millennium Development Goals.

The Mekong River Basin includes parts of China, Myanmar and Viet Nam, nearly one-third of Thailand and most of Cambodia and the Lao PDR. The total land area is 795,000 km^2. From its headwaters, thousands of metres high on the Tibetan Plateau, it flows 4,800 km through six distinct geographical regions, each with characteristic features of elevation, topography and land cover. The Upper Mekong Basin is that part of the basin upstream of Chiang Saen near the Laos-China border, while the Lower Mekong River Basin (LMB) is downstream of this point.

Large floods, such as those, which occurred in 2000, 2001 and again in 2002, have the capacity to cause loss of life and huge property damages. Floods of these magnitudes can affect between one and eight million people throughout the LMB (Mekong River Commission Secretariat (MRCS), 2005). Improved flood forecasting was recognised as a key reason for the establishment of the MRC-RFMMC in 2005.

The Flood Management and Mitigation Programme is a rolling programme that commenced operations in January 2005 and was funded to a total value of around US$ 20 million. At the heart of the programme is the Regional Flood Management and Mitigation Centre in Phnom Penh. This provides technical and coordination services to the four countries in the Lower Mekong Basin. Forecasts, flood data, technical standards and training packages are key outputs of the programme. The FMMP aims to prevent, minimise or mitigate people's suffering and economic losses due to floods, while preserving the environmental benefits of floods.

The Road Map Mission, conducted in May 2006 (Malone, 2006), recognised that the existing forecasting models were outdated and unreliable, and that the development of improved forecasting methods was a major step towards the upgrading of flood forecasting services in the LMB. The introduction and development of new rain-based hydrological forecasting models to improve reliability, accuracy and lead-time is just the first step in this process. Improved data availability and the establishment of a real-time operational database, integrated with the models, is a logical precondition for improved forecasts.

DATA AVAILABILITY

One of the clear drawbacks of the current flood forecasting system in use at the MRC-RFMMC is the inflexibility and limited availability of data, particularly rainfall information. The system is fragile: if water level data from one input station is missing the model cannot run. As inputs from a total of seven different sources in six different countries are used, it happens all too often that one or more of these sources have (technical) difficulties in sending the data, which means the data is received late or not at all, and the forecast is made late or not at all. The rainfall data reported by the sources is currently mostly used to check the model output and adjust it manually.

The input for the new hydrological models now being developed is primarily (observed and forecast) rainfall data. For best spatial distribution and because the station network in the Mekong Region is very sparse, grid-based (satellite) rainfall products will initially be used as input. These products need to be adjusted using ground-based observations. A minimum set of rainfall data for the region is available through the World Meteorological Organization Global Transmission System. However, to realise the objective of reliable short- and medium term forecasts, (improved) daily delivery of rainfall data transmitted directly from the MRC member countries to the MRC-RFMMC is essential.

As one of the main objectives of the MRC is to facilitate data exchange, over the years several projects have been carried out to improve the hydro-meteorological network in the MRC Member States. The latest are Appropriate Hydrological Network Improvement Project (AHNIP) and Mekong Hydrological Cycle Observing System (M-HYCOS). Analysis of the raingauge network carried out under these projects and earlier projects (Mekong River Commission Secretariat (MRCS), 2001), consistently shows that for Thailand and Viet Nam the

average coverage is sufficient but that the spatial distribution needs improvement. Most of Cambodia and the Lao PDR suffer from inadequate network coverage. It is also mentioned that 'the network operation and maintenance problems are serious in Cambodia and the Lao PDR' while Thailand and Viet Nam need only limited support for operation and maintenance (O&M) (Mekong River Commission Secretariat (MRCS), 2001).

As capacity building was a major objective in the AHNIP and M-HYCOS projects, state of the art telemetry equipment and rainfall and water level loggers were installed. Because of the earlier mentioned lack of resources for O&M these projects and instruments have often been beset by problems. The objective may have been to move immediately to modern technologies but the overall status of the present meteorological networks in the Lao PDR and Cambodia is still far from ideal. To understand this one should consider the following observations:

- it appears that the responsible organisations in Cambodia and the Lao PDR do not have adequate funding to ensure proper operation and maintenance. Moreover, all spare parts have to be imported at considerable cost;
- the advantage of a data logger with telemetry is the fact that data can be read immediately or at high frequencies. However, daily water level fluctuations on the main stream Mekong are usually not very big and loggers provide limited advantages over reliable manual observations in such cases;
- to date the number of automatic telemetry stations is far too low, even after implementation of the new M-HYCOS project. This is especially true for rainfall stations in Cambodia and Lao PDR;
- the overriding reason for introducing automatic telemetry stations in industrialised countries has been the rising costs of labour. Investment and maintenance costs are high but are offset by much lower operation costs. This advantage does not apply in Cambodia and Lao PDR, where investment and maintenance is higher and observers are paid comparatively low salaries.

A significant increase in the number of rainfall stations, which report daily to their respective head offices by using simple but robust and adequate technology is proposed. These stations use manual rain gauges and communicate through text messaging over the mobile phone network. Gaps in the station network are to be filled by setting up simple manual rainfall stations. Detailed analysis of the situation regarding rainfall stations in Cambodia, the Lao PDR, Thailand and Viet Nam has been carried out (Regional Flood Management and Mitigation Centre of the Mekong River Commission (MRC-RFMMC), 2007a,b,c,d). With relatively simple and inexpensive methods, the number of daily reported rainfall stations in Cambodia can be increased from 26 to 52; for Lao PDR these numbers are 33 and over 50. For both countries the spatial distribution of the network can be significantly improved (Pengel et al., 2007). The map in Figure 1 shows the situation for Cambodia.

Further analysis of the available rainfall stations in Viet Nam and Thailand is needed. However, it seems that a sufficient number of rainfall stations report daily or at higher frequencies (Regional Flood Management and Mitigation Centre of the Mekong River Commission (MRC-RFMMC), 2007c and 2007d). An agreement on a method of timely and efficient data delivery to the MRC-RFMMC will be the next step.

MODELS

URBS

As the MRC-RFMMC needed to have a first version of the system operational by the flood season of 2008, the Australian hydrological model, URBS, was selected as a trial model. The URBS model is a semi-distributed non-linear model, and is used extensively for flood

forecasting by the Australian Bureau of Meteorology and by the Yangtze (Chiangjiang) Water Resources Commission in China. URBS combines the rainfall-runoff and runoff-routing components of the modelling process and allows users to configure the model to match the characteristics of individual river basins. The model is robust, developed for use in a real time environment, and has several features, which readily lend itself to application as a flood forecasting model. The URBS model will eventually be one of a suite of hydrological and hydraulic models available to forecasters in the MRC-RFMMC.

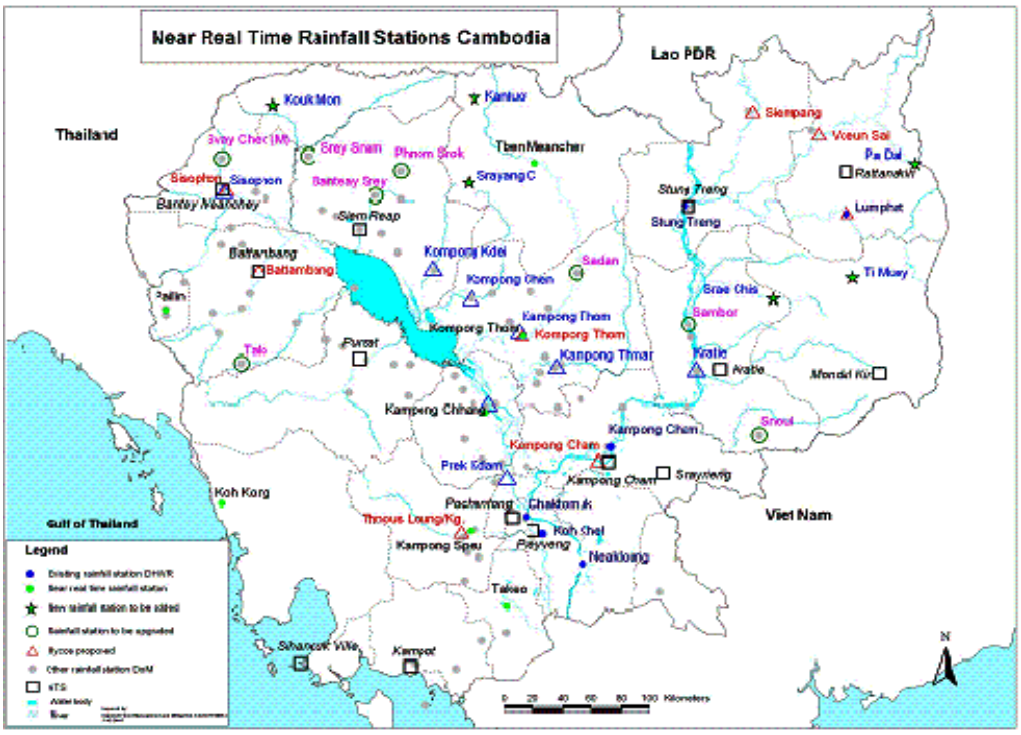


Figure 1. Map of daily reported rainfall stations in Cambodia

The conceptual runoff routing model, URBS (Carroll, 2004), is a hydrologic modelling programme that enables the simulation of river basin storage and runoff response by a network of conceptual storages representing the stream network and reservoirs. The URBS model combines two hydrological modelling processes into one model: rainfall runoff modelling, which converts the gross rainfall into net or excess rainfall; and runoff routing modelling, which takes the excess rainfall as input and converts it into flow. Users can select from several bucket-type rainfall runoff models that may be applied uniformly or spatially varied over a river basin. The selection of the most appropriate rainfall runoff model and its associated parameters is carried out as part of model calibration.

Because of the semi-distributed nature of the model, the temporal and spatial variation of rainfall across a river basin can be taken into account and generally provides more accurate results than traditional lumped models such as the unit hydrograph.

The URBS model can be set up as a rainfall runoff routing model or as a simple runoff routing or flood routing model, and it can be used as a design or as a flood-forecasting tool. The model may be applied as an event model or for continuous simulation. Typically for flood forecasting, the model is calibrated as an event model and then applied as a continuous simulation model.

URBS has several features that readily lend themselves to application as a flood-forecasting model. It has enhanced data management: input data such as rainfall and water level data are separate to the model and are accessed during running. It shows robust performance: the model still runs if key gauging station data is missing. Forecast rainfall can be added to the model with a variety of techniques using results from external sources. It allows the use of

linked ratings: known stage-discharge relationships can be incorporated into the model to produce both flow and height results at gauging stations. Dependent ratings, where the upstream water level is dependent on downstream water level, can also be used. Runoff can be routed through reservoirs using known storage characteristics and simple operating rules applied. Matching forces the model to fit the observed data at gauging stations, thereby improving the forecast accuracy at downstream locations. Another key feature of the model is adaptability: it can be readily incorporated into any flood forecasting system.

The Bureau of Meteorology, Australia, uses the URBS model as an event model extensively for flood forecasting on basins of up to 250,000 km^2 (Malone, 1999 and 2003). It was tested against five other hydrological models in the Yangtze River Flood Control and Management Project (Markar et al., 2002) and was one of three hydrological models adopted for real-time use as a continuous simulation model in the project (Markar et al., 2005).

CATCHMENTSIM

For the Mekong River Basin, URBS river basin models were developed using the GIS package CatchmentSIM (Ryan, 2004). This is a 3D-GIS topographic parameterisation and hydrologic analysis model, which automatically delineates watershed and sub catchment boundaries, generalises geophysical parameters, and provides in-depth analysis tools to examine and compare hydrologic properties of sub catchments. One of the advantages of CatchmentSIM is that it includes a macro language, which enables the user to write scripts to develop any hydrological modelling package based on sub catchment networks. The example in Figure 2 shows the Se Bangfai river basin (Lao PDR) derived using publicly available digital elevation data from the NASA Shuttle Radar Topography Mission.

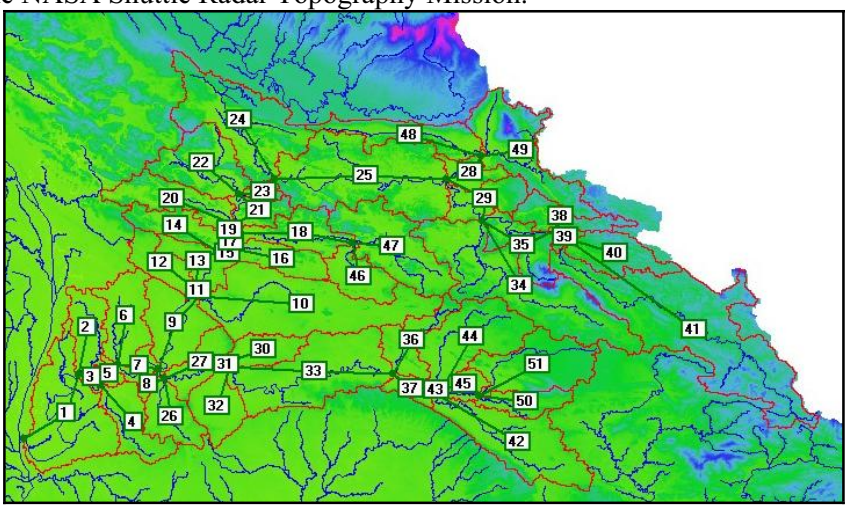


Figure 2. CatchmentSIM model of Se Bangfai River Basin

Calibration was undertaken using the rainfall, height and flow data from the MRCS HYMOS database. Each model has been calibrated over several flood seasons.

Model building

CatchmentSIM was used to compile a series of 51 linked URBS models, 48 runoff routing models and three flood routing models.

The model of the Se Bangfai River basin is typical of the runoff routing models developed and consists of 55 sub-areas representing 9,300 km^2. Rainfall and discharge data from the available stations was extracted from the MRCS HYMOS database. The rainfall stations available from HYMOS typically do not provide full coverage of the observed rainfall

in the Mekong Basin catchments. There are often no stations to indicate the rainfall in the headwater areas in the upstream sparsely inhabited parts of the river basins. A technique, based on the methodology described by Wei et al. (1973), was used to estimate the rainfall on each sub-area in the river basin. The Australian Bureau of Meteorology (Malone, 2003) and the Yangtze (Chiangjiang) Water Resources Commission in China (Markar et al., 2005) adopted this same methodology.

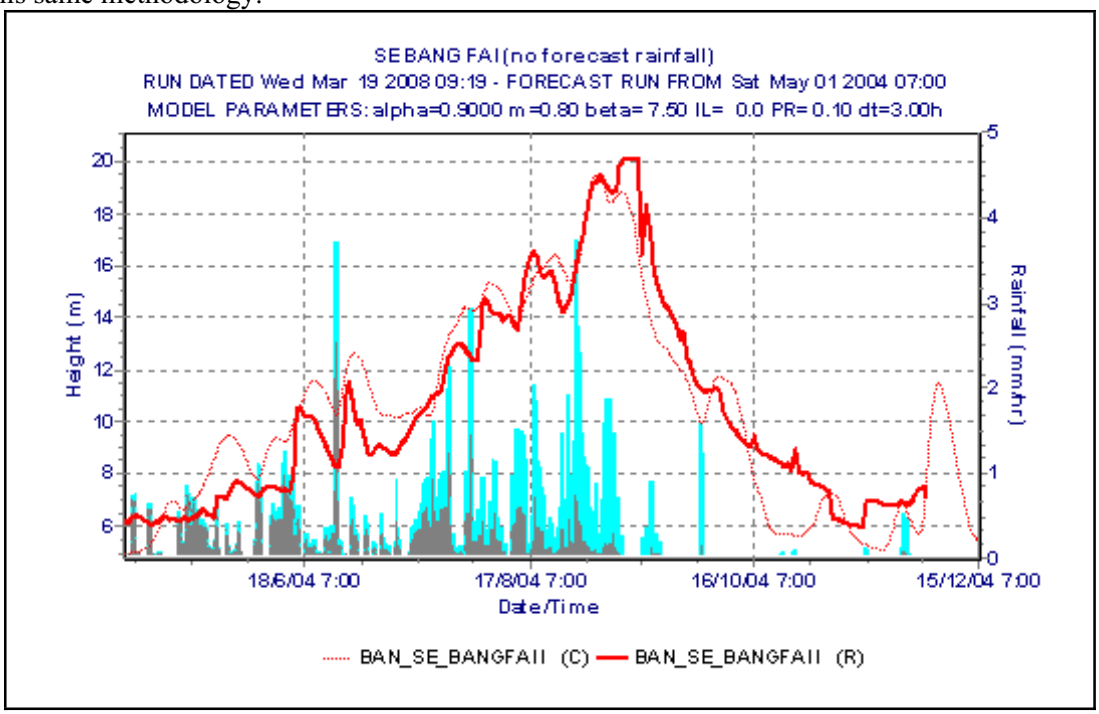


Figure 4. Model calibration at Se Bangfai 2004

For each flood season, rainfall runoff and runoff routing model parameters were varied to obtain the best fit to the observed water level data at the gauging station located near the outlet of each river basin.

Figure 4 shows an example of the calibration at Ban Se Bangfai in 2004. While model performance based on daily rainfall data is adequate, it is expected that accuracy will improve using data from more (near-) real-time stations in the river basin, especially as more frequent rainfall observations than daily data are expected to become available.

The inflows from each of the 48 river basins are linked together via a series of flood routing models. For the Mekong between Chiang Saen and Kratie, a linear Muskingham routing model with an error correction matching feature is used to derive flows and heights at key locations. Downstream of Kratie, the behaviour of the system is more complex, with diversions and interaction between the Mekong River and the Tonle Sap, the largest fresh water lake in Asia. The URBS model was able to simulate this complex hydraulic situation by treating the lake as an off river water body, filling during the early part of the flood season and draining during the later part of the flood season.

Flood Early Warning System (FEWS) and Operational Procedures

Following completion of the model calibration programme, the next challenge for the MRC-RFMMC is to link the models to the real-time database and include forecast rainfall in order to extend forecast lead-times (Malone et al., 2007). This will be accomplished as part of the implementation of the flood forecasting 'environment' Delft-FEWS, which started in March 2008.

The Flood Early Warning System (FEWS) was developed with the objective of creating a

flexible system for the integration of flood data and flood simulation models for organisations such as the MRC-RFMMC. It provides a platform for data handling and can connect a wide range of monitored and forecasted weather inputs on one side with hydrological and hydraulic flood routing models on the other side. It has been equipped with generic tools providing a variety of data handling tasks, such as data validation, interpolation, aggregation and error correction in forecasts, including a variety of visualisation and forecast dissemination options.

Its many users have made Delft-FEWS a very robust and reliable instrument. It is used by quality conscious organisations such as the Environment Agency in the United Kingdom, the ministries in the Netherlands and Germany that deal with flood forecasting in the Rhine Basin, and the US National Weather Service. Delft-FEWS is used both by small and large organisations, and is also deployed in the Mekong Region, for instance for the Mun River Flood Forecasting System.

At the MRC-RFMMC the Mekong FEWS will be deployed as a stand-alone system at first, automatically linking the URBS models with the input data, enabling primary validation and gap filling, automatic bias adjustment by using known water levels and discharges, visualisation of inputs and outputs, and automatic reporting to the flood page at the MRC website. According to the present planning the system should be ready to run in parallel from June 2008. However, the flood forecasts on the website will be the results of the 'old' system, until enough experience and confidence has been built with the new system.

With both the new and the old system it is essential to have a clear set of instructions, the so-called 'operational procedures'. A first draft of these was made in August 2007 in close consultation with all involved MRC-RFMMC staff and management. Based on this document two separate documents will be developed: one document should be a more general, policy document (the 'Policy Document'), while the second is the detailed list of steps to take, the actual operational document or 'Operational Manual'. The Operational Manual will be a living document, which needs to be updated regularly, and which offers detailed instructions on how to prepare the flood forecast using the MRC-RFMMC flood forecasting system. The Policy Document will explain the 'why' and only in general terms outline the 'how'. This document will have to be endorsed by the MRC member states and will only change with major MRC policy changes.

PLANNING AND FUTURE DEVELOPMENTS

The MRC-RFMMC considers that the URBS model shows sufficient potential for use as a flood-forecasting model and has embarked upon a programme to develop a suite of URBS models for the Mekong River Basin. It is envisaged that in the future URBS will be one of several hydrological models available to forecasting staff in the MRC-RFMMC. However, for expediency it has been selected as the initial model to fast track the introduction of improved forecasting techniques.

Eventually, the hydrological models will provide the inflows into a real-time hydraulic model of the LMB. The linking of the individual hydrological models to hydrodynamic models of the Mekong main stream will be considered at a later stage.

As each model was completed, a calibration report outlining the modelling processes, plus inputs and outputs was produced. These reports will be stored in the model database system and will be instantly retrievable. The individual model development programme was completed by the end of 2007.

An important challenge is to match the expectations of the potential users of the MRC-RFMMC flood forecast products with a realistic view of the accuracy that can be achieved, especially for medium range (five-to ten-day) forecasts. The dissemination of the results should reflect the inherent uncertainty of forecasts. Forecasting further into the future involves increased uncertainties, especially regarding weather patterns. This issue has to be resolved by intensive contact and discussions with stakeholders, and by using international best practices in

flood forecasting, especially for dissemination of the results.

CONCLUSIONS

Any new forecasting system for the Mekong should include significant updating of the existing observation network and data collection system in data sparse areas of the basin. A programme to upgrade the existing (rainfall) stations by providing a simple but effective means of communication at short notice, and by setting up simple new manual rainfall stations, has commenced. The first steps of this programme have been successfully conducted in Cambodia; further trials are planned in Cambodia and the Lao PDR.

The URBS model has been demonstrated to be a useful flood-forecasting model on large river systems in Australia and China. Calibration and testing of the first version of the models is now complete. The complex hydraulic behaviour of floods in the LMB has been simulated using hydrologic techniques and initial results of the models are promising.

The FEWS system currently being installed will link the real time data to the URBS models and provide a streamlined interface to data, models and results, enabling forecasters to concentrate on producing accurate and timely forecasts. The Operational Procedure documents will guide both staff and stakeholders on how the MRC-RFMMC prepares the flood forecast. This will add to transparency and increase the trust in the forecast results.

If sufficient real-time data is made available to the MRC-RFMMC in time, and the FEWS system has been implemented, the new modelling system could be deployed prior to the wet season in 2008.

REFERENCES

Carroll, D.G., 2004. URBS: A Rainfall Runoff Routing Model for Flood Forecasting and Design, Version 4.00

Malone, T., 1999. Using URBS for Real-time Flood Modelling, Water 99 Joint Congress, Institution of Engineers, Australia

Malone, T., A. Johnston, J. Perkins and S. Sooriyakumaran, 2003. Australian Bureau of Meteorology, HYMODEL – A Real-time Flood Forecasting System, International Hydrology and Water Resources Symposium, The Institution of Engineers, Australia.

Malone, T., 2006. Australian Bureau of Meteorology, Roadmap Mission for the Development of a Flood Forecasting System for the Lower Mekong River Basin- Technical Report, Mekong River Commission.

Malone, T., Shallcross, W, 2007. Development of a flood forecasting database for the Lower Mekong River, Mission Report, Mekong River Commission.

Markar, M.S, Ricky T.F. Kwan, and A.L. Conroy, Li Mingxin, Zheng Jing, and An Lina, 2002. Evaluation of Five Hydrologic Models for Real-time Flood Forecasting Use in the Yangtze River Catchment, Flood Defence.

Markar, M.S., S.Q. Clark, T. Malone, M. Gooda and W. Shallcross, Chen Yali and Min Yawou, 2005. A New Flood Forecasting System for the Yangtze River, Floods, from Defence to Management.

Mekong River Commission (MRC), 2005. Overview of the Hydrology of the Mekong Basin, Mekong River Commission. ISSN: 1728:3248.

Mekong River Commission Secretariat (MRCS), 2001. Improvement of the Hydrometeorological Network (basin wide), Component 2 - Final Report Volume 1 - Main Report.

Pengel, B.E., Katry Phung and T. Malone, 2007. Requirements for Data Inputs to the New Flood Forecasting System - Improved Real-Time Data Exchange. 5th Annual Mekong Flood Forum Proceedings, Mekong River Commission.

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007a. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Cambodia

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007b. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Lao PDR

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007c. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Viet Nam

Regional Flood Management and Mitigation Centre (MRC-RFMMC), 2007d. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Thailand

Ryan, C., 2004. CatchmentSIM: A Terrain Processing and Hydrologic Analysis Model, CRC Toolkit, Version 1.26

Wei, Tsong Chang and J.L. McGuinness, 1973. Reciprocal Distance Squared Method - A Computer Technique for Estimating Areal Precipitation, ARS-NC-8, Agricultural Research Service, US Dept of Agriculture.

HYDRO-METEOROLOGICAL INFORMATION EXCHANGES AND COMMUNICATION IMPROVEMENTS SUPPORT FOR URBS MODEL IN MEDIUM–TERM FLOOD FORECAST OVER THE MEKONG RIVER BASIN

PERAPOL BEGKHUNTOD, HATDA PICH AN AND KATRY PHUNG

MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC), Phnom Penh, Cambodia

ABSTRACT

The improvement of flood forecasting services for the mainstream and main tributaries of the Lower Mekong River by the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) includes the development of improved hydrological models. These models were recommended in the Roadmap of May 2006, to provide forecasts and early warning information for the Mekong River Commission (MRC) Member States, and tools for preparedness and mitigation of natural disasters, especially river floods and flash floods over the region. The URBS model, which has extensively been used in Australia and China for flood forecasts, was selected as trial model in the MRC. The model is robust in real (near-real) time environments and offers several flood forecasting features. Topographic parameterisation and hydrological analysis have been developed and calibrated using CatchmentSIM in a variety of river basins where historical data are available and stored in the HYMOS database at the Mekong River Commission Secretariat (MRCS).

The MRC currently has access to 19 telemetry stations in the four riparian countries, Cambodia, the Lao PDR, Thailand and Viet Nam, and to two stations in China under the 'Appropriate Hydrological Network Improvement Project (AHNIP) sponsored by the Australian Agency for International Development. The MRC is also in the process of installing the Mekong Hydrological Cycle Observing System (M-HYCOS), sponsored by the French Development Agency, as a regional component of the global World HYCOS of the World Meteorological Organisation (WMO). These two projects aim to strengthen both the technical and institutional capacity for real-time hydro-meteorological data monitoring in the Mekong River Basin. In the future, AHNIP and M-HYCOS will be combined into a single MRC network with a total number of approximately 50 hydro-meteorological stations. Collaboration with national agencies involved in hydro-meteorological observations is very important to developing new tools for flood forecasting.

In the future, collaboration with international organisations which can provide satellite communication will play a role in the development of communication systems from stations to the data terminal centre via a data collection platform linking ground-based stations and satellites, both geo-stationary satellites and low earth orbit satellites. Data acquisition, collection and communication improvements will be key components in expediting the modelling process. Establishing basin-wide cooperation for multi-national data observation and collection has been challenging. Improvements have been pursued by the MRC Member States to support the regional implementation for coordination and development of water and related resources for the countries' mutual benefit and the people's well-being.

INTRODUCTION AND PRESENT SITUATION

The present Flood Forecasting and River Monitoring System of the Mekong River Commission

(MRC) was developed by the U.S. Army Engineer Division, North Pacific in 1970 following the severe floods of 1966 in the Mekong River Basin, and applying the Streamflow Synthesis and Reservoir Regulation (SSARR) Model.

After devastating floods in 2000, the MRC Council during its annual meeting in October 2000 called for immediate action and for the development of a Flood Management and Mitigation Strategy. This Strategy was the basis for the later development of the Flood Management and Mitigation Programme (FMMP) in the Mekong River Basin. The Strategy was approved by the MRC Council in November 2001, while the FMMP was initially approved by the MRC Council in November 2002. An adjusted version of the FMMP, dated November 2004, attracted the required donor funding and was used for implementation. The overall objective of the FMMP is to prevent, minimise and mitigate people's suffering and economic losses due to floods, while preserving the environmental benefits of floods.

The process of operational floods forecasting follows three basic steps:

1. Data collection and transmission;
2. Forecasting and presentation;
3. Dissemination of the forecast.

In close collaboration with the National Mekong Committees (NMC) of the four MRC Member States (Cambodia, the Lao PDR, Thailand and Viet Nam) and with other national agencies in each country, both historical and operational hydro-meteorological data are delivered to the MRC Secretariat (MRCS), so that it can produce the regular operational forecast. This is in accordance with the Procedures for Data and Information Exchange and Sharing of the MRC (Mekong River Commission (MRC), 2001). The operational data collected for flood forecasting and river monitoring activities in the MRCS are given in Table 1.

Table 1. Operational data delivered regularly to the MRCS

Item	Wet season (June – October)	Dry season (November - May)
Forecast Activity	Flood Forecasting	River Monitoring
Data delivery to MRCS	Daily	Weekly
No. of days of forecast	5-day forecast	7-day forecast
Water level data	44 stations (including 2, from China)	23 stations
Rainfall data	44 stations (including 2, from China)	21 stations
Forecasting point	21 stations	21 stations

TOWARDS THE NEW FLOOD FORECASTING SYSTEM (FFS) AT THE MRC

The Road Map Mission of FMMP in May 2006 (Malone and Martin, 2006) recognised that the existing SSARR Model was no longer supported, and that a major step towards upgrading of the flood forecasting services in the Lower Mekong River Basin (LMB) was required through the development of an improved forecasting method. The URBS model was selected for the development of new rain-based hydrologic forecasting models, to improve reliability, accuracy and lead-time. During the flood season 2008, the URBS model will be put into operation and be tested for LMB conditions, while the old SSARR model will be operated in parallel.

URBS

The rainfall runoff routing networked model, URBS (Carroll, 2002, 2004), is a computer-based hydrologic model of sub-basins based on centroidal inflows. There are two runoff routing models available to describe river basin and channel storage routing behaviour: 1) rainfall runoff model which converts the gross rainfall into net rainfall, 2) runoff outing model which takes the net rainfall as input and converts into flow. The basic model assumes that the river basin and channel storage for each sub-basin is lumped together and represented as a single non-

linear reservoir. The model is comparable with the general runoff and streamflow routing program (RORB) (Laurenson and Mein, 1990), where each conceptual non-linear reservoir is represented by the storage-discharge (S-Q) relationship. The derived or assumed model parameters are set at the sub-basin level and can be compared directly with similar river basins without requiring a re-scaling of calibrated parameters.

INPUT DATA AND COMMUNICATIONS

Operational hydro-meteorological data are delivered to the MRCS and the MRC-RFMMC in accordance with the MRC Procedures for Data and Information Exchange and Sharing (Mekong River Commission (MRC), 2001). Apart from the data received from the Member States, interpretation and analysis are carried out on other available weather data such as satellite images, rainfall estimation and forecasts from sources such as the US Geological Survey and National Oceanic and Atmospheric Administration, Climate Prediction Centre. If sufficient real (near-real) – time data over the LMB networks are made available to the MRC-RFMMC in time, the URBS model has the potential to perform more reasonable accurately forecasts. Sources of hydro-meteorological data are available from these networks.

The MRC hydro-meteorological networks

The MRC currently operates 19 telemetry stations under the 'Appropriate Hydrological Network Improvement Project (AHNIP) and also in the process of installing the Mekong Hydrological Cycle Observing System (M-HYCOS). These two projects aim to strengthen both the technical and institutional capacity for real-time hydro-meteorological data monitoring in the Mekong Basin. In the future, AHNIP and Mekong-HYCOS will be combined into a single MRC network with a total number of approximately 50 hydro-meteorological stations (Begkhuntod, 2008) as shown in Figure 1. There are two types of sensors in AHNIP Project (Bubble and Shaft Encoder) while acoustic radar will be additional applied at appropriated permanent infrastructures over some tributaries in Mekong-HYCOS Project.

Hydro-meteorological networks in the MRC Member States

Since 1960, the number of hydro-meteorological stations in the Lower Mekong River Basin (LMB) has been considerably increased. Remarkable increase in its number has been observed particularly in past two decades of the 1970s and 1990s. At the end of the year 2000, the number of hydro-meteorological stations in riparian countries reached 180 in Thailand, 138 in the Lao PDR, 63 in Cambodia and 51 in Viet Nam. The status of these hydro-meteorological stations has been significantly increased in Thailand and Viet Nam, It has been gradually increased in the Lao PDR and slow progress has been made in Cambodia due to the cost of operation and maintenance in fiscal budget. The updated stations networks is shown in Figure 2 (Cambodia), Figure 3 (Lao PDR), Figure 4 (Thailand) and Viet Nam in Figure 5

DATA EXCHANGES AND COMMUNICATION IMPROVEMENTS

Hydro-Meteorological data are observed and exchanged following Greenwich Mean Time standard via the WMO Global Telecommunication System (GTS). The main goal of surface meteorological observation is to gain information about meteorological elements (pressure, temperature, humidity, wind speed and direction, etc.) and atmospheric phenomena (fog, rain, thunderstorms, snow cover, visual range, etc.). The MRC-RFMMC is mainly involved in the use of the major elements of the surface-based

subsystem and manual hydrological stations and telemetry stations, which provides all data for URBS modelling.

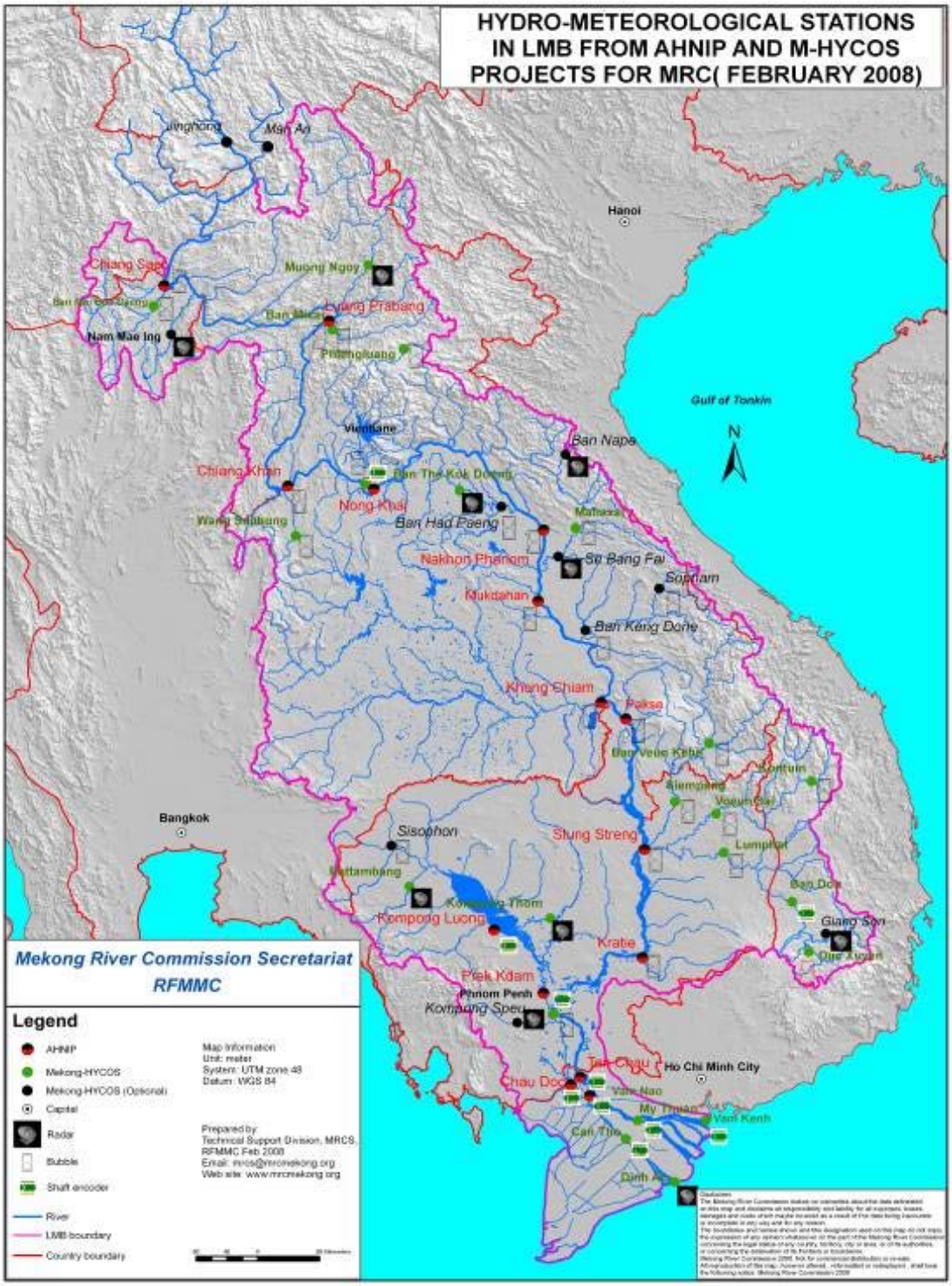


Figure 1. MRC Hydro-Meteorological Networks, AHNIP and Mekong-HYCOS

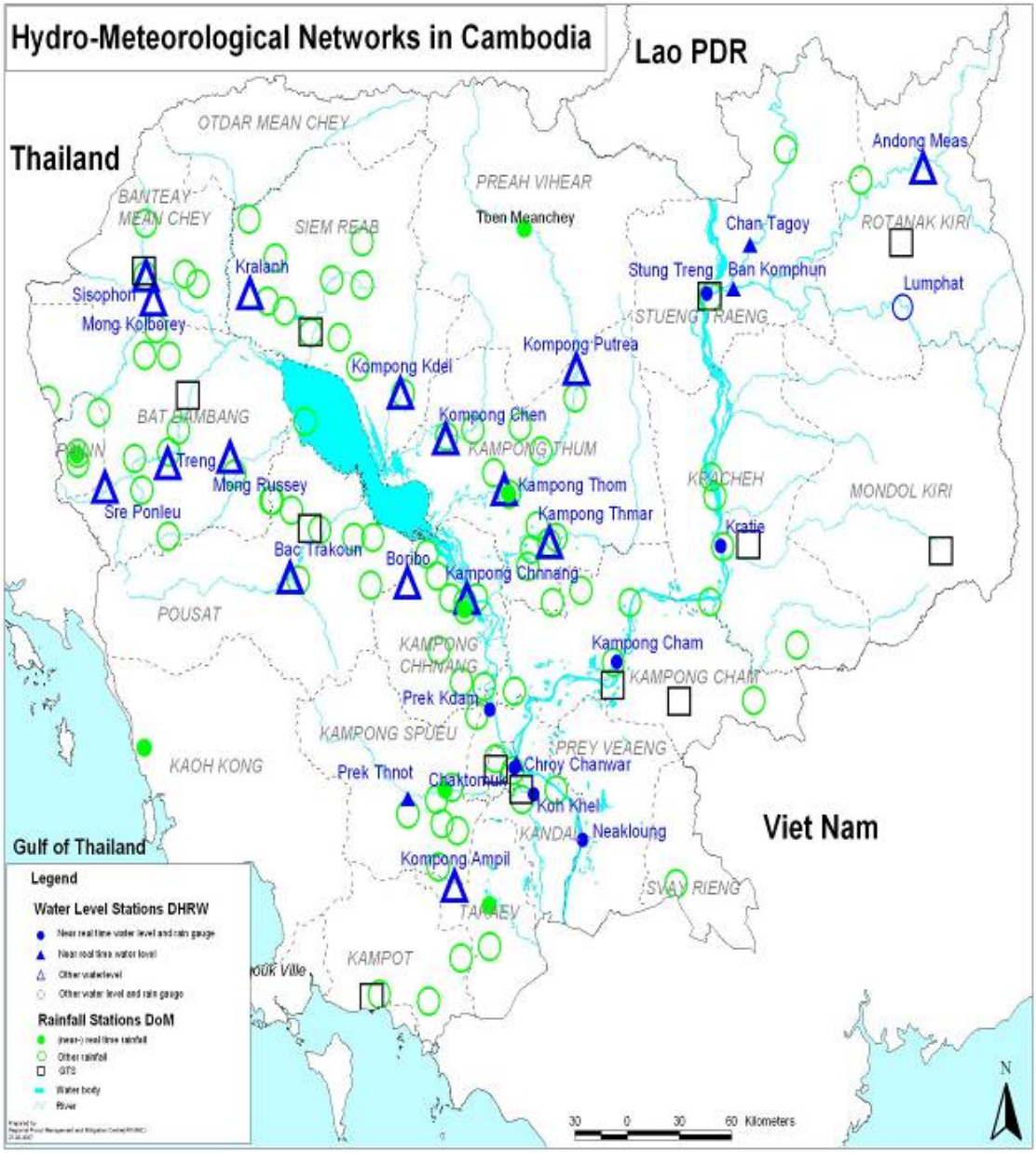


Figure 2. Hydro-Meteorological Networks in Department of Meteorology (DOM) and Department of Hydrology and River Works (DHRW)

Communcation system at national meteorological centres in the LMB

Methods of communication in the four riparian countries are different and based on infrastructure and on investment support from central government. The communication systems in Thailand and Viet Nam between stations and regional/national data terminal centres have high capability, using LAN, Intranet, or VSAT before input encoding data into a Message Switching System for globally exchange via GTS, from national meteorological centres to the regional telecommunications hub (RTH).

The GTS communication system in the Lao PDR has been significantly improved through support from WMO's Technical Cooperation Program/Voluntary Cooperation Program in close collaboration with RTH at Bangkok. However, encoding of data collection from some stations to the DMH still suffers delays and support is needed to migrate this from VHF with

single sight band to new instruments, such as GSM. In Cambodia, GTS has been established and began operation in 2007, but data observation and encoding need to be considered in order to increase the capacity of observers. WMO procedure for standard operation of GTS for 24-hours is to be encouraged at the DOM.

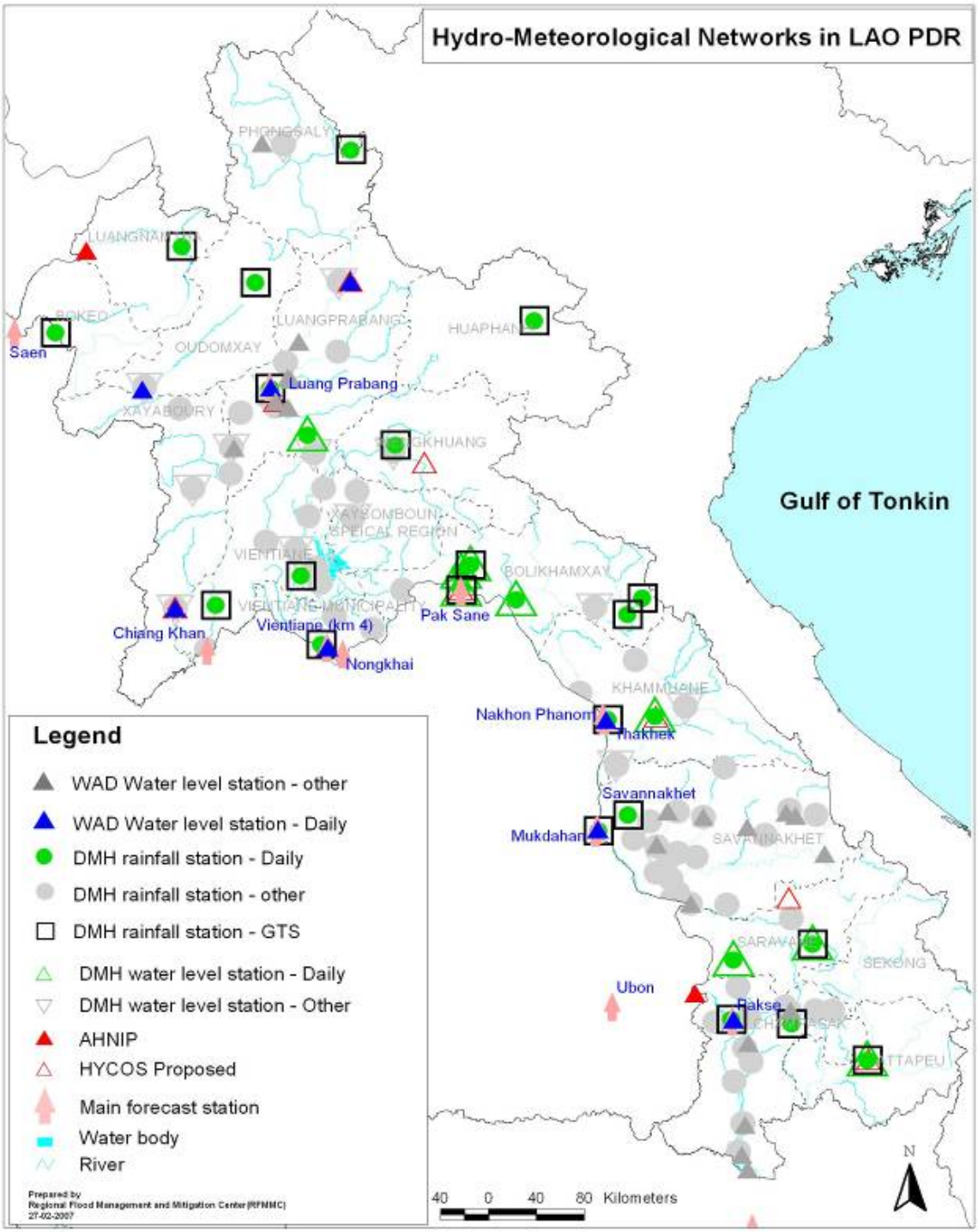


Figure 3. Networks in Department of Meteorology and Hydrology (DMH) and Waterway Administration Division (WAD)

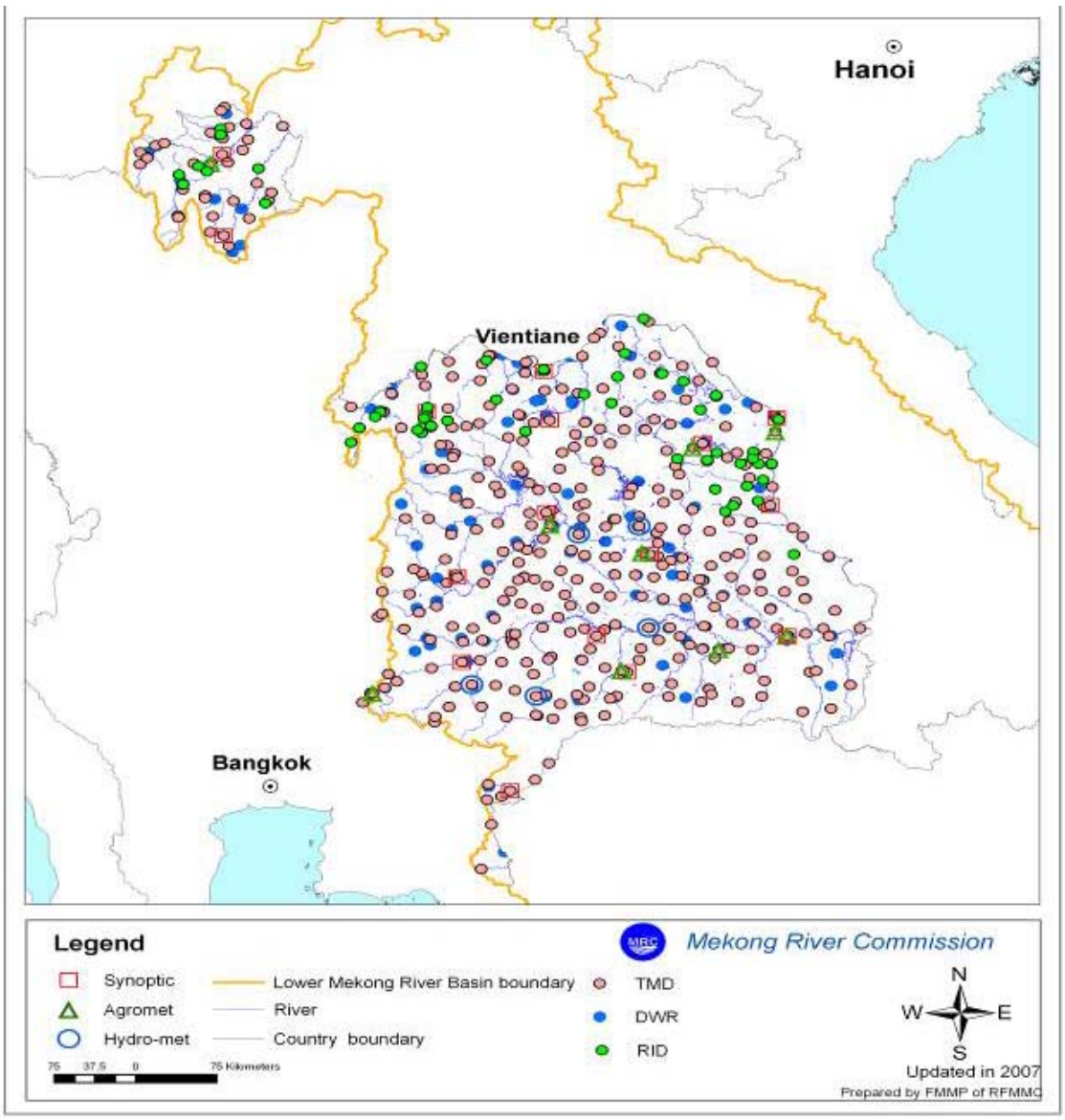


Figure 4. Hydro-Meteorological Networks of the Thai Meteorological Department, Royal Irrigation Department, and Department of Water Resources (2T, 3T, 5T and 9T basins)

Progress made on the improvement of data exchanges to the MRC-RFMMC for flood forecasts

The MRC-RFMMC has promoted and supported national data terminal centres and involved national agencies in the process of data sharing through the establishment of Memoranda of Understanding (MOU) or Terms of Reference (TOR) with the concerned ministries and the development of the long-term contracts with the responsible national line agencies in the four countries. To exchange this hydro-meteorological data the HYDMET Software for data handling and transfer has been promoted. Real-time data from telemetry stations in AHNIP is also managed and stored with this software package. After running the model for flood forecasting, all operational data will be transferred for storage in the HYMOS database with in the MRC Information and Knowledge Management Programme. The most challenging part of this is real (near-real) time automatic and timely data transfer from national agencies to the MRC-RFMMC database.

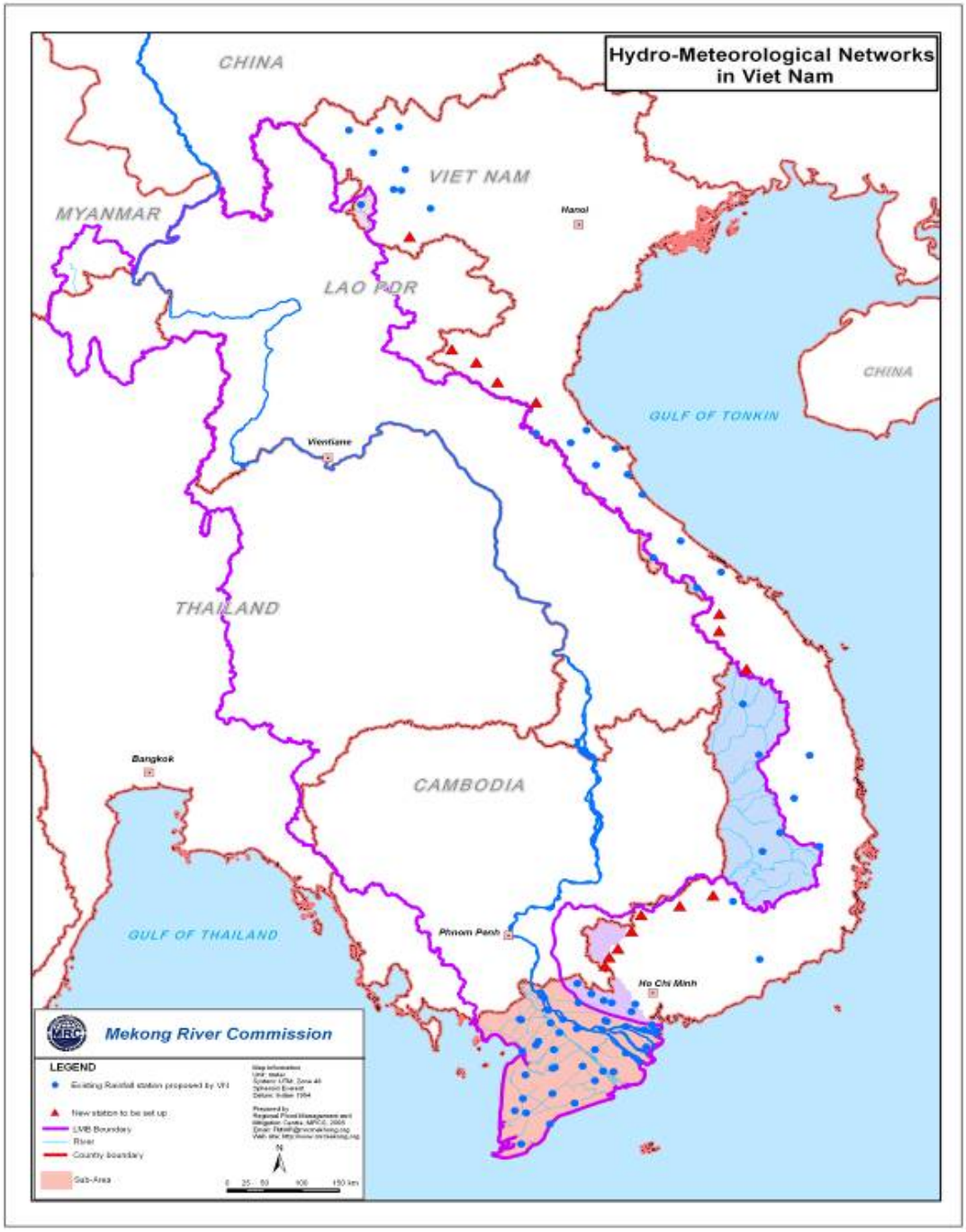


Figure 5. Hydro-Meteorological Networks in Mekong Delta managed by Southern Regional Hydro-Meteorological Centre at Ho Chi Minh, and in Central Highland managed by Central Highland Regional Hydro-Meteorological Centre at Pleku.

In 2007 a highly participatory process of interaction between the MRC-RFMMC and the National Mekong Committees (NMC) and national agencies was set up to maintain and enhance data collection and so improve the accuracy of the flood forecasting system. The MRC-RFMMC will need an increased amount of (near) real time data for the daily flood forecast and moreover needs accessible data to develop and improve new tools for medium-term flood forecasting (hydrological and hydraulic models). Therefore an agreement on which data will be

made available by the national agencies to the MRC-RFMMC and how this will be transferred (method of communication, time and timeliness, frequency) is essential. This agreement should be made with the national agencies through the NMCs well before the 2008 flood season.

Cambodia

The MRC and Ministry of Water Resources and Meteorology of the Kingdom of Cambodia signed an MOU in 2007 to allow the DOM and the DHRW to deliver daily real time and near real time water level and rainfall data directly to the MRC-RFMMC. This will be used for improved short-term flood forecasting and the development of the medium-term flood forecasting system. Contracts for improvement of networks and data transfer from the DOM and the DHRW of Cambodia to the MRC-RFMMC, as shown in Figure 2, have also been signed. The DOM, with the cooperation of the MRC-RFMMC, conducted a pilot project to test near real time rainfall data transfer by using SMS through HYDMET software to the database at the DOM and the MRC-RFMMC.

According to the MOU between the DOM and the MRC-RFMMC for data transfer and network improvement, seven existing rainfall stations will be improved to give near real time data transmission, and seven new rainfall stations will be established with near real time data transfer. In total, there will be 14 near real time rainfall stations within the DOM. In May 2008, the MRC-RFMMC will support the DHRW in improvement of near real time data transfer by SMS from ten existing historical hydrological stations used by the MRC-RFMMC for flood forecasting, and also with re-installation and improvement of near real time data transfer for four existing hydrological stations on the main tributaries of the Great Lake. Finally, 14 DHRW hydrological stations will provide near real time water level by using SMS and HYDMET software for flood forecasting in this coming flood season. Communication improvements in the new and upgraded stations in the networks include supply of GSM Modems in data logger, use of GSM Mobile phones to send SMS to data terminals, and database preparation and management through HYDMET software, as described in MRC Operational Data Delivery Procedures.

Lao PDR

The MRC and the Water Resources and Environment Administration a signed an MOU in 2007 to allow the DMH to deliver daily real time and near real time water level and rainfall data directly to the MRC-RFMMC. This will be used for improved short-term flood forecasting and development of the medium-term flood forecasting system. The contract for network improvement and data transfer from the DMH to the MRC-RFMMC, as shown in Figure 3, was prepared and signed between the MRCS and the DMH.

In April 2008, the DMH and the MRC-RFMMC conducted a pilot project to test near real time data transfer by SMS from two stations, Vientiane Km 4 and Pak San through HYDMET software to the database at the DMH. In addition, a list of rainfall stations was discussed and prepared for improvement of near real time data transfer in the coming flood season. Communication improvements in the new and upgraded stations in the networks include supply of GSM Modems in data logger, use of GSM Mobile phones to send SMS to data terminals, and database preparation and management through HYDMET software, as described in MRC Operational Data Delivery Procedures.

Thailand

This *Concept Note*, which also serves as a basic framework agreement between the MRCS and the TNMC, has been prepared based on the outcomes of official discussions with the Thai Meteorological Department, the Department of Water Resources, and the Royal Irrigation

Department. This Concept Note has also been based on an official discussion with the Electricity Generating Authority of Thailand. The outcome of discussions with these national agencies has contributed to a better technical understanding for the MRC-RFMMC, and serves as the basis for the formulation of this Concept Note. This Concept Note describes the proposed approach now considered by the MRC-RFMMC, to be endorsed by the TNMC and national agencies in order to secure timely delivery of operational rainfall and water level data. The approved Concept Note will serve as a basic framework agreement, enabling the MRC-RFMMC team to work in more detail with each line agency to develop TORs for data transfer/exchange. The TNMC will be kept updated on the move and progress of the implemented activities.

This approach is consistent with the (limited) budget available for data exchange at the MRC-RFMMC and the data exchange discussed with the concerned agencies. It should be clear that there is no official approval for any of the discussed data exchanges as yet. Still, all of the agencies expressed their willingness to supply operational data useful for flood forecasting to the MRC-RFMMC and have also expressed their interest in the following:

1. Sharing in experience and knowledge gained by the MRC-RFMMC, such as application of the URBS hydrological model;
2. Receiving operational data from Cambodia and especially the Lao PDR (an agreement on exchange of operational data seems logical);
3. Participating in future activities planned by the MRC-RFMMC, like Satellite Rainfall Estimation and Flash Flood Guidance training, or products and implementation; and
4. Support for their data handling efforts.

The well-established hydro-meteorological network in Thailand, as shown in Figure 4, provides data distribution over approximately 130,000 km^2 of the LMB. This gives significant temporal and spatial resolution and uses a variety of high technology equipment not found in the other Member States.

Viet Nam

In Viet Nam a draft MOU is being processed by the Ministry of Natural Resources and Environment and is expected to be finalised and signed soon. Based on discussions with the Viet Nam National Hydro-Meteorological Forecasting Centre (NHMFC), the MRC-RFMMC has jointly worked on the draft Contract for real time and near real time rainfall and water level data transfer from Viet Nam to the MRC-RFMMC. The objective of this contract is to improve the network coverage of the NHMFC rainfall stations and secure proper delivery to the MRC-RFMMC of timely, accurate and reliable real-time and near real-time water level and rainfall data. This will be used for a *joint undertaking* of operational flood forecasting and river monitoring.

The deliverables to be provided under this contract are: the improved network coverage of NHMFC rainfall stations as agreed in the work plan; quick and efficient transmission of water level and rainfall data from presently available near real time stations as well as the jointly established stations with the MRC-RFMMC, for operational purposes; and sending of discharge data when it becomes available. Data will be delivered by electronic transfer using HYDMET software, as described in MRC Operational Data Delivery Procedures.

CONCLUSION

The MRC-RFMMC will improve flood forecasting services at the mainstream and main tributaries of the LMB by development of improved hydrological models as recommended by the Roadmap of May 2006. Collaboration with national agencies in each member country on data acquisition and collection is crucial to reaching the aim of development of the new tools for

medium-term flood forecasting.

The input for the new hydrological models now being developed is primarily (observed and forecast) rainfall data. For best spatial distribution, and because the station network in the Mekong Region is very sparse, grid-based (satellite) rainfall products will initially be used as input. These products need to be adjusted using ground-based observations. A minimum set of rainfall data for the region is available through the WMO Global Transmission System. However, to realise the objective of reliable short- and medium-term forecasts, improved daily delivery of rainfall data transmitted directly from the MRC Member States to the MRC-RFMMC is essential.

As one of the main objectives of the MRC is to facilitate data exchange, several projects have been carried out to improve the hydro-meteorological network in the MRC Member States. The latest are AHNIP and M-HYCOS. Analysis of the raingauge network carried out under these projects and earlier projects (Mekong River Commission Secretariat (MRCS), March 2001), consistently shows that for Thailand and Viet Nam the average coverage is sufficient but the spatial distribution needs improvement. Most of Cambodia and the Lao PDR suffer from inadequate network coverage. It is also mentioned that 'the network operation and maintenance problems are serious in Cambodia and the Lao PDR' while Thailand and Viet Nam need only limited support for operation and maintenance (O&M) (Mekong River Commission Secretariat (MRCS), 2001).

The new forecasting system for the Mekong clearly includes significant updating of the previous observation network and data collection system in data sparse areas of the basin. A number of means (MOUs and contracts) have been in place in order to facilitate upgrade of the existing (rainfall) stations by providing a simple but effective means of communication at short notice, and by setting up simple new manual rainfall stations. This work has been an ongoing and significant effort undertaken by the MRC-RFMMC in close cooperation with national agencies in the four Member States. The implementation of the first phase of this undertaking has been successfully conducted in Cambodia; further work is planned in the Lao PDR.

REFERENCES

Begkhuntod, P., 2008. Satellite-Based Rainfall Estimation and Hydro-meteorological Networks for Flood Forecasting in the Mekong River Basin, *Proceeding, the 1st International Workshops on Prevention and Mitigation of Meteorological Disasters in Southeast Asia, Kyoto, Japan, March 2008.*

Carroll, D.G., 2002. URBS A Catchment Management and Flood Forecasting Rainfall Runoff Routing Model, Version 3.94, July 2002.

Carroll, D.G., 2004. URBS A Rainfall Runoff Routing Model for Flood Forecasting and Design, Version 4.00, April 2004.

Laurenson, E.M. and Mein, R.G., 1990. RORB – Version 4 Runoff Routing Program User Manual, Monash University, Dept. of Civil Engineering, Australia.

Malone, T. and Martin, W., 2006. Roadmap Mission for the Development of a Flood Forecasting System for the Lower Mekong River Basin, *Technical Report, Mekong River Commission, September 2006.*

Mekong River Commission (MRC), 2001. 'Procedures for Data and Information Exchange and Sharing'.

Mekong River Commission Secretariat (MRCS), 2001. Improvement of the Hydrometeorological Network (basin wide), Component 2 - Final Report Volume 1 - Main Report.

IDENTIFICATION AND MEASUREMENT OF FACTORS AFFECTING FLOOD VULNERABILITY IN THE LOWER MEKONG RIVER BASIN

NGUYEN HUY DZUNG[1] AND CHRIS JOY[2]

[1]*MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC), Phnom Penh, Cambodia*
[2]*Consultant to MRC Flood Management and Mitigation Programme (FMMP), Phnom Penh, Cambodia*

ABSTRACT

Flood prone communities are vulnerable to a variety of adverse flood impacts, such as food security impacts, health impacts, educational outcome impacts, livelihood impacts, household income impacts, poverty impacts, etc. What are the factors that allow some families, villages and communes to better cope with floods than others? To answer this question it is necessary to quantitatively determine the socio-economic impacts of floods on these communities. Surprisingly, flood impacts have not been rigorously measured in the Lower Mekong River Basin (LMB) in a manner that allows (i) identification and quantification of the underlying factors affecting vulnerability, and (ii) definition and quantification of Flood Vulnerability Indices (FVI).

FVIs are of fundamental importance to the better management of flood risk at the community level (family, village and commune). Once FVIs have been defined mathematically, the relative significance of the underlying factors will be apparent. This will provide an indication of where and how resources should be allocated to reduce flood vulnerabilities most effectively. In passing it is noted that many Non Governmental Organisations (NGO), International Organisations (IO) and donors are delivering a variety of Community-Based Flood (or general disaster) Risk Management (CBFRM) programmes that differ in focus. There appears to have been few attempts to monitor and evaluate (M&E) the effectiveness of these interventions. Quantitatively defined FVIs will provide a basis for the M&E of these programmes and for sharpening their focus. In addition, while it may be possible to reduce the socio-economic costs of flooding in certain key areas of the LMB by structural works, in many areas flood risk can only be cost-effectively managed by reducing the socio-economic vulnerability of the flood prone population. Given the high rate of poverty in flood prone villages across the LMB, definition and quantification of FVIs will directly alleviate flood-induced poverty. In order to complete the quantification of FVIs, the proposed methodology comprises:

- identification of appropriate FVIs and underlying factors (through discussions with collaborators);
- community-based surveys at the family level to measure the socio-economic impacts of floods (and droughts) on individual families. (information on drought vulnerabilities will also be gathered during these surveys);
- statistical analysis of survey results to quantitatively relate FVIs to the underlying factors, including pilot testing (measurement) of the results in unsurveyed villages;
- formulation and pilot testing of an extrapolation methodology to map the FVIs;
- regional mapping.

In undertaking this project, the Mekong River Commission (MRC) does not want to duplicate efforts and results of others. Rather, the approach will be to build on and extend existing work and to ‘fill-in any gaps’. Thus, this project will be undertaken on a collaborative basis with significant technical and manpower inputs to be provided from key NGOs, IOs and

Line Agencies (LA) in the LMB.

Preliminary phases were undertaken across four MRC Member States in the period of June 2007 until February 2008 to assess the need for such a project, its relevance to agencies operating at the community level and the potential contributions of these agencies to the project. The mission succeeded in receiving positive feedback from agencies and in mapping out the NGOs and IOs who are working in flood and drought disaster risk reduction in all four MRC Member States. The available information on flood, drought and community-level socio-economic surveyed data, produced by those organisations that are favourable and probably suitable to be incorporated in the flood and drought vulnerability indices is also well confirmed.

However, the level of contribution from the stakeholder agencies still cannot be measured or affirmed at this stage. It is proposed that in future the MRC should spend more time introducing and discussing projects with relevant stakeholders in the four countries, to provide them with a better understanding of the nature of the actions and to increase their role as partners.

INTRODUCTION

The people of the Lower Mekong River Basin (LMB) are exposed to regular and on-going threats of floods and droughts. Whilst the impacts of flood and drought disasters are typically reported in the news media at an 'aggregated' *national level* - the flood of 2000 caused some US$ 450 million of damage in Viet Nam and Cambodia - these impacts are largely *inflicted and suffered locally at the community level*. Thus, any agency that purports to help the countries and peoples of the LMB better manage the impacts of floods and droughts must be able to make effective improvements at the community level, i.e. to reduce flood and drought vulnerabilities[1] at the family, village and commune level. Improvements in flood forecasting and warning systems at the national and provincial levels will be ineffective if there is no consequent reduction in flood vulnerability at the village level.

The Mekong River Commission (MRC) has recently embarked on a US$ 25 million Flood Management and Mitigation Programme (FMMP). To ensure that the various projects under this programme will produce effective outcomes that target local communities, the MRC - along with all other stakeholders in the field of disaster preparation, response and recovery planning and capacity building - need to understand the various factors that affect flood and drought vulnerability. The MRC has no mandate to undertake work at the community level. However, it does have a mandate to provide technical assistance and technical 'tools' to assist the four Member States in better managing their water resources, including flood risk management. Hence, the genesis of this project, which will - if it proceeds - constitute the provision of technical assistance and 'tools' (flood and drought vulnerability indices and maps) to Cambodia, the Lao PDR, Thailand and Viet Nam.

VULNERABILITY DEFINITION

Vulnerability and resilience

The Department for International Development (DFID) of the UK has recently defined vulnerability as follows[2]:

[1] The converse of reducing flood and drought vulnerability is to increase flood and drought resilience

[2] As quoted in 'Community Based Disaster Risk Reduction Strategy (2007-2012) for Flood and Drought of the Kingdom of Cambodia', Draft report, April 2007 (ADB Technical Assistance Grant TA-4574 CAM)

'The characteristics of a person or group and their situation that influence their capacity to cope with, resist and recover from the impact of a natural hazard'

Thus, in *flood vulnerable communities*, floods cause pronounced and persisting adverse economic impacts on the well being of the community.

Resilience is the reverse side of vulnerability and refers to the ability of a community and its infrastructure to recover from the adverse impacts of natural disasters; it is a measure of both the time and extent of the recovery.

In contrast to a flood vulnerable community, the adverse impacts of flooding on a *flood resilient community* are reduced and of shorter duration. A community with high flood resilience returns to 'business as usual' more quickly than a community with low resilience.

Flood vulnerability

What specifically do we mean by 'flood vulnerability'?

Floods inflict a variety of adverse socio-economic impacts on flood prone communities, which include a threat to life and limb, increased levels of illness, economic loss (to both assets and livelihoods), disruption to education, increased or sustained levels of poverty, etc.

Flood vulnerability can be considered to be the susceptibility of a person or group to the adverse impacts of flooding

Thus, there are a number of different 'vulnerabilities' that reflect the various adverse impacts of flooding, such as health, livelihood, food security, economic, educational and poverty vulnerabilities.

MANAGEMENT OF FLOOD IMPACTS

There are two principal elements that determine the adverse impacts of flooding on a community: exposure and susceptibility.

- *exposure* reflects the characteristics of the flood (likelihood of occurrence, magnitude, nature) and the characteristics of the location of interest (village);
- *susceptibility* (or vulnerability) reflects the inherent ability of villagers to weather the adverse effects of flooding, and is dependent on underlying socio-economic factors, general health, coping strategies, etc.

The most effective way of reducing adverse flood impacts is by formulating an integrated and appropriate mix of management measures for the particular flooding situation, i.e. a flood risk management plan (FRMP). Thus, the principal way of reducing flood risk will be through *reducing the vulnerability of the flood prone communities*. The principal way of reducing the susceptibility of communities to the adverse effects of flooding is by developing and implementing a *community-based flood risk management plan* (CBFRM). Key components of such a plan are early warning arrangements, together with preparedness, response and recovery plans. A CBFRM plan may also include financial measures and 'flood education'.

Long-term flood prone populations develop a natural resilience (or acceptable base level of vulnerability) to floods; it is commonly referred to as '*living with floods'*. These people have lived with floods for many generations and have developed traditional coping mechanisms that mitigate the negative impacts of flooding. In fact, according to such peoples, the positive impacts of floods generally outweigh the negative impacts - at least for 'normal' floods. It is only when a flood is 'abnormal' – e.g. its onset is early, its duration is longer than expected, its recession is delayed - that underlying 'abnormal' flooding vulnerabilities emerge.

PROJECT METHODOLOGY

Objectives

Some communities are more susceptible than others to the negative impacts of flooding. Why is this so? What underlying factors determine 'flood vulnerability'? If we are to better manage flood vulnerability, we need to answer these questions.

The specific objectives of this project are: i) to quantitatively determine the socio-economic impacts of flooding on flood prone communities and to identify underlying factors contributing to these impacts; ii) to define FVIs that are appropriate to the better management of community flood risk; iii) to develop statistically valid mathematical relationships that quantitatively relate FVIs to underlying factors; and iv) to devise a method for mapping the FVIs on a Geographic Information System (GIS) basis across the LMB.

Beneficiaries

Again, FVIs are of fundamental importance to the better management of flood risk at the community level (family, village and commune). Once FVIs have been defined mathematically, the relative significance of the underlying factors will be apparent. This will provide an indication of where and how resources should be allocated to reduce flood vulnerabilities most effectively. In passing it is noted that many non government organisations (NGO), international orgnisations (IO) and donors are delivering a variety of CBFRM (or general disaster) programmes that differ in focus. There appears to have been few attempts to monitor and evaluate (M&E) the effectiveness of these interventions. Quantitatively defined FVIs will provide a basis for the M&E of these programmes and for sharpening their focus. In addition, while it may be possible to reduce the socio-economic costs of flooding in certain key areas of the LMB by structural works, in many areas flood risk can only be cost-effectively managed by reducing the socio-economic vulnerability of the flood prone population. Given the high rate of poverty in flood prone villages across the LMB, definition and quantification of FVIs will directly alleviate flood-induced poverty.

Approaches and timeframe

The nub of this project is to identify and develop (in partnership with appropriate agencies) suitable *quantitative* flood and drought vulnerability indices and to statistically relate them to key underlying physical, infrastructure, socio-economic, personal, etc., factors, as determined by community-based surveys. The intention is then to map these indices across the flood prone areas of the LMB to the extent that the underlying national data permit.

The proposed methodology for this project consists of five phases:

- *Phase I – Fact Findings and Concept Development (June – July 2007),* is to assess the need for such a project, its relevance to agencies operating at the community level and the potential contributions of these agencies to the project. It's now complete;
- *Phase II - Pre-Consolidation (December 2007 - February 2008)*, aims at remedying the shortcomings of Phase I - Fact Finding and Concept Development, collect outstanding examples of community-based survey data and national statistics, and prepare a catalogue of collected data and information;
- *Phase III – Consolidation (April - July 2008)*, aims to review the available data and information and finalise the proposed methodology to measure and map the FVIs. This Phase encompasses the formation of a Scientific Partnership Working Group (SPWG) of interested Line Agencies (LA), NGOs and IOs to provide overall guidance to the Study, along with an additional round of national visits, culminating in national workshops in

each member country;

- *Phase IV - Survey Design and Execution, Analysis and Verification of FVIs (August - December 2008)*, aims to measure flood and drought impacts and associated factors, the analysis of results to relate FVIs to underlying key factors, and the verification (or otherwise) of the FVI relationships by comparing FVIs estimated from the mathematical relationships to measured (surveyed) FVIs in a vulnerable village not included in the original survey;
- *Phase V - Extrapolation, Verification and Mapping of FVIs (January - June 2009)*, involves the verification of the proposed extrapolation procedure to 'map' the FVIs, including application of the procedure to a limited geographical area of MRC member states, followed by the 'test' mapping of FVIs across one province in each MRC member state. Phase V will culminate with the development of a plan to map FVIs across all the areas of the Lower Mekong River Basin subject to mainstream Mekong flooding.

In undertaking this project, the MRC does not want to duplicate efforts and results of others. Rather, the approach will be to build on and extend existing work and to 'fill-in any gaps'. Thus, this project will be designed and undertaken as a 'joint project' between key stakeholders, as represented on the SPWG, and the FMMP. Or on the other hand, this project will be undertaken on a collaborative basis with significant technical and manpower inputs to be provided from key NGOs, IOs and LAs in the LMB. During the project, research results will be progressively communicated to the wider community of stakeholders through a series of peer review regional workshops held at a critical milestone (these workshops will review and modify the methodology as necessary). After the project is complete, results will be disseminated via technical conferences, workshops and via the usual channels of stakeholder agencies (e.g. NGOs could disseminate results to communities).

STATUS OF PROJECT ACHIEVEMENT

Preliminary phases (Phase I and II) have been undertaken across four MRC Member States since June 2007 to assess the need for such a project, its relevance to agencies operating at the community level and the potential contributions of these agencies to the project. The mission succeeded in receiving positive feedback from stakeholders and in mapping out the LAs, NGOs and IOs who are working in flood and drought disaster risk reduction in all four MRC Member States. The data consist of information from national to commune level that are favourable and suitable for the flood and drought vulnerability analysis and mapping is available at concerned government agencies and NGOs, IOs. However, the data available at NGOs and IOs are scatter and limited in geographic area coverage (only in project target areas). Furthermore, no standard format has been used to record data since each organization has its own format to follow.

Most assessments of flooding impacts only focus on quantifying immediate direct damages and only in financial terms in order to provide governments and aid donors with estimates of the amount of funds required to address emergency and reconstruction needs; they may also be relevant for insurance companies. Long-term indirect costs in the flows of goods and services, reduced levels of production and non-market impacts such as environmental damage and psychosocial effects are frequently omitted from such assessments (United Nations Development Programme (UNDP), 2004). This focus on direct damages and loss of life is largely due to the fact that there are difficulties in accounting for indirect and non-monetary damages and because economic studies of this nature are, not surprisingly, a low priority in the post-disaster recovery effort.

CHALLENGES FOR MOVING FORWARD

To some extent, the data are available both qualitative and quantitative. Data from the IOs/NGOs are rather scattered, but they can be collated. The pure data that are favourable to and can be used as basis for the Flood and Drought Vulnerability Indices is available and can be accessed. However, questions will be how the MRC will get access to those data, and how it will make best use of those data for its Flood and Drought Vulnerability Indices. Furthermore, since yet there is no consistent indirect damages data on food and drought in place.

At this stage the level of contribution from the stakeholder agencies can still not be measured or affirmed. Therefore, engaging partners for the project is a challenge that requires MRC to do more, not only to convince stakeholders of the project, but also to partner them into the project implementation.

RECOMMENDATIONS

It is proposed that in future the MRC should spend more time introducing and discussing projects with relevant stakeholders in the four countries, to provide them with a better understanding of the nature of the project. The relevant stakeholders (LAs, NGOs, IOs) working in disaster risk management should be involved in project implementation from the start. More in-depth orientation and education workshops on the vulnerability definition, and on the nature of project implementation, are recommended for government agencies in order to raise awareness and understanding of project benefits and promote support, participation and contribution.

THE MEKONG REGIONAL FLASH-FLOOD GUIDANCE AND EARLY WARNING SYSTEM - A TECHNICAL OVERVIEW

ROBERT W. JUBACH, EYLON SHAMIR, CHRISTOPHER SPENCER AND JASON SPERFSLAGE

Hydrologic Research Center (HRC), San Diego, California USA

ABSTRACT

Global, high-resolution, spatially-distributed databases for land-surface features, the advent of real-time remotely-sensed rainfall data and the availability of increased computational power have led to distributed hydrologic simulation systems that are being implemented in data sparse areas of the world. The regional MRC Flash Flood Guidance (FFG) System presented herein will benefit from these developments and will calculate diagnostic flash flood indices as quantitative measures of flash-flood potential. For more than ten years the technical method to be used to produce these indices has been proven via operational application by the US National Weather Service and more than three years by the Central America Flash Flood Guidance System.

Using continuously operating servers as regional platforms for analysis and communication, evaluations of flash flood threats will be done automatically for hourly to six-hourly time scales for about 8,350 small stream basins in the MRC member countries. Satellite precipitation estimates will be used together with available regional in-situ precipitation gauge data to obtain bias-corrected estimates of the current rainfall distribution and intensity over the region. These precipitation data are also used to update soil moisture estimates. Recognizing the significant uncertainty associated with the estimation of precipitation from remotely sensed data and the often-limited data for hydrologic model calibration, the system includes sub systems for uncertainty estimation. This allows for consistent characterization of the risk of flash flooding for each small basin and each time interval of interest.

In collaboration with National Mekong Committees and Line Agencies, the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) will serve as an institutional and technical base for a continuously operating server that will be the focal point for analyzing data sets from the partners, to include dynamic real-time and historical time series of rainfall from in situ sensors, and static spatial data sets of topography, land use, soils, population, and other basin characteristics. The server will continuously model the hydrologic regime in each of the small basins and estimate basin-specific flash-flood indices. A second server will provide national products to partners, and transfer regional flash-flood threat products to the MRC website or other out-reach media. From the riparian partner's perspective, each will need only a PC and Internet access to retrieve their national flash flood warning products, on demand and at the times of their choosing. These products, in conjunction with national insight into flash-flood prone areas of their countries, will better prepare the countries to develop and issue warnings to specific communities most at risk.

INTRODUCTION

As in many parts of the world, flash floods are destructive in the countries of the Lower Mekong River Basin (LMB). For example, in Vietnam, Thailand, and Laos during 2006 most

human casualties and damage from floods were attributed flash floods in small basins (Annual Mekong Flood Report 2006, Mekong River Commission). Because of concerns over flash floods in the region, the Hydrologic Research Center through a program with the U.S. National Weather Service (U.S. NWS) with funding from the U.S. Agency for International Development/Office of Foreign Disaster Assistance (USAID/OFDA) has been engaged to develop and implement a regional flash flood early warning system for the countries of Cambodia, Laos, Thailand and Vietnam. Based on Hydrologic Research Centers' (HRC) experience, the USAID/OFDA funded program would implement a system that is based on high-resolution precipitation estimate from satellite, real time gauge networks for critical meteorological variables and spatial GIS datasets.

The system is designed as a diagnostic tool for meteorological and hydrologic services to analyze weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then importantly to make a *rapid* evaluation on the potential threat or imminence occurrence of a flash flood for a location. The system provides values of flash flood guidance and flash flood threat for the outlet of small basins – the basins most prone to flash flooding. Flash flood guidance (FFG) is defined as the amount of rainfall for a given duration over a small basin needed to create minor flooding (bankfull) conditions at the outlet of the basin. Flash flood threat (FFT) is defined as the rainfall of a given duration in excess of the corresponding flash flood guidance value. The FFT then becomes an indication of areas where flooding is imminent or occurring and where immediate action is or will be shortly needed.

The technical method that would be used to produce this guidance is the same that has been proven over the last 30 years via operational application by the U.S. National Weather Service. This method is based on physically based hydrologic modeling involving soil water accounting and capacity of the draining channel at a level of minor flooding (bankfull) conditions. Evaluations of the threat of flash flooding may be done over hourly to six-hourly time scales (depending on availability and latency of real-near real time hydrometeorological data). Satellite rainfall estimates would be used together with available in-situ rainfall gauge data to obtain bias-corrected estimates of current rainfall volume over the region. The bias-corrected satellite rainfall estimate will update the soil moisture estimates to evaluate flash flood threat.

A similar regional system has been successfully implemented for the seven countries in Central America and has been operational since the summer of 2004. The South East Asia system would be modeled after the Central America system, which has the base node in Costa Rica with system products and data made available to the other six countries from the computational server via the Internet. The other six countries need only a PC and Internet connectivity at a minimum to obtain real time system products and data.

PROGRAM GOALS

USAID/OFDA's specific goal and vision for the proposed flash flood early warning system for four countries of the LMB under its Asia Flood Network Program (a program to transfer U.S. flood-related technology and assistance to Asia) is to implement a complete early warning system comprised of three primary elements as noted below:

- implement a computational system for flash flood guidance;
- develop protocols for guidance dissemination;
- provide training.

The Regional Flash Flood Guidance and Early Warning System (FFG) will be implemented for the countries of the Lower Mekong River Basin (Cambodia, Lao PDR, Thailand and Vietnam). The implementation of the system will require a complete coordination with regional partners for integration into the existing infrastructure. Details of the primary

elements are discussed below. The final design specifics will be determined in collaboration with the U.S. NWS, USAID/OFDA, MRC, and the LMB countries.

TECHNICAL APPROACH

Element 1 – Implement a computational system for flash flood guidance

A computational system would be installed that ingests real time rainfall and other data, operates a hydrologic model for estimating flash flood thresholds, tracks soil moisture, displays data and information, supports a database containing historical and static data, and communicates guidance information to the appropriate users in each of the LMB countries. The computational system would be installed in the Regional Flood Management and Mitigation Centre (MRC-RFMMC) with outputs transmitted to each country where warnings would be developed and disseminated per appropriate protocols. The MRC-RFMMC would act only as the computational and dissemination system centre and would not issue alerts or warnings.

Background

The basis of the threshold runoff and flash flood guidance computations used in the proposed system were developed for the U.S. NWS for operational implementation over the continental U.S. (period of development and validation: 1989 - 2000). The proposed areal flash flood guidance method is based on hydrologic/hydraulic principles including soil moisture accounting on large scales, and the determination of the condition of extreme surface flow transport on fine scales. The capability to do this is afforded by present day digital spatial data and operational satellite data. In addition, the Central America Flash Flood Guidance (CAFFG) system was implemented and is currently operational in Central America providing guidance information available to the seven countries. Experience and validation statistics are available from application over more than 280,000 km^2 in U.S. and over the first wet season in Central America (approximately 500,000 km^2).

HRC will implement the flash flood guidance system at the MRC-RFMMC from existing software components as implemented for the CAFFG system for application to the region. In addition to data provided by MRC and the countries, HRC would use available global digital databases and hydrologic/hydraulic principles to develop a software system for producing estimates of flood-causing rainfall volume of a given duration (3 - 6 hours) over the region for small basins approximately 100 – 300 km^2 in area. The flash-flood guidance estimates would be used with available estimates of 3- to 6-hourly rainfall accumulations produced by merging satellite and rain gauge data to determine the likelihood of flash flood occurrence in near real time. Note that the durations ultimately will be dependent on the time scales for available real-time precipitation estimates.

For the satellite precipitation estimate the HydroEstimator (HE) from the U.S. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service (NOAA/NESDIS) will be used. The HE is a real time operational product that has been produced globally (60N-60S) since August 2002. The HE precipitation estimate is aggregated to hourly values for about 16 km^2. A detailed description of the HE algorithm is in Vicente et al. (1998, 2002). Briefly, the HE precipitation estimate is based on the assumption that cloud-top brightness temperature and cloud height are correlated with strength of convective updraft and rainfall rate. That is, colder, higher clouds are associated with stronger updrafts and heavier rain and warmer, lower clouds are associated with weak updrafts and light or no rain. The brightness temperature is measured by the IR band (10.7 micron). To account for processes that are not captured by the top of the cloud brightness temperature (e.g., precipitable water, relative humidity, temperature, winds, topography) the HE precipitation algorithm incorporates variable fields from an operational Numerical Weather Prediction model.

Figures 1and 2 are excerpts of hourly precipitation estimates for the LMB region. These figures are from the first week of August 2006. During this week persistent heavy rain and flash floods events were reported in Northern Thailand, Laos and Vietnam (Annual Mekong Flood Report 2006). It is apparent from the figures that the severity of the storm is captured and the H-E precipitation estimate provides essential spatial and temporal information. In order to increase the effectiveness and reliability of the precipitation estimate the FFG system will merge the HE product will merge available near real time gauge data for removal of magnitude biases.

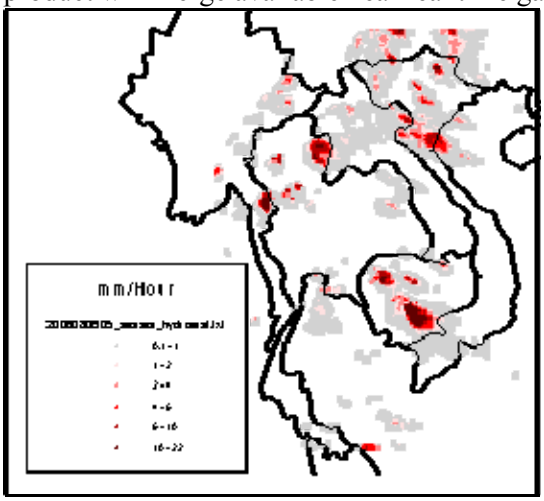


Figure 1. HydroEstimator hourly precipitation for 6 Aug 2006 0500 GMT

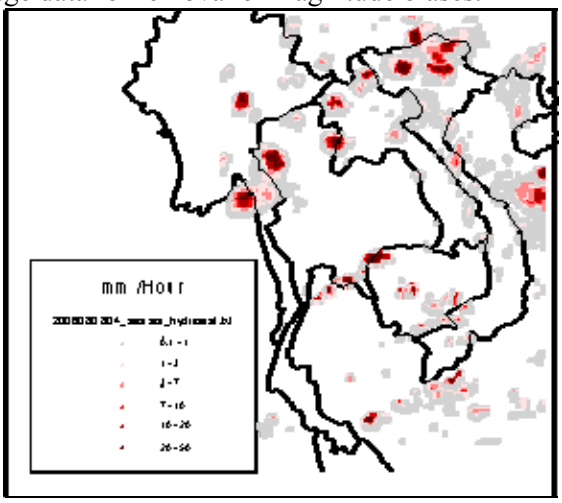


Figure 2. HydroEstimator hourly precipitation 8 Aug 2006 0400 GMT

Products

The flash flood guidance products developed will be of immediate utility for the production of guidance and warnings. Figure 3 shows examples of the main products of the system using the CAFFG system output for the country of Nicaragua. The main products of the flash flood guidance system will be:

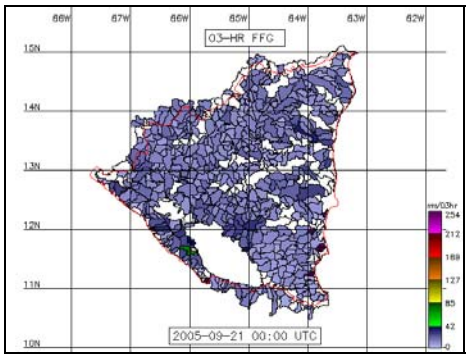
- small basin flash flood guidance;
- flash flood threat;
- bias adjusted mean areal precipitation;
- soil moisture for small basins throughout the area.

Data requirements for computational system implementation and operations

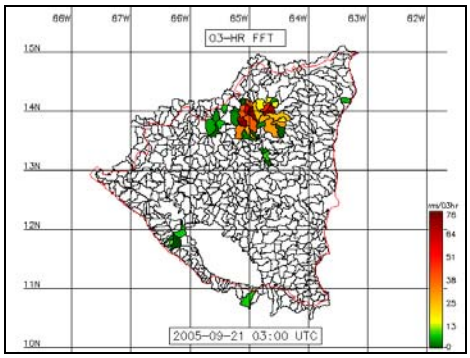
HRC has been working with the MRC and the countries to obtain all required historical and real-time hydrometeorological data for the project. Much of the global data are already readily available and the MRC has provided pertinent data that is available for the LMB. HRC in collaboration with the MRC is assembling a database for the FFG development. The current database includes:

- *Hydrometeorological database.* This data set is required for the development and parameter estimation of various components of the FFG models. We received two datasets from MRC that includes historical data for the LMB basin.
    - *HYMOS Dataset.* The HYMOS database is an archiving system of the real/near real time gauge data. The HYMOS archive has minimal quality control procedures. The database includes daily precipitation, streamflow discharge and stream level. The streamflow data is mainly for the main stem of the Mekong River and large tributaries. Data from the HYMOS are available up to 2004;
    - *Decision Support Framework (DSF).* The DSF department at MRC is part of the Water Utilization Program. The DSF resources include a set of models and a

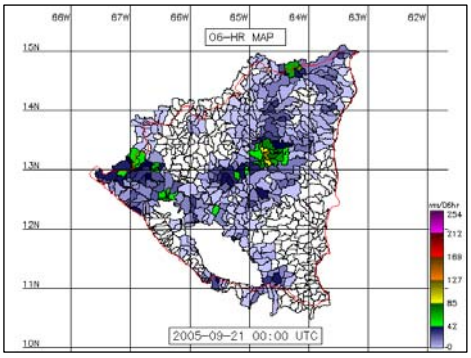
database that is created manually applying various quality control procedures. This dataset includes surface meteorological variables such as minimum and maximum daily surface temperature, wind speed, relative humidity, radiation, pan evaporation, and precipitation. The dataset has built-in automatic procedures for quality control and spatial and temporal interpolation of missing data. Data from the DSF dataset are available up to 2003.



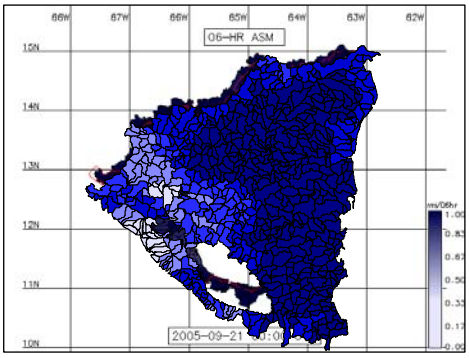
Example 3-hour flash flood guidance product



Example 3-hour flash flood threat product



Example 3-hour mean areal precipitation



Example 3-hour soil moisture product

Figure 3. Example 3-Hour CAFFG products shown for Nicaragua

- *Spatial GIS Data.* The GIS layers are a necessary component for the system development. All the pertinent GIS layers were made available by the MRC. These include: digital elevation model, administration boundaries, land cover land use, hydrographic network and soil properties. These layers in combination with available global data sets provide a fairly complete dataset for system development. Optimally, the addition of a GIS layer that describes the soil properties outside the LMB - more specifically for the coastal basins in Vietnam and for Thailand would be needed to complete the spatial dataset;
- *Cross Section Data.* The FFG system development requires an estimate of a threshold in which exceeded streamflow is considered to generate a minor flooding. Various methods to derive these thresholds exist. The preferred method is to define a geo-morphological index that characterizes the geometry of the basins' outlet cross sections. For a regional estimate of the bankfull index it is possible to develop empirical equations that relate various spatial basin characteristics derived from GIS analysis (e.g., area, slope, channel length and land cover) to the cross section characteristics at the basin outlet. The development of such regional equations requires a database of cross sections in streams that drain small areas (< 2000 km^2). The availability of the data needed for the region appear minimal;

- Real and near real time surface meteorological data. Near real time precipitation data are needed for system operation. The data are mainly needed for the bias correction of the HE, or in case of missing data from the HE the gauged precipitation will be used to generate a regional precipitation product. In addition, surface meteorological data will be used to drive the model land surface interaction routines. At this time, available near real time data are available from 40 gauges along the main stem of the Mekong River. These data available from the gauges are daily manual downloads of 24-hour precipitation accumulation, occurring between 7.00 hr (observation time) and 10.00 hr (anticipated max latency for download completion). These data products are received by the MRC-RFMMC via a File Transfer Protocol (FTP) through the HYDMET network. At present, no direct access is available to telemetry data collected directly by the four MRC Member State's national agencies. Efforts are presently underway by MRC to obtain such real-time data but the time frame for such a possibility is yet unknown.

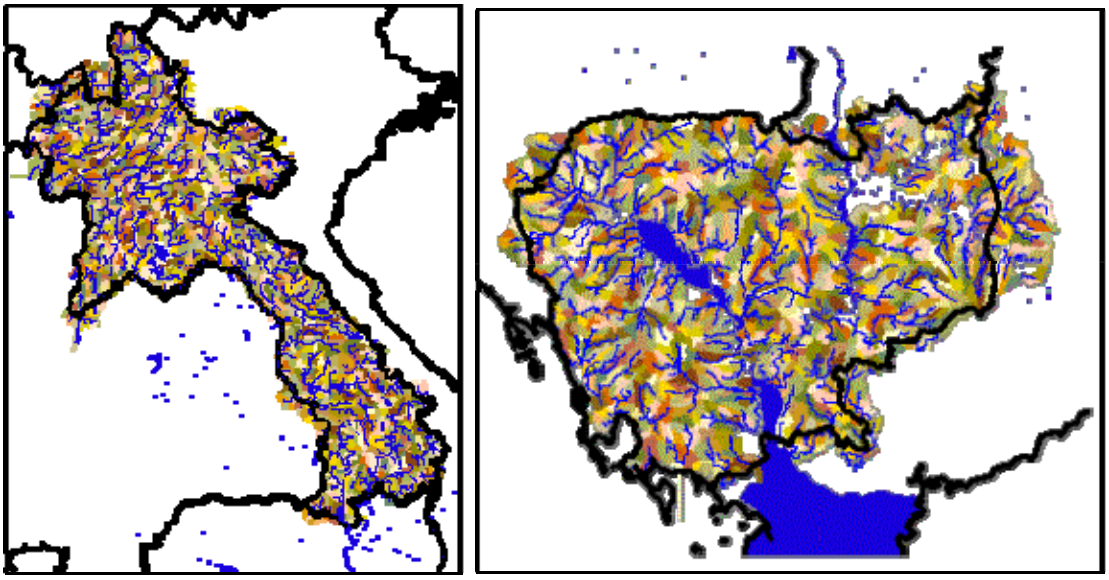
HRC will plan to localize and tailor the FFG system for optimized hosting and operation within the existing MRC-RFMMC infrastructure. In addition to its primary data sources of HE output (via FTP from NOAA/NESDIS) Global HydroEstimator) and surface meteorological data (via FTP from NOAA, excepting precipitation measurements), the Flash Flood Guidance System (FFGS) will use the existing 40 real-time daily precipitation gauges presently available to MRC-RFMMC while anticipating additional data availability, perhaps hourly, in the future. It is the hope of both HRC and MRC-RFMMC that the coming FFGS system will provide sufficient emphasis toward the urgent need for hourly, real-time surface meteorological data to allow MRC-RFMMC to gain real-time access to all available station data reported throughout the four member states.

Initial delineation of LMB flash flood basins for computational system

The delineation of small flash-flood basins consistent with the objectives of the FFG was undertaken for several countries including the four countries of Cambodia, Laos, Thailand, and Vietnam. The initial delineation was submitted to MRC for quality control and the finalized delineation, which incorporates MRCs input was produced. The delineation yields about 8,350 basins with area of 100 - 300 km^2. The delineation of the stream network and associated drainage basins utilized the Shuttle Radar Topography Mission digital elevation model data. The raw data has 90-m resolution, but was processed to a coarser resolution (360-m) for this effort to reduce the required processing time while maintaining accurate delineation results. A stream hydrography from the MRC and the Digital Chart of the World database was used for quality control of the delineation results. Figure 4 presents the results of this delineation effort for the countries of Cambodia and, Laos. These basins and associated geometric properties will serve as the basis for the flash flood guidance computations in the proposed system.

Element 2 – Develop protocols for guidance dissemination

Protocols for flash flood warning dissemination would be developed that are consistent with the 1995 Agreement concerning main stem Mekong River forecasting responsibilities, the overall Flood Management Plan, riparian capacities, existing agreed-to procedures for data and information exchange, and the extant relationships between the MRC and the riparian countries. Moreover, lessons learned from guidance-information dissemination implemented by the USAID/OFDA-MRC flood-referencing project would be considered, as well.



Laos PDR Cambodia

Figure 4. Delineation of small watershed (100 - 300 km^2) throughout LMB and riparian countries

Dissemination system component implementation

The implementation of the dissemination system involves close liaison with implementation of FMMP Component 4. The eventual protocols will be consistent with the 1995 Agreement concerning main stem Mekong River forecasting responsibilities, the overall Flood Management Plan, riparian capacities, existing agreed-to procedures for data and information exchange, and the extant relationships between the MRC and the riparian countries. This element will include the following steps:

a. Identification and implementation of the communication protocols for transmitting the forecast information (maps, tables, text) from the MRC-RFMMC to the relevant agencies;
b. Assist the responsible national agencies to establish criteria for issuing warnings based on FFG system products. This would be accomplished on a country by country basis using all available local information on the occurrence of past flash floods. The process would involve the adoption of objective criteria and methodology for developing these warning criteria and would take into consideration FFG system component uncertainty;
c. Assist the national dissemination agencies in developing informative and useful flash-flood warning messages for transmission to the public.

Element 3 – Training

The appropriate training of the MRC and riparian country staff would be a critical aspect of the system. Training and system documentation would be keys to sustaining the system.

Background

The system integrates information from a variety of real time and static sources, and uses a variety of modeling components to produce flash flood guidance. Reliability of system performance requires well-trained MRC-RFMMC staff, who will maintain the system, validate information integrity, initiate and ensure reliable archival function, perform necessary procedures in cases when the back-up system must be engaged, and monitor communications. The quality of the information received by the users on the other hand depends critically on

appropriate interpretation of the flash-flood guidance by the personnel of appropriate agencies. The latter requires training of such personnel on the physical basis, functions, applicability and expected uncertainty of the guidance products. This will also allow these personnel to pass this knowledge on to the end users throughout their country.

Training is a key component in the overall project as it is the mechanism through which MRC and the agencies take ownership of the system and obtain the ability to independently perform all operations in the future.

Training program implementation

The implementation of the training program involves the following steps:

a. hands-on training of personnel at the MRC-RFMMC on system software/hardware design, functionality and maintenance requirements;
b. training workshops will address the issues pertaining to the development, requirements and use of the system products by the National Meteorological and Hydrologic Services (NMHS) and response-agency personnel (including the MRC-RFMMC personnel). These workshops will discuss the physical basis of the system, design, functions, applicability, and requirements (e.g., format) of the guidance products, communications, warning protocols, and the methodology for evaluating guidance performance;
c. perhaps the most significant training activity that will contribute to system sustainability will be systems operations training. This will include validating system components, evaluating system performance and developing protocols for its use in the LMB region. Operations training will include both lectures and hands-on experience and a simulation of situations that are likely to occur in real time. During the operations training, the agencies will be requested to evaluate the utility of the areal flash flood guidance on a regular basis. Evaluation would be based on measures such as people affected by a certain event, people warned who acted when warned; people warned who did not act when warned. Response agencies will be requested to acquire information as to the effectiveness of the areal flash flood guidance warnings by accounting for casualties among those that heed the warnings and those that received the warnings but did not respond. Reports of flash floods that occurred would be used to monitor the reliability of the areal flash flood guidance.

REFERENCES

Mekong River Commission (MRC), Annual Mekong Flood Report 2006, March 2007 ISSN: 1278-3248.

Vicente, G.A., R.A. Scofield, and W.P. Menzel, 1998. The operational GOES infrared rainfall estimation technique. *Bull. Amer. Meteor. Soc.*, 79, 1883-1898.

Vicente, G.A., J.C. Davenport and R.A. Scofield, 2002: The role of orographic and parallax corrections on real time high resolution satellite rainfall rate distribution. *Int. J. Remote sens.*, 23, 221-230.

ACHIEVEMENTS AND LESSONS LEARNT FLOOD EMERGENCY MANAGEMENT STRENGTHENING (FEMS) COMPONENT 4 OF THE MRC FLOOD MANAGEMENT AND MITIGATION PROGRAM (FMMP)

LOY REGO

Asian Disaster Preparedness Center (ADPC), Pathumthani, Thailand

ABSTRACT

The Mekong River Commission Secretariat (MRCS) through its National Mekong Committees (NMC) and with support from the Asian Disaster Preparedness Center (ADPC) has implemented the projects on Flood Emergency Management Strengthening (FEMS), Component 4 of the Flood Management and Mitigation Programme (FMMP) of the Mekong River Commission (MRC). The objective of FEMS is to 'ensure emergency management systems in the riparian countries are dealing more effectively with Mekong floods'. FMMPs Component 4 has four projects (two completed and two ongoing) implemented by the ADPC with financial support from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH' and the European Commission Humanitarian Aid Department (ECHO).

The target areas under the GTZ-funded project are located in four provinces, two each in Cambodia (Kandal and Prey Veng provinces) and Vietnam (An Giang and Dong Thap provinces). In each province there are two target districts which make up a total of 8 eight target districts in the two countries (Cambodia: Leuk Dek and Lovea Em districts of Kandal, Peam Chor and Sithor Kandal districts of Prey Veng and Vietnam: Chau Thanh and Tan Chau districts of An Giang and Thanh Binh and Tan Hong of Dong Thap). The project commenced in September 2004 and has been completed in December 2007.

Two completed ECHO funded projects were: 1) The Phase I project, *'Capacity Building for Preparedness Planning in the Lower Mekong Basin using Flood Information Products'*, was implemented during 2003-2004,under the 3rd DIPECHO Action Plan for South East Asia. This project resulted in capacity building for flood preparedness planning and response through the use of flood information products by MRC in Cambodia, Lao PDR, Thailand and Vietnam; 2) The Phase II project, *'Capacity Building for Planning and Implementation of Flood Preparedness Program at Provincial and District Levels in the Lower Mekong Basin'*, was implemented during 2005 - 2006 under the DIPECHO 4th Action Plan for South East Asia to enhance capacity of the provincial and district DM committees for undertaking planning and implementation of flood preparedness programs at their provincial and district levels in the pilot areas namely; Kratie and Kampong Cham in Cambodia, Can Tho and Tien Giang in Vietnam and Champasack, Khammouane, Saravanh and Savannakhet provinces in Lao PDR.

Based on the lessons learnt from the first two phases it was recommended by the national, provincial and district level authorities to continue the on-going, the Phase III project, *'Support to Implementation of Flood Preparedness Programs at Provincial, District and Commune Levels in the Lower Mekong Basin*', during 2007 - 2008 under the 5th DIPECHO Action Plan for South East Asia, with specific disaster preparedness activities in proposed districts in three provinces including Kratie in Cambodia, Tien Giang in Vietnam and Khammouane province in Lao PDR. The time frame of Phase III project is from January 2007 to May 2008.

The paper *describes significant achievements* from the implementation of both GTZ and ECHO-funded projects, i.e. the development and implementation of Flood Preparedness Program (FPP), strengthened capacities of national, provincial, district and commune disaster

management authorities, integration of FPP priority actions into local development planning, public awareness raising on flood risk reduction, promotion regional knowledge sharing and enhanced transboundary cooperation on emergency assistance between the border provinces between Cambodia-Vietnam and Lao PDR-Thailand.

The paper further *summarizes good practices and draws up lessons learnt* for continued strengthening of emergency management systems in the riparian countries in dealing with the Mekong floods more effectively.

INTRODUCTION

Background (Introduction to FMMP and to GTZ and ECHO projects)

Fully recognizing both the positive and negative impacts of the Mekong annual floods, the Mekong River Commission (MRC) has launched its Flood Management and Mitigation Program (FMMP), over the 6 year period from 2004 to 2010, with the following objective:

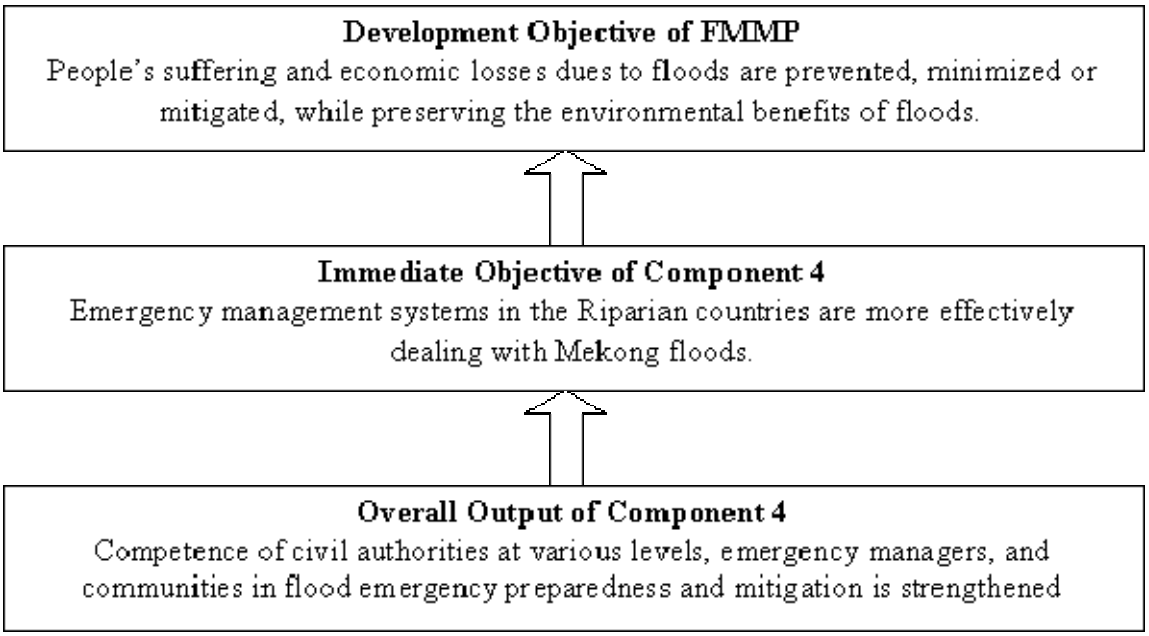
> '*People's suffering and economic losses due to floods are prevented, minimized, or mitigated, while preserving the environmental benefits of floods'.*

The FMMP is made up of five major components: 1) Establishment of a Regional Flood Management and Mitigation Centre; 2) Structural and Flood Proofing Measures, 3) Mediation of Transboundary Flood Issues; 3) Flood Emergency Management Strengthening; 4) Land Management[1)].

Knowing the causes and the impacts of the Mekong floods an important issue remains to be solved which is 'how to get people ready for floods before they come' and 'how to help people cope with floods'. The current perception of flood management is still 'to response to floods when they occur' rather than to prevent major damage or to be prepared in the forehand. To deal with the Mekong floods more effectively there is a need to strengthen the capacity of local disaster management authorities in flood preparedness and emergency response. The current limited capacities and resources at national and local level for effective emergency management is apparent in different ways:

- limited capacity at national level and in particular at provincial and district level to understand, interpret and effectively use advanced flood forecasting and hazard information;
- limited exposure to good practices in flood preparedness planning;
- limited capacities for undertaking preparedness and mitigation planning and concerted implementation among disaster management authorities and their line departments at all levels;
- weak public awareness activities to inform/educate people how to prepare before floods, how to cope with floods while they occur and how to recover from it afterwards.

Therefore the fourth component 'Flood Emergency Management Strengthening' focuses on enhancing the '*competence of civil authorities at various levels, emergency managers and communities in flood preparedness and mitigation'*, which will ultimately lead to the component objective of '*Emergency management systems in the Riparian countries more effectively dealing with Mekong floods.'*



FMMPs Component 4 has four projects (2 completed and two ongoing) implemented with technical support from the Asian Disaster Preparedness Center (ADPC) with financial support from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH' and the European Commission Humanitarian Aid Department (ECHO). The two on-going projects are financially supported by GTZ from September 2004 to December 2007 and by ECHO from January 2007 to May 2008.

Component 4 outputs

The following outputs were planned to be achieved under the component:

- *GTZ funded project:*
  1. flood preparedness programs developed and implemented in 2 provinces and 4 districts each in Cambodia and Vietnam;
  2. National capacity in Cambodia and Vietnam developed to support Provincial and District Flood Preparedness Programs;
  3. public awareness campaigns in selected districts of the pilot provinces conducted;
  4. regional knowledge sharing in flood emergency management facilitated;
  5. preparedness for Province to Province Transboundary Emergency assistance facilitated;[2)]
- *ECHO funded project (Phase III):*
  1. capacity of key officials of the Provincial and District Committee for Disaster Management (PCDM/DCDM) of Khammouane Province enhanced on developing Flood Preparedness Programs and implementation of priority action areas.
  2. District Flood Preparedness Program developed and priority action areas identified by the target districts implemented
  3. Capacity of the Commune Disaster Management Committees/Teams in four districts of Cambodia and Vietnam is enhanced in implementation of Flood Preparedness measures
  4. one Regional Experience Sharing Workshop and three National Seminars on 'Lesson Learnt in Flood Preparedness Planning at Province, District and Commune

levels' conducted in Cambodia, Vietnam and Lao PDR.

The target areas of the project were selected by the provincial authorities based on the following criteria: being the most flood vulnerable, border province, poverty rate, current capacity of PCDM and DCDM, willingness to work with external organizations.

The target areas under the GTZ-funded project are located in four provinces, two each in Cambodia (Kandal and Prey Veng provinces) and Vietnam (An Giang and Dong Thap provinces). In each province there are two target districts, which make up a total of 8 eight target districts in the two countries (Cambodia: Leuk Dek and Lovea Em districts of Kandal, Peam Chor and Sithor Kandal districts of Prey Veng and Vietnam: Chau Thanh and Tan Chau districts of An Giang and Thanh Binh and Tan Hong of Dong Thap).

The target areas under ECHO project (Phase III) are namely; Kratie in Cambodia, Can Tho, Tien Giang in Vietnam and Khammouane province in the Lao PDR. The above two projects under the Component 4 are complimentary to each other in different target areas.

MAIN ACHIEVEMENTS, LESSONS LEARNT AND CHALLENGES

Development and implementation of Provincial and District Flood Preparedness Programs (FPP)

In Cambodia, under the GTZ-funded project two provincial FPP (of Kandal and Prey Veng provinces) and four district FPP (of Leuk Dek and Lovea Em districts of Kandal Province, Peam Chor and Sithor Kandal districts of Prey Veng Province) were developed by the PCDM and DCDM of the target areas with technical assistance form the National Committee on Disaster Management (NCDM)-Cambodia and from the project.

Under the ECHOIII project the FPP of Kratie province and its four districts (Kratie, Sambour, Chulluong and Prek Prasab) in Cambodia as well as the FPP of Khammouane province and Nong Bok district in the Lao PDR were developed.

This was achieved through a series of consultative meetings and workshops at the provincial and district levels and one consultation with provincial and district offices. Focal points from each PCDM and DCDM of selected provinces and districts were identified and they acted as key facilitators in all consultative meetings and workshops.

The contents of the FPP include the background information on the province/district, the existing activities of each member departments before, during and after floods, the ToR for four operational teams namely Search and Rescue Team, Health, Hygiene and Sanitation Team, Information Management and Assessment Team and Emergency Relief Operation Team, and identification of priority actions to mitigate flood risks. The four operational teams are made up of clusters of relevant departments within PCDM and DCDM, based on their existing activities and capacities [4)].

All target districts in the selected provinces of Cambodia have implemented the priority sub-projects identified under the FPP. In Cambodia these include:

- building capacity of Commune DM Committee on Community based flood management;
- improving skills of District and Commune officials in Damage and Needs Assessment (DANA);
- district resource inventory development;
- development of program on meeting the needs of Women headed household (WHH);
- improved dissemination of flood early warning through installation of village and home flood marks;
- improvement of safe areas;
- orientation workshops for teachers and educators on flood risk reduction;
- training of trainers (TOT) for the Provincial and District Facilitations to link flood risk

reduction activities into commune development/investment plan.

In Vietnam the existing flood and storm control planning at provincial and district levels are already well in place. However there is a need to strengthen the capacity of district and commune levels in the implementation of the flood and storm control (FSC) plan. Therefore sub-priority projects were identified and carried out to strengthen the capacity and assist the implementation of the FSC plan. These projects included:

- search and rescue trainings for district Red Cross;
- emergency kindergarten management trainings;
- swimming lessons for children;
- community based flood management trainings;
- retrofitting of emergency kindergarten.

In Vietnam between 2000 and 2005, the number of child casualty reaches an alarming rate of 76% of total death toll in An Giang and Dong Thap provinces. Drowning is identified as one of the leading causes. In an effort to reduce the death toll, the PCFSCs of target provinces issued guidelines to its members to organize swimming lessons for children in flood affected areas, with provincial Committee for Sports and Physical Training (CSPT) as the lead agency. At the district level, the People's Committee assigns district CSPT in collaboration with Youth Union, Department of Education, CPFC, Department of Health, Finance and Planning to realize the guidelines.

The GTZ funded project, from its conceptualisation stage, realizes this life saving activity as crucial to contribute towards the 'Living with Floods' strategy of the Government in the Mekong Delta and was listed as one of the priority action areas to be undertaken. Hence, under the project, 2 swimming lessons in each target district for children 6-14 years old were provided, in collaboration with the district Committee on Sport and Physical Training (CSPT). While district CSPT provided skilled Trainers, the volunteers from Women Union, including the parents, provided the logistical support.

Assessment on the current status and needs in strengthening Search and Rescue capacities in An Giang and Dong Thap provinces was carried out with assistance from An Giang and Dong Thap authorities in December 2007 to identify the gaps and needs (material, financial, institutional, human resources, etc.) of search and rescue capacities in the target areas through systematic documentation of on-going initiatives in conjunction with the existing provincial and district Flood and Storm Control Plans

Another assessment on Emergency Kindergarten Facilities was conducted in the target areas of both projects to identify the gaps and needs in emergency kindergarten establishment, maintenance and upgrading with regards to the existing provincial and district Flood and Storm Control Plans. The outcomes of the assessments are shared with the Provincial Committee on Flood and Storm Control for future planning for improvement. Following the assessment some kindergarten facilities have been improved in An Giang, Dong Thap and Tien Giang.

Lessons learnt

- senior officials of the target districts and provinces in Cambodia and Lao PDR for the first time jointly developed the FPP involving the provincial and district line departments;
- during the FPP development process, a huge number of key officials from national, provincial, district and commune Disaster Management Committee and its Secretariat in Cambodia, Lao PDR and Vietnam participated in the development and implementation of the FPP, thus enhancing their skills in effectively dealing with floods; and planning and programming for flood risk reduction;
- the focal points involved in leading the FPP process of the target provinces became resource persons for other flood prone provinces and helped their Provincial and District

DM committee in training their staff to lead and guide preparation of FPP in their district;

- joint planning enhanced the cooperation (horizontally and vertically), information sharing and understanding of DRM by all PCDM and DCDM member line departments;
- the lead role of PCDM/DCDM in the planning process helps them realize their capacity is not limited only to response;
- planning and follow-up implementation enables the line departments to recognize their extended roles in DRM and the possibility of mobilizing internal resources;
- significant involvement of NCDM – helps ensure sustainability of the process;
- better understanding of Commune Committee on Disaster Management (CCDM) on community-based disaster/flood management concept and planning provided important foundation for integrating of disaster/flood management activities into future commune development plan;
- continuation of the collaboration between PCDM/DCDM/CCDM and PSDD to ensure the integration of FPP activities into the Commune Development Plan (CDP)/Commune Investment Plan (CIP);
- people tend to underestimate their existing resources. Resource Inventory which was conducted by DCDM has enriched DCDM knowledge and understanding of the existence and the needs for resources that can be made available for taking action before, during and after flood event;
- DCDM Secretariat and the line departments have better overview of what needs to be mobilised and what is required when developing the FPP by using the resource inventory information;
- more women are being involved in the ground implementation (of the priority sub-project) on raising the awareness of female-headed households in flood risk reduction, commune orientation on CBFM and teacher's orientation on flood risk reduction;
- Ministry of Women Affairs and Veterans at provincial and district level along with leading women-related NGO are working together to raise the awareness of female-headed households in flood risk reduction which has rarely brought into public attention in the past, nor been on the active agenda of women's empowerment needs.

Challenges

- linking the FPP process at different levels;
- integrating the FPP into the development planning process, particularly in the Commune Development;
- planning process initiated under the SEILA program;
- sustaining the momentum of the FPP, especially following the years with no serious floods;
- segular allocation of resources for the FPP;
- the expansion of the planning process to other districts and provinces;
- the inclusion of gender issues into the FPP;
- replication of CBFM orientation sessions in the remaining communes by CCDM in collaboration with PCDM and DCDM;
- support implementation of action plan developed under the FPP;
- continuation of the collaboration between PCDM/DCDM/CCDM and PSDD to ensure the integration of FPP activities into the CDP/CIP.

Integration of flood risk reduction into local development planning process

Recognising the limited financial and geographical coverage of the projects extra efforts were invested to establish linkages and synergies with on-going planning processes in the country. In

Cambodia, Project to Support Democratic Development through Decentralization and Deconcentration (PSDD), formerly known as SEILA Program, was identified for such purpose. The Representatives from PSDD Office in the provinces under both GTZ and ECHO projects were invited to all the FPP Development workshops. The finalized provincial and district FPPs has been shared with PSDD provincial offices. PCDM/DCDM of the target provinces and districts have been working closely with PSDD to integrate flood risk reduction activities into the CDP and CIP.

The training on Community-based Flood Management conducted for commune disaster management authorities in Cambodia and Vietnam has contributed to better understanding on flood/disaster management concept. This has a positive impact, particularly in Cambodia, on the process of integrating flood risk reduction into CDP/CIP because the commune council leaders who are in charge of CDP/CIP development are also Chairperson of the CCDM.

To introduce the PSDD facilitators at district and provincial levels to basic flood risk reduction concepts, bridging the gap between disaster risk management and development scenarios a Training of Trainers (TOT) for provincial and district PSDD facilitators was conducted. Once trained, these facilitators will further train the members of Commune Councils and CCDM, accelerating the process for inclusion of Disaster Risk Reduction (DRR) into CDP and CIP In 2007 several flood risk reduction projects were included in the commune development plans in all three target provinces of Kandal, Prey veng and Kratie.

Lessons learnt

- the exercise of political will by the highest ranking government officials and line departments is a prerequisite to a successful integration initiative. Without the acceptance, participation and ownership of the local government officials and line agencies to reduce disaster risks within their sectors and spheres of influence, integration cannot be sustained;
- the successful identification of local advocates or ‘program champions’ can have a significant impact in terms of local stakeholder ownership and greatly facilitates the integration process;
- decentralization provides an enabling environment for integration disaster risk reduction into official development plans and this is logically best undertaken at the local government level where responsibility and resources for participatory development planning is vested. In the context of Cambodia, this is at the commune level;
- while decentralization holds much promise for integration disaster risk reduction, this is not likely to occur without significant efforts in awareness raising, advocacy and capacity building;
- efforts towards building local capacity in disaster risk reduction are typically addressed to local government disaster management bodies and committees but for effective disaster risk reduction integration to occur it is imperative that institutional capacity is likewise provided to all other government line agencies or departments (i.e., health, agriculture, women affairs, etc.);
- integration should be addressed using horizontal and vertical approaches, through integration into the overall local government development planning processes and by integration into the departmental or sectoral plans of the various line departments;
- given very limited resource mobilization potentials in rural areas of the country, integration into local development plans remains the most viable long-term resource allocation option for sustained flood risk reduction.

Challenges

- the critical mass of integration experiences and lessons learned from the projects can be

translated into the development of specific integration guidelines and tools for commune, district and provincial officials including procedures for monitoring and review. In this manner, the potential for replication to other communes is significantly enhanced;

- the facilitation of actual commune-level flood emergency management planning to more effectively demonstrate the linkages of commune to district and provincial flood risk reduction plans and its integration into local development plans;
- funding support to commune disaster risk reduction activities and projects identified and prioritized through the PSDD mechanism (i.e., district integration workshop process) in order to provide local government units with the motivation and incentive to continue and further enhance the practice of integrating disaster risk reduction integration into development planning;
- active participation and advocacy of the projects, in coordination with other disaster management stakeholders in the country, for integration of disaster risk reduction at national and ministerial levels can significantly strengthen provincial and local capacities for disaster risk reduction in the longer term and should be pursued as a complimentary strategy.

National capacity to support the Provincial and District Flood Preparedness Program

Throughout the implementation of both projects, the involvement of the National Disaster Management Office (NDMO) in Cambodia, Lao PDR and Vietnam is significant and grants immense credibility to the project. Not only they participate in all the workshops and trainings in the capacity of facilitators/trainers, but they promote too the engagement of other line ministries in the flood preparedness programs development, especially at the provincial and district levels. In addition, in the process; the capacity of NDMOs to undertake the similar activity in other provinces has been significantly enhanced.

The NDMO shows its commitment in supporting the project implementation such as seniors officials involved in various activities under the project like (1) Flood Preparedness Program Development, (2) Implementing sub-priority activities, (3) Playing the coordination role with national line agencies, local and International DRR partners (4) Committing to replicate the process in other disaster/flood prone provinces, districts and communities. The profile and role of NDMO at national, provincial and district levels have been raised through the project implementation.

In Cambodia initiatives of integrating disaster/flood risk reduction into local development plan has been promoted through dialogues and consultation with government line ministries, development agencies and DRR partners. Capacity of staff at the national level (NCDM) has been strengthened through involvement in project implementation.

The Manual on Flood Preparedness Programs for Provincial and District Level authorities in the Lower Mekong Delta Countries has been developed based on assessment of the needs of local disaster management authorities and practitioners to improve flood preparedness planning in Cambodia, Lao PDR and Vietnam. The manual will help these provincial and district level disaster management committees of the riparian countries to develop and implement Flood Preparedness Program. In addition, this also serves as a training resource handbook for the national disaster management officials, practitioners and NGOs to conduct capacity building activities on flood preparedness.

This manual provides basic understanding and describes implementation arrangements required for flood preparedness planning through the 10 chapters as follows:

1. Flood Preparedness Planning
2. Preparation of a Provincial and District Profile
3. Hazard, Vulnerability and Capacity Assessment (HVCA)
4. Institutional Mechanism for Flood Preparedness and organizations involved in flood risk management

5. Institutional Terms of reference (TOR) for Flood Preparedness Planning
6. Flood Risk Reduction Measures to be taken before, during and after floods
7. Preparation and Maintenance of Resource Inventory
8. Assessment and Upgrading of Flood Preparedness Program
9. Mainstreaming Special Needs of Vulnerable Groups into flood planning
10. Integration of FPP with the National, Provincial and District Development Plans

Under the ECHO project the Lao version of the Training Manual and Handbook focusing Provincial and District level was prepared by LNMC and NDMO through wide consultation with stakeholders at national, provincial and district level. It was disseminated widely by NDMO to all the national level agencies including NGOs and civil Society organizations.

Technical Support Unit (TSU) was established in August 2007 as part of at the Southern Office of Department of Dyke Management, Flood and Storm Control (DDMFSC) in Ho Chi Minh City. TSU is working as the Mekong Delta hub of information and communication on Flood Risk Reduction (FRR) and link with overall National Disaster Management partnership in Vietnam. It has technical and coordination functions in support to provincial and district DM authorities in flood /disaster risk reduction.

Lessons learnt

- direct involvement and participation of national officials from the NDMOs in the project implementation have contributed to better coordination and cooperation between NDMO at the national level and provincial and district authorities which will ensure the sustainability of future activities;
- a pool of resources, amount of knowledge and experiences in flood preparedness and emergency management at the national and local levels (within NDMOs, line agencies, local and international NGOs) do exist, however, they have not been widely shared among stakeholders;
- there is a need for support from NDMOs in the development and implementation of provincial and district FPP in other flood prone areas;
- insufficient capacity in resource mobilization at all levels.

Challenges

- continued strengthening of NDMOs in supporting the provincial and district FPP;
- institutional strength (i.e. disaster management system and mechanism at all levels) is prerequisite for long-term sustainability;
- initiative of integration flood risk reduction into local development plan has been initiated at the grass root level, but the practice of integration is not completely integrated into national policies, programs and project cycle of national line ministries;
- future operation of the TSU depends on strong commitment of the NDMOs in the country with regard to its support to provincial and district FPP development and implementation.

Public awareness campaigns in selected districts of the pilot provinces conducted

One of the major emphasis in the Mekong flood plains has been to keep the communities aware of the flood risks at all times so that they are prepared and will be able to response to any flood situation with little consequential damages to both their lives and properties. Therefore, regular and continuous public awareness raising activities are identified as crucial to reduce the flood risks. Public awareness raising activities were also identified as priority areas under the FPP.

The public awareness campaign involved the dissemination of flood risk reduction messages through printed materials, video CDs and community stage plays or dramas while the

campaign targeting vulnerable groups used more direct communication channels including group discussions and classroom dissemination. In addition, the series of training and workshops conducted as part of the larger program were also venues for raising awareness and can thus be considered as one of the media for which flood risk awareness was undertaken.

The flood booklets produced was based on a previous version used by ADPC in a similar program in 2002. A review of the materials with the national and provincial officials resulted in some modification after which thousands of copies were printed and disseminated. The booklet formed part of the information materials provided during various orientations and training conducted for provincial, district and commune council members, women focal persons, local school officials and teachers.

Large posters with simple easy to read and understand flood preparedness and mitigation messages were produced and prominently displayed in public places. The posters came in three types depicting flood risk reduction measures before, during and after the occurrence of floods. A second set was designed specifically for the flood risk awareness for school children. These posters provides highly visual depiction prevention measures for school children and was adapted from the school posters produced and widely used by the Save the Children Alliance in Vietnam. In addition a poster on flood related 4 on-site motto (on-site leadership, human resources, materials/equipment and logistics) was produced and disseminated for the first time in Vietnam.

A video CD entitled 'Living with Floods' was produced by the Oxfam GB in Cambodia in 2005 and was used extensively in their own community-based disaster risk reduction program in various parts of the country. The video was, in turn, adapted and produced by Oxfam from an original version produced by the Vietnam Red Cross (VNRC). In collaboration with Oxfam, copies of the video were distributed to the PCDMs, DCDMs in the target provinces with an agreement that these would be played in community social and formal gatherings and further distributed to homes and establishments that have video players. In Vietnam with the permission from VNRC the Living with Floods Video was reproduced and disseminated to district and commune officials who came to various trainings and to local villagers who attended the cultural performances.

Other outstanding achievement in public awareness campaign is School Flood Safety Program (SFSP) and the production of 'Flood Information Kit for Teachers and Educators' and its use in SFSPs. Teachers and educators are recognized as the key information disseminators who have great influence not only on school children but also on the community at large. Raising their awareness on community flood risk reduction measures can enable the information to reach out to a large audience.

The SFSP aimed at fostering provincial level partnership in child safety initiatives, providing orientation sessions for schools teachers and officials of Department of Education on flood hazard, means of protection and what to do before, during and after floods in their school, conducting awareness campaign activity in their Schools through awareness campaign such as Painting and Quiz competition to raise awareness on Flood Safety measures for children, conducting School Flood Risk Assessment by the schools and promoting common IEC material through SFSP Teacher Information Kit containing flood booklet, information for teachers, students booklet, pictures used as teaching materials, VCD 'Living with Flood', Puppetry Cartoon of Flood disaster and an A-4 size posters on household safety measures and prevention against child drowning. SFSP kits were delivered and applied effectively at Primary and Secondary Schools in the target areas. SFSP campaigns were organized by Provincial Department of Education in hundreds of primary and secondary schools in Tien Giang, An Giang, and Dong Thap provinces in Vietnam and in Kratie province in Cambodia.

The use of community cultural performances as media for disseminating flood risk reduction information proved to be extremely popular and cost-effective. Actor and singer troupes are common in the country and while they are very popular, performances are usually limited to special public occasions and celebrations. The use of this popular medium of culture and entertainment was in line with existing cultural heritage of Cambodia and Vietnam. The

cultural troops under the provincial Department of Culture and Arts in Cambodia and the district Office of Information and Culture (OIC) took charge in the performances which attracted thousands of villages in the target communities. Such traditional performances combine the entertainment values with educational purposes.

The IEC materials have been used not only under the projects but also used and reproduced by NDMO and other local and international NGOs in their training and awareness raising activities on flood risk reduction. Bill board/flood information board installed on school play ground and at popular communication route, e.g. local market, cross road and bridges, become effective means in conveying messages on flood safety measures to the public.

Lessons learnt

- formulation and design of public awareness campaigns can be tedious and time consuming but once developed these tend to have a long lifespan and can repeatedly used;
- when local stakeholders are motivated and take ownership of the initiative, local capacities and resources that were not initially evident can emerge;
- public awareness campaigns must be designed and communicated based on existing local social and cultural practices if the messages are to be understood and retained;
- one does not have to 'reinvent the wheel', existing awareness materials and tools developed by other organizations can be successfully adapted to local conditions contributing to a shorter research and design phase;
- public awareness is best approached with creativity and innovation. The most effective ideas and methods came from the organizations and groups with mandates related to the arts, culture, media and women affairs. Use of creative 'non-conventional' channels and mediums of communication was a key factor that led to increased community awareness;
- cost-effectiveness and ease of replication are the key characteristics of the two most effective awareness methods undertaken in the program; community cultural performance and incorporation into the school learning curriculum;
- building local capacity to undertake public awareness campaigns in the future can create a multiplier effect when awareness activities are replicated by local stakeholders themselves;
- reaching the most vulnerable segments of a community population (e.g., women, elderly, children, etc…) will be more effective if a specific and focused awareness campaign designed toward their specific views and perspective is undertaken;
- the provincial and district Office of Culture and Information has wide-ranging experiences in designing and conducting traditional performances with focused messages. Identifying them as the lead agency in undertaking the key activities under public awareness raising creates a valuable collaborator who can take the activities further to other areas with similar problems;
- relay the information on flood risk reduction measures at local levels and the health issues to all the teachers in each school through in-school orientation;
- SFS Campaign demonstrated the importance role and responsibility of teachers and education in enhancing culture of preparedness and child safety;
- children are amongst the most vulnerable group but awareness of public can be done through education of children;
- educational institutions are a major public infrastructure, which can create long-lasting impact on future generations;
- partnerships at provincial level provide opportunities for up- scaling such initiatives.

Challenges

- sustaining the awareness of the communities on flood risk reduction should be treated as a regular program rather than as a one-off event and require involvement and contribution from all stakeholders – the disaster management authorities, the relevant line agencies, non-government organizations as well as the general public;
- provincial and district Culture and Information offices should be given proper guidance and training on risk reduction measures and programs for them to be able to design and deliver comprehensive, effective and innovative public awareness raising programs on various subjects of floods, drought, etc. It should be part of the annual flood and storm control plan of the local disaster management authorities;
- in order to reach a greater mass of population in flood prone areas, different types of information dissemination media need to be researched. Many families listen to radio and watch television regularly during the rainy season on flood monitoring news, but the technical nature of these messages sometimes creates confusion and suggestions have been made to present similar forms of traditional performances on radio and television;
- educating the public not just on the negative impacts of floods but also on its positive impacts and promote 'Living with Floods' concepts;
- flood preparedness information should be included in the existing curriculum, for example in the national program on social and life skill enhancement in Cambodia;
- involvement of private sectors in mobilizing resources for public awareness campaign.

National and regional knowledge sharing

Under GTZ-funded project four national workshops, two each in Cambodia and Vietnam, were organized to provide opportunities for knowledge sharing among national and local disaster management authorities, line agencies in flood preparedness program development and implementation. More importantly, representatives of PCDM outside the project target areas, i.e. from all flood prone provinces along the Mekong and around the Great Lake in Cambodia as well as PCFSC from all flood prone provinces in the Vietnam Mekong delta, were invited to participate in the national workshop. Under the ECHO project three national flood forum were held for the first time in Cambodia, Lao PDR and Vietnam. The forum discussed completed activities, emerging needs and reviewed the progress each country has made towards a holistic and balanced flood preparedness program. As an on-going activity of FMMP, it provides a suitable framework to strengthen cooperation and information exchange among the MRC member countries, the international community, IOs and CSOs.

A regional workshop on 'Innovative Approaches to Flood Risk Reduction in the Mekong Basin' under GTZ-funded project was held in Khon Kaen, Thailand in October 2007. More than 120 participants from 16 countries representing the National, Provincial, District Governments, Red Cross Societies, NGOs working in flood risk reduction as well as officials from universities, UN Agencies, and donor agencies attended the workshop. The workshop focused on eight themes: 1) Development and implementation of Flood Preparedness Program at provincial, district and commune levels, 2) Promoting community awareness and strengthening community resilience, 3) Improving access to early warning, 4) Implementing children and women focused programs for flood preparedness and risk reduction, 5)Integration of flood risk reduction into national, sectoral and local development plans and programs, 6) Capacity strengthening of disaster management authorities at national, provincial and district levels, 7) Province-to-province transboundary cooperation in emergency management and 8) Partnerships and networking for Flood Risk Reduction.

Under the ECHO-funded project a regional workshop on Flood Management in the Lower Mekong Basin was also organized in April 2008. The objective of the workshop is : to disseminate the experiences and best practices of FMMP in the field of Flood Preparedness Programs in the region, to seek inputs on expansion and up scaling of these practices in the countries of Lower Mekong Region by themselves and with technical support from MRC and

its partners and to discuss regional cooperation on national and sub national partnerships in FMMP and role of national partners. About 60 participants from the MRC member countries, provincial disaster management representatives, regional partners and donors.

Under the GTZ-funded project a series of case studies were produced as good practice document which captures good practices and experiences from the projects. The first two case studies were prepared with the following themes: 1) Enhancing the capacity of provincial, district and commune disaster management committees in Cambodia-Developing and implementing flood preparedness programs, 2) Improved dissemination of flood forecasts through community-based early warning system-Building the local capacity in flood vulnerable communities in Cambodia.

The other six case studies being completed are: 1) Reaching out to the Public: Raising Community Awareness to Flood Risk Reduction in Cambodia, 2) Sustaining the Flood Emergency Management Strengthening Project-Creating the Momentum for Mainstreaming, 3) Across Generations-Developing the Capacity of Teachers and Educators in Flood Risk Reduction-Cambodia, 4) Lending a Voice to the Most Vulnerable: Mainstreaming Gender Issues in the Flood Preparedness Programs-Cambodia, 5) Creating a Safer Tomorrow for the Future Generations- A Comprehensive Approach to Ensure the Safety of Children in the Mekong Delta in Vietnam, 6) Reaching out to the Public - Raising the Awareness of the Community in Flood Risk Reduction in the Mekong Delta, Vietnam.

In March and April 2008 two study tours were conducted for Cambodian and Vietnamese provincial and district disaster management authorities to visit and learn from each other from on-going and past ground activities implemented through flood preparedness programs (FPP) and also have a chance to learn from other partners including local and international NGOs.

Lessons learnt

- sharing of knowledge and experiences between disaster management authorities at national and local (provincial and district) levels and concerned line agencies has help the authorities reflect their strength and weakness in order to improve future FPP development and implementation;
- replication of activities under the projects is being undertaken as other flood prone provinces outside the project target areas expressed their interest to follow the example;
- the Forum should not be only for knowledge sharing but also for discussion on how to share and exchange information, capacity and resources in flood preparedness among the flood prone provinces;
- the national and regional meetings should be a regular event organized by national and regional stakeholders in order to promote coordination and cooperation at national and regional levels;
- a lot of good practices has not been well documented and shared and/or if documented but it has not been widely shared among stakeholders;
- exchange of visits proved to be more effective in sharing practical knowledge and experiences.

Challenges

- accessibility of provincial and district authorities to information and knowledge on flood preparedness;
- establishment of a sustained local, national and regional communications, networking and partnership to enable knowledge sharing environment;
- good practices can be useful when it is applied in local context.

Province-to-province transboundary cooperation on emergency assistance

Between the border provinces of Cambodia and Vietnam such as Kandal-An Giang and Prey Veng-Dong Thap, there is a tradition of holding regular half-day provincial meetings, held biannually and hosted in turn by the border provinces. At district level, quarterly meetings are regular features. The provincial delegations are usually headed by the Provincial Governor from Cambodia and Chairperson of the Provincial People's Committee representing the Vietnam side.

A technical meeting between PCDM of Kandal province and PCFSC of An Giang province was held in Chau Doc district, An Giang province on 6 February 2007. In addition to the members of PCDM/PCFSC of both provinces participants from other target provinces of Prey Veng and Dong Thap, representatives from VNMC, CNMC, NCDM, DDMFC and ADPC also attended the meeting as observers. 4 priority areas of cooperation identified were: (1) Joint search and rescue training; (2) exchange information on flood and storm forecast; (3) health care and; (4) Preparedness and prevention of avian influenza, insects and animal diseases during flood season).[5)]

The four priority areas agreed at transboundary technical meeting between PCDM of Kandal province and PCFSC of An Giang province has been included in the regular cooperation between Kandal and An Giang in May 2007.

Organized by Khammouane Provincial Disaster Management Committee (PCDM) in Khammouane province, a transboundary meeting on Flood Preparedness and Emergency Assistance Cooperation between Khammouane Province, Lao PDR and Nakhon Phanom Province, Thailand was held on Tuesday 11 December 2007. The meeting discussed the transboundary flood preparedness and emergency cooperation between the two participating provinces. Key cooperation areas are :1) Information sharing and exchange, 2) capacity building, 3) Exchange of visits and academic seminar and 4) disaster drills.[6)]

Lessons learnt

- existing socio-economic transboundary cooperation between neighbouring provinces of Cambodia-Vietnam and Lao PDR-Thailand provides better environment for including transboundary flood preparedness and emergency assistance into their regular cooperation agenda;
- cooperation at provincial level is less formal and practical in dealing with cross-border flood/disaster events;
- identification of a priority activities in terms of emergency assistance and flood preparedness) for collaboration is be based on common needs and capabilities of both sides;
- experiences and knowledge can be directly shared and put into practices due to their similarities and conditions.

Challenges

- the concept of DRM not a priority yet in the context of the cross-border collaboration issues;
- limited understanding of local authorities in flood/disaster risk management, limited resources and capacities;
- expansion of transboundary cooperation to other provinces which are cross-border areas
- language barrier.

REFERENCES

Mekong River Commission Secretariat (MRCS), 2004. Program document: 'Flood Management and Mitigation Program (FMMP)'.

Mekong River Commission Secretariat (MRCS), 2004. Flood Emergency Management Strengthening (FEMS), Component 4 of the Flood Management and Mitigation Program (FMMP).

ECHO-Phase III project. Project document: '*Support to Implementation of Flood Preparedness Programs at Provincial, District and Commune Levels in the Lower Mekong Basin'*, during 2007-2008 under the 5th DIPECHO Action Plan for South East Asia,

Flood Preparedness Program, 2006-2007, Kandal Province, Cambodia

Minutes of transboundary meeting between Kandal PCDM, Cambodia and An Giang PCFSC, Vietnam, 6 February 2007

Minutes of the Meeting on Trans□Boundary Flood Preparedness and Emergency Assistance Cooperation between Khammouane Province, Lao PDR and Nakhon Phanom Province, Thailand, 11 December 2007, Thakhek, Khammouane Province, Lao PDR

ASIA FLOOD NETWORK: USAID/OFDA FLOOD MITIGATION AND PREPAREDNESS PROGRAM IN ASIA

MS. A. SEZIN TOKAR[1], RICHARD PAULSON[2], ERIC WOLVOVSKY[2], ANGEL BENNETT[2], AND KELLY SPONBERG[2], ROBERT JUBACH[3], SAUD AMER[4], GULEID ARTAN[5] AND GREG HUSAK[6]

[1]*USAID Office of U.S. Foreign Disaster Assistance, Washington, DC, USA*
[2]*National Oceanic and Atmospheric Administration, Silver Spring, MD, USA*
[3] *Hydrologic Research Center, San Diego, CA, USA*
[4] *U.S. Geological Survey, Reston, VA, USA*
[5] *U.S. Geological Survey, Sioux Falls, SD, USA*
[6]*University of California, Santa Barbara, CA, USA*

ABSTRACT

Floods affect more people than any other natural disasters in the world. During the last decade, floods affected more than 100 million people and claimed more than 9,000 lives (Centre for Research on the Epidemiology of Disasters (OFDA-CRED EM-DAT), 2008). During 1997-2006, Asia was the home to more than 96% of flood-affected population in the world. Asia Flood Network (AFN) is a U.S. Agency for International Development, Office of U.S. Foreign Disaster Assistance (USAID/OFDA) flood mitigation and preparedness initiative in Asia that aims to reduce vulnerability to flood hazard in Asia. The objectives of AFN are to: 1) build regional/national capacities on climate, weather, and hydrological forecasting and warning, 2) encourage hydrometeorological data and information exchange in transboundary river basins, and 3) improve dissemination of forecasts and warnings to the users and population at risk. USAID/OFDA in collaboration with National Oceanic and Atmospheric Administration (NOAA) and U.S. Geological Survey (USGS) have provided technical assistance and conducted various trainings on flood related technology in Asia. AFN activities are mainly focused on the Mekong and Ganges-Brahmaputra-Meghna river basins, where vulnerability to flooding is extremely high. The Mekong River Commission (MRC) and the International Centre for Integrated Mountain Development (ICIMOD) are USAID/OFDA's regional partners in implementing AFN activities.

Riverine flooding in the Mekong River is a slowly developing annual event that affects the lives of the people of the Lower Mekong River Basin, where floods in 2000 killed more than 800 people. In contrast, flash floods typically are local in extent, highly destructive, and come and go in a matter of hours. Flash floods often are briefly noticed by officials, citizens, and organization that traditionally have been powerless to detect and warn of such floods, especially in small sub basins in rural areas of the developing world where weather and hydrologic monitoring networks are scarce. Yet, according to the World Meteorological Organization (WMO), flash floods claim more lives worldwide than any other natural disaster, including riverine flooding. Consistent with WMO findings, the USAID/OFDA and MRC are establishing a Regional Flash Flood Guidance System to monitor continuously the potential for flash floods throughout MRC member countries under AFN. The System will be operated from the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) in Phnom Penh, will analyse the incidence of rainfall, and prepare flash-flood guidance and threat information for small basins in MRC member countries. By early 2009, this guidance and threat information will be available operationally to National Mekong Committees and Line Agencies in each country so as to provide them with yet another tool to use in preparation and dissemination of flash-flood warnings to communities at risk. Ancillary AFN activities in support of the system

will be: (a) Satellite Rainfall Estimation (SRE) capacity development, designed to assist MRC-RFMMC staff compute regional SREs which are calibrated by regionally available raingauge data, and member-country staff computing national SREs which are calibrated by nationally available data; (b) the RANET program, which will conduct a communications needs assessment and evaluate alternatives to provide timely warnings and information to rural communities and government offices to identify and address the gaps in existing communications networks.

INTRODUCTION

An early warning system and preparedness plans are vital tools in reducing the loss of lives and the socio-economic impacts of floods. An effective flood early warning system should provide sufficient lead-time to prepare for and efficiently respond to extreme hydrometeorological events. Since 2001, to support the flood forecasting activities of the Mekong River Commission (MRC), the U.S. Agency for International Development, Office of U.S. Foreign Disaster Assistance (USAID/OFDA) and its partners continue to provide 24-hour satellite rainfall estimates and short-term forecasts of rainfall over the Mekong River basin and surrounding areas. USAID/OFDA's support for rainfall estimations and forecasts led to the implementation of the Asia Flood Network (AFN) in 2003. MRCs Flood Management and Mitigation Program (FMMP), *Component # 1: Establishment of a Regional Flood Management Centre,* and AFN seek to achieve a common goal of reducing vulnerability and adverse impacts of floods while taking advantage of the positive effects of floods.

As illustrated in Figure 1, the mitigation of and preparedness for floods can be defined as an end-to-end process including: (1) data collection and monitoring; (2) hydrometeorological forecasting; (3) planning, preparedness, decision making, and coordination; (4) dissemination of information to people at risk; and (5) actions taken by population at risk to lessen the impact of potential hazards. Each component in this process is critical to reducing the impacts of floods and providing essential lead-time for response, and failure of one component will lead to failure of the goal of disaster risk reduction. State of the art technology and a perfect forecast will not save lives if the populations at risk are not informed or do not have plans and policies in place for effective response or prepared for potential hazards. Similarly, well-prepared communities remain vulnerable to hazards if they do not have access to information and forecasts, which provide lead-time to take necessary actions. Therefore, an integrated approach to disaster risk reduction is critical in reducing the impacts of floods and other natural disasters.

In cooperation with the National Oceanic and Atmospheric Administration (NOAA) and U.S. Geological Survey (USGS), USAID/OFDA continues to collaborate with MRC and International Centre for Integrated Mountain Development (ICIMOD) in Asia to identify and fill in gaps with end-to-end flood forecasting and early warning. The programs complement USAID/OFDA-funded community based, early warning activities in the region. In USAID/OFDA and Hydrologic Research Centre (HRC) presentations, AFN activities will be presented by addressing the end-to-end process of mitigation.

Satellite rainfall estimation: data collection and monitoring

Monitoring extreme hydrometeorological events is the first step towards understanding what could potentially occur in the future. Hydrometeorological observations, such as rainfall, temperature, snowfall and streamflow, are essential in simulating the hydrologic cycle. Ground observation networks are commonly used in collecting rainfall and other hydrometeorological data. However, in many countries, satellite-based precipitation estimations may serve as the main source of rainfall data due to scarcity of hydrometeorological networks, long delays in or absence of data transmissions, limited access to some areas, and the absence of data sharing in many transboundary river basins. The NOAA Climate Prediction Centre developed merged

satellite- and ground-based rainfall estimation technique, which has been used globally to provide alternative to monitor precipitation only by ground networks. The merged satellite- and ground-based rainfall estimation (RFE) brings value-added information to raingauge interpolations as a near real-time rainfall dataset. The estimation complements real-time raingauge, and independent satellite-based information.

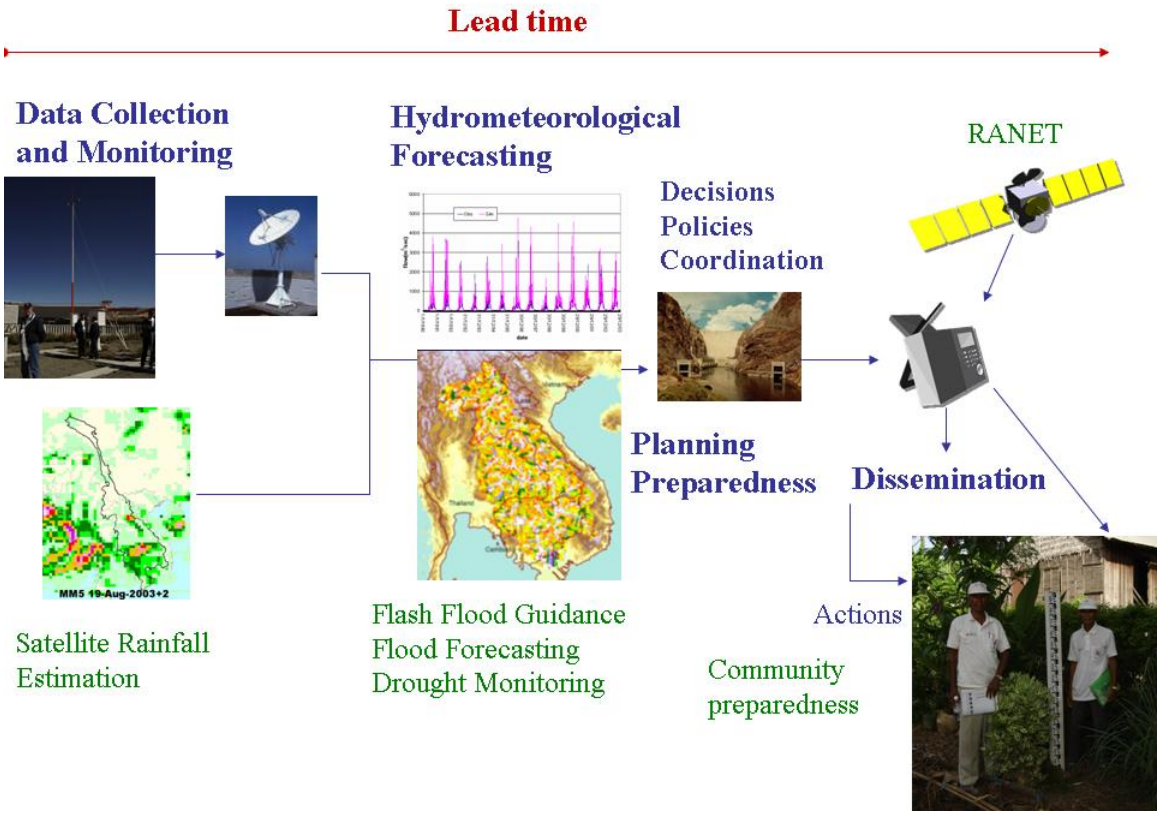


Figure 1. An end-to-end flood mitigation process

The dataset also provides a valuable opportunity for the monitoring of seasonal moisture, particularly when comparing historical averages of anomaly and normal rainfall. Through AFN, USAID/OFDA, in partnership with MRC and ICIMOD, conducted workshops on the use of RFE technology to strengthen the capacity of National Meteorological and Hydrological Services and regional organizations in Asia. Under AFN, NOAA and USGS have been cooperating with MRC and ICIMOD on the use of satellite precipitation estimation to forecast and monitor flooding, flash floods, and droughts. In 2008, MRC, USAID/OFDA and NOAA are planning to hold the second workshop to prepare MRC and member countries for operational computation of daily SRE in the basin and potentially initiate validation activities in the Lower Mekong River Basin (LMB) which will enable regional partners to integrate local raingauge data, validate remote sensing data, improve accuracy for the region, and reduce the time lag of data transmission.

In 2005, ICIMOD hosted training workshops on the use of RFE. Under AFN, ICIMOD has completed verification of RFE using local gauge data (Figure 2). The validation conducted by ICIMOD determined that the RFE does a good job at reflecting the overall pattern of rainfall. However, the RFE also does not estimate rainfall perfectly. As a result of these imperfections varying in each region part of the workshop for MRC will focus on how to conduct a validation to determine to what degree and where these biases occur.

Although floods have had a significant impact in Asia, droughts have also been prevalent

in recent years throughout the region. The MRC Council acknowledged droughts as a problem at their recent 13th meeting and endorsed an MRC regional Drought Management Programme. USAID/OFDA, NOAA and USGS believe that many of the flood-management and mitigation tools that are being implemented at the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) have direct application to drought monitoring and management as well. SRE has been used in Africa and Central America to monitor the onset and intensity of drought events. The USGS in collaboration with the University California at Santa Barbara has developed software tool to monitor drought in Asia. The program uses spatially and temporally over-sampled SRE data to estimate gamma distribution parameters for each pixel in for a set of meaningful preset time intervals. These distribution parameters are then used in the development of a Standardized Precipitation Index (SPI), which is a probability index that measures the intensity of drought. The SPI boost the probability of detecting the onset of a drought event compared to other drought monitoring indexes. Since the SPI measures the probability of the precipitation to deviate from the mean for a specified time period it could be use to monitor other hydrological extremes, beside drought, such as localized intense rainfall events that can cause flooding of headwater basins.

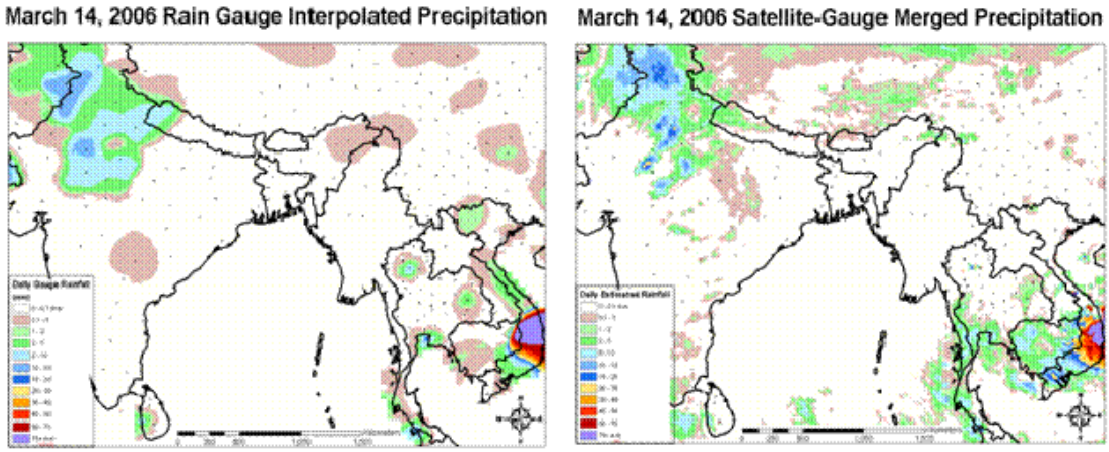


Figure 2. Raingauge versus satellite/gauge merged precipitation estimates

Hydrometeorological forecasting

Building capacity to forecast hydrometeorological parameters, such as rainfall, temperature, soil moisture, and river flow, is critical to providing sufficient lead-time for warnings on potentially dangerous river and weather conditions. Modelling hydrological and meteorological processes remain essential to response planning, not only for early warnings but also for management of water resources, agricultural planning, flood mitigation, navigation, scenario-based risk-evaluation, and environmental impact-assessments.

Flash floods are the main cause of weather related deaths in many countries, due to rapid-onset, limited warning procedures and emergency actions, the high velocity of water flows, and the associated debris flows. In 2005, under AFN, MRC and ICIMOD hosted flash flood guidance workshops. As a result of the MRC workshop, USAID/OFDA, USG partners, and MRC agreed to transfer technology for flash flood guidance, which was developed for seven Central American countries after Hurricane Mitch devastated the region in 1998. In May 2008, MRC, USAID/OFDA and HRC will be conducting the second workshop to introduce the proposed regional Flash Flood Guidance System (FFGS) for the lower Mekong River basin. The participants will also discuss monitoring, detection, development and dissemination procedures and protocols of warning population at risk. A technical overview of proposed FFGS system is given on the presentation and the paper by R. Jubach.

The USGS Geospatial Streamflow Model (GeoSFM) (Artan et al., 2007a and Asante et

al., 2007a, b) application began as a project of USAIDs Famine Early Warning Systems Network (FEWS NET) to provide for streamflow forecasts for data scarce regions. The GeoSFM was designed to utilize NOAA RFE, rainfall from forecast weather models, and potential evapotranspiration (PET) field estimated calculated from input variables produced by NOAAs Global Data Assimilation System (GDAS). The GeoSFM is a physically based river basin-scale (semi-distributed) hydrologic model consisting of a GIS-based pre-processing module and a rainfall-runoff component. The rainfall-runoff component of the GeoSFM is a physically based hydrologic model with few parameter and variable input data requirements.

After the 2005 AFN Satellite Precipitation Workshop, MRC and other participating representatives selected the Nam Ou and Se Done River basins in Lao PDR as GeoSFM test basins. Participants of the workshop selected these two basins because the Nam Ou and Se Done Rivers contribute large flows to the Mekong, significantly impacting the Mekong River main stem forecasts. A study (Artan et al., 2007b) of the model applicability was carried, when forced with RFE the GeoSFM short-term river forecast for two basins (Nam Ou and Se Done) indicated that the model has forecasting skills. Model skills were positively correlated with basin area size; with 81% of the observed day-to-day variability was explained for the Nam Ou River basin (Figure 3). The study demonstrated that a GeoSFM and NOAA RFE-based flood forecasting system is able to identify large events that can significantly influence the state of the flows on the main stem of Mekong River. At a monthly time scale model performance was fairly accurate for smaller basins. Implementing a flood forecasting system for the relatively hydro-meteorological data-poor Lao PDR head-watersheds may, in the aggregate, provide highly useful forecast information that will support the MRCs recently adopted role as provider of medium term Mekong River forecasts.

In 2008, the USAID/OFDA and USGS are coordinating capacity development and the transfer of the GeoSFM to the Lao Hydrology and Meteorological Service.

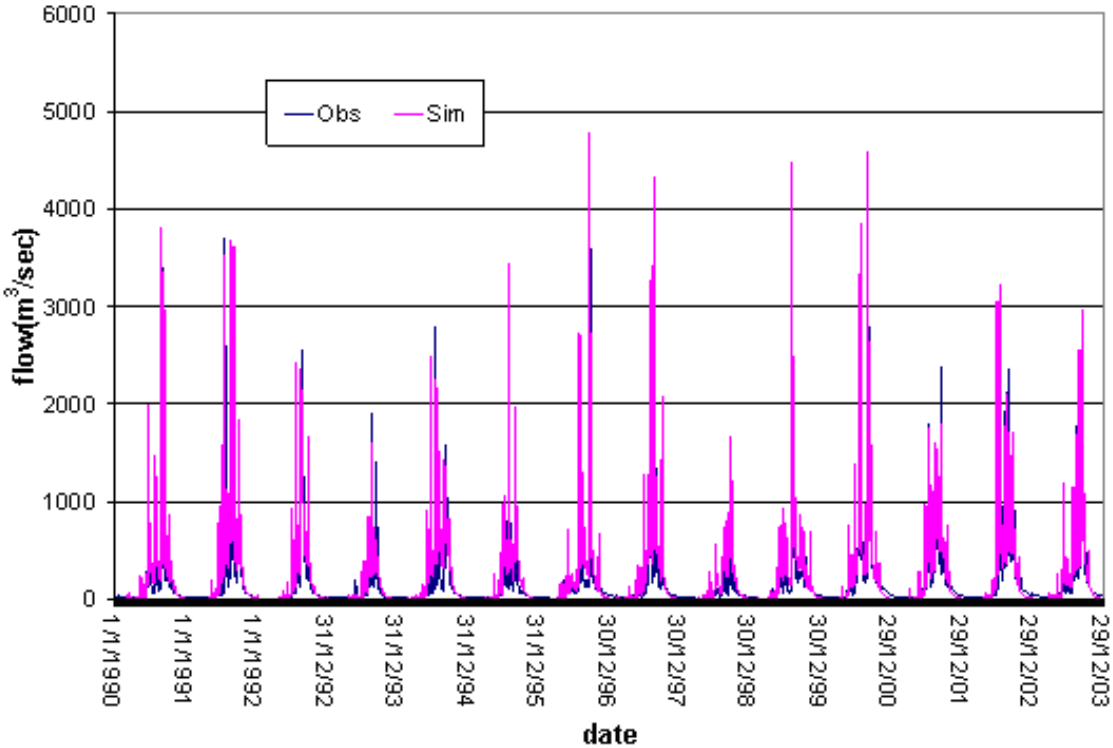


Figure 3. Observed and simulated hydrographs from calibrated GeoSFM for the Se Done River at Souvanna Khili station.

Planning, preparedness, decision-making, and coordination

For successful flood mitigation, decision makers must continuously monitor potentials for extreme hazards, implement necessary measures such as planning for extreme events, developing policies for disaster management, protocols for warning of affected populations, and provide coordinated, effective, and timely responses to disasters. USAID/OFDA seeks to collaborate with the MRC on development of a Concept of Operation (CONOPS) manual for theMRC-RFMMC. Such a manual will define all of the tools and procedures utilized at theMRC-RFMMC for forecasting riverine flooding and providing flash flooding guidance, which will be especially valuable in the context of the MRC because staff turnover. The CONOPS manual also can serve as a guide to member-country based initiatives to develop similar national-level documentation. A study tour to US River Forecast Centres and other relevant institutions is proposed as part of CONOPS development for the MRC and member countries

Dissemination of information to people at risk

State of the art technology and perfect forecasts alone cannot save lives and property if forecasts and warnings do not reach populations at risk with sufficient lead-time to enable them to take appropriate measures in order to reduce the impact of disasters. In 2005, MRC and NOAA held a workshop on implementing the Radio and Internet (RANET) technology in the lower Mekong River basin. RANET is an international collaboration to improve access to weather, climate, and related development information for populations in remote areas that lack resources. The technology assists in day-to-day resource decisions and preparation against natural hazards. RANET identifies appropriate, low-cost communications technologies - primarily based on radio and Internet standards - that can be used to augment existing communication systems in developing countries. A key tenant of the RANET program is local ownership and management. RANET depends on four critical components (Figure 4) to move information from capital cities to rural communities. As a result of the workshop, NOAA and MRC received pilot project proposals from riparian countries. In 2006, representatives from Lao PDR and Thailand attended the RANET Introductory training workshop in Washington, D.C., and developed country implementation plans. In 2007, MRC and member country representatives participated in RANET training session and dissemination of tsunami warning information in Indonesia. In proposed USAID/OFDA and MRC program under AFN, RANET will conduct a communications needs assessment and evaluate alternative schemes to provide timely warnings and information to rural communities and local government offices to identify and fill the gaps in the existing communication systems.

Actions Taken by Population at Risk to Lessen the Impacts of Potential Hazards

As stated above, state of the art technology will not save lives if populations at risk do not understand what actions to take or how to prepare for potential hazards in advance. USAID/OFDA continues to support community-based preparedness and early warning projects in the region to raise community awareness and capacity to reduce vulnerability to extreme floods. Since 2003, USAID/OFDA and MRC have been implementing a community-based flood preparedness project in Cambodia in partnership with American Red Cross, Action Contra la Faim, and the Cambodian Red Cross.

SUMMARY

An integrated approach to flood management is essential to increase resiliency to weather/climate induced disasters. MRC and USAID/OFDA share the goal of mitigating the

flood-related loss of life and property due to extreme hydrometeorological events in the LMRB, which provides a basis for joint cooperation under the FMMP and AFN programs. USAID/OFDA and MRC have developed a program implementing the technologies stated above to reduce vulnerability to floods and manage river resources for sustainable development.

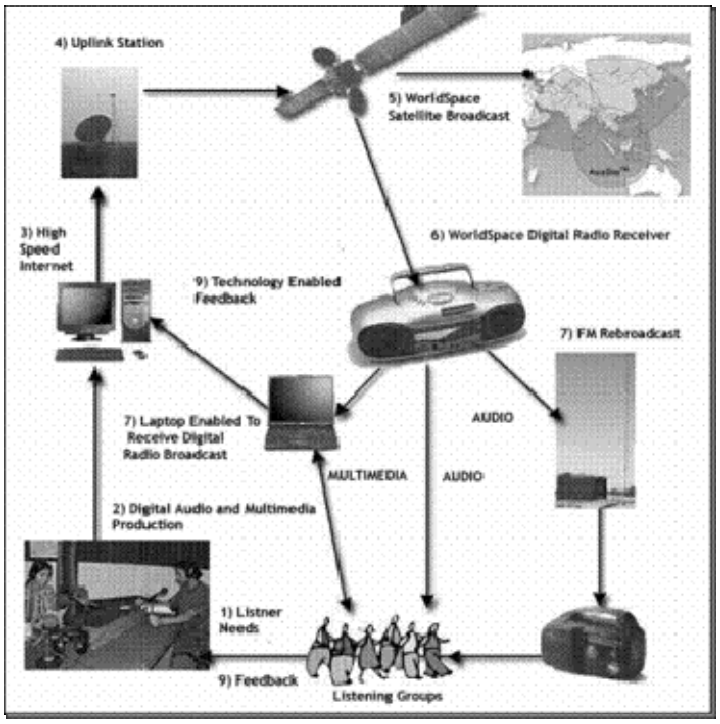


Figure 4. RANET components

REFERENCES

Artan, G, H. Gadain, J. Smith, K. Asante, C. J. Bandaragoda, J. Verdin. 2007a. Adequacy of satellite derived rainfall data for stream flow modeling, Natural Hazards, 43(2): 167-185.

Artan, G., Kwabena Asante, Jodie Smith, Shahriar Pervez, Debbie Entenmann, James Verdin, and James Rowland, 2007b. Users Manual for the Geospatial Stream Flow Model (GeoSFM), U.S. Geological Survey Open-File Report 2007-1440, p. 194

Asante K., R.. Macuacua, G. Artan, R. Lietzow, and J. Verdin, 2007a. Developing a Flood Monitoring System from Remotely Sensed Data for the Limpopo Basin, IEEE Transactions on Geoscience and Remote Sensing, 45(6): 1709-1714.

Asante, K.O., Artan, G.A., Pervez, S., Bandaragoda, C. and Verdin, J.P., 2007b. Technical Manual for the Geospatial Streamflow Model (GeoSFM), Reston, Virginia, U.S. Geological Survey Open-File Report 2007-1441, p. 99

ENHANCING COOPERATION BETWEEN MEKONG RIVER COMMISSION (MRC) MEMBER STATES IN ADDRESSING TRANSBOUNDARY FLOOD AND RELATED ISSUES

HUYNH MINH NGOC AND NICO BAKKER

MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC), Phnom Penh, Cambodia

ABSTRACT

In the aftermath of the devastating floods of 2000, the Mekong River Commission (MRC) developed a strategy and programme to deal with the threat of future flood disasters in the Mekong River Basin. Its Strategy on Flood Management and Mitigation outlined the role the MRC could play in the management of flood risk in the Lower Basin and led to the formulation of a Flood Management and Mitigation Programme (FMMP), which was finalised in 2004.

In addition to establishing and enhancing the flood database, plus tools and capacity for better management and mitigation of flood problems in an integrated manner, the FMMP, through its Component 3 (FMMP-C3), also contributes to the goal of enhancing effective regional cooperation. This component follows the objective 'to identify potential transboundary issues for negotiation, mediation and conflict prevention; and develop mediation and conflict management capacity' as set in the MRC Strategic Plan for 2006 - 2010.

The FMMP-C3 aims to strengthen cooperation and enhance capacity to address differences and disputes in transboundary flood issues by developing and achieving the following products and targets:

- common understanding and agreement on transboundary flood issues in the basin;
- information and reference documents related to international, regional and national 'best' practices, instruments and case studies for use in capacity building and referral in case of differences and disputes related to implementation of the Mekong Agreement;
- development and implementation of a comprehensive capacity building for the National Mekong Committees, national line agencies and MRC Secretariat (MRCS) staff in the field of conflict management and addressing differences and disputes related to transboundary flooding and related issues;
- establishment of a toolbox for facilitating and supporting the process of addressing differences and disputes. This will include administrative (e.g. manuals, guidelines and procedures), technical (numeric and/or physical models, assessment frameworks), and knowledge and information ('best' practices, cases studies, literature and instruments) tools.

The component will run for a period of three years from 2007 - 2009, with significant financial support from the Government of the Netherlands.

INTRODUCTION

Two of the most common transboundary issues that can lead to problems in international river basins are the twin menace of droughts and floods. Both can be caused by nature, including climatic changes, and/or by human induced developments or expansion of activities. In many cases an attempt by one riparian state to mitigate the harshness of nature in droughts or floods exacerbates the problems and causes harm for others within its own boundaries and in the other

riparian countries.

In recent years, the Mekong River Commission has made significant progress in developing a number of mechanisms to promote cooperation and prevent conflict among its Member States, at the same time helping them to achieve timely and amicable agreement on a range of transboundary issues. Coupled with its conflict prevention obligation through cooperation and mitigation of adverse impacts, the MRCs founding document, the 1995 Mekong Agreement, establishes a clear legal obligation for MRC Member States to cooperate and resolve any disputes and differences that might arise. The mission of the MRC has been clearly stressed in its Strategic Plan for 2006 - 2010 *'to identify potential transboundary issues for negotiation, mediation and conflict prevention; and develop mediation and conflict management capacity'*

In addition to establishing and enhancing the flood database, plus tools and capacity for better management and mitigation of flood problems in an integrated manner, the FMMP, through its Component 3 (FMMP-C3), also contributes to the goal of enhancing effective regional cooperation. This component follows the objective 'to identify potential transboundary issues for negotiation, mediation and conflict prevention; and develop mediation and conflict management capacity' as set in the MRC Strategic Plan for 2006–2010.

TRANSBOUNDARY FLOOD ISSUES IN THE MEKONG RIVER BASIN

Common understanding on the issues and possible options for addressing transboundary flood issues are important topics for exploration of any problem that arises. The MRC Member States, with assistance and facilitation from the FMMP, have jointly identified transboundary flood issues (TBFI) through a bottom-up and intensive participatory approach. The identification of TBFIs aims to build common and better understanding among the member countries regarding transboundary flood issues in the Mekong River Basin, as well as ways that the countries could or would like to address these.

By 'transboundary' it is understood that something that happens in one country has positive or negative impacts in one or more other countries. These transboundary impacts are 'inter-jurisdictional'. In the case of river basins with two or more riparian states, the transboundary/cross-border dimension gives rise to the upstream/downstream (consecutive) or left bank/right bank (concurrent) legal relationship, depending upon the location of the national boundaries/borders

TBFIs include both those of natural origin and those caused or worsened by human activities and/or interventions. Natural TBFIs may be identified, avoided and/or mitigated through cooperation before and after an occurrence; while floods caused or made worse through human activities/interventions may pose a contentious issue, difference or dispute that needs addressing and resolving. Figure 1 was developed to illustrate the origins, nature and solutions associated with TBFIs.

Focus was given to man-made flood impacts, as these potentially cause differences and disputes between parties concerned. For this reason the MRC Member States, during the exercise to identify TBFIs, adopted the following working definition:

'Any existing or potential substantial adverse impact on the natural, economic or social environment within an area of a Riparian State resulting from a change of the water conditions during the occurrence of floods and/or during the flood season of the Mekong River system caused by a human activity, originating wholly or in part from within one or more areas of one or more other Riparian States'.

The following six groups of TBFIs have been identified and agreed between the Member States (Figure 2).

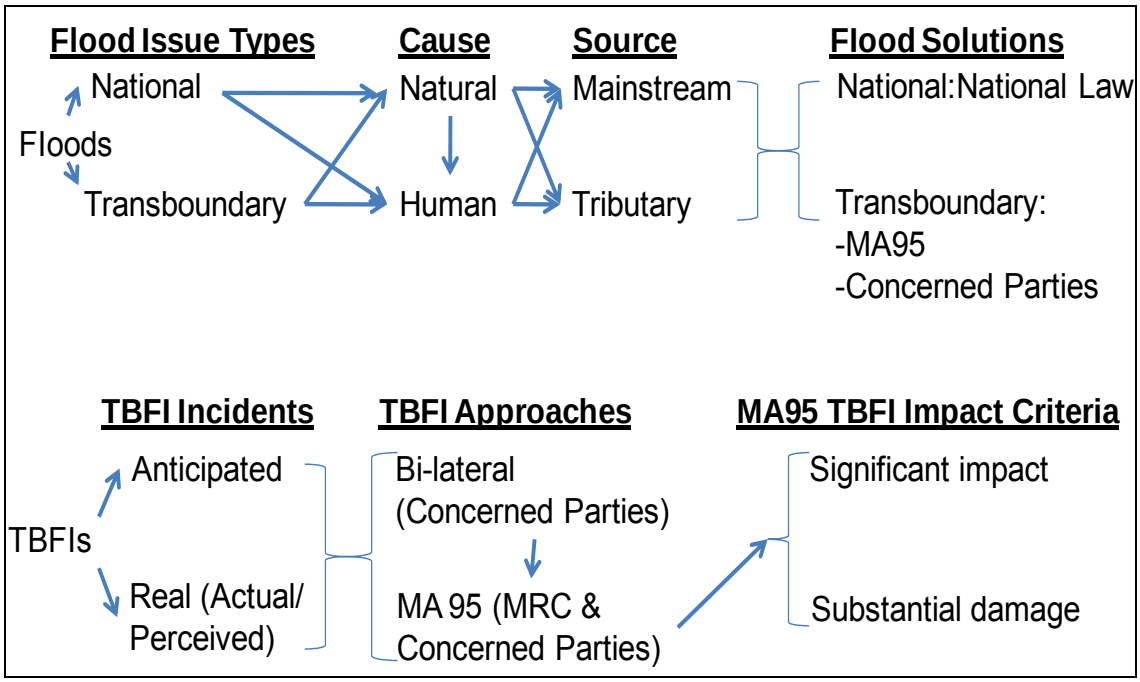


Figure 1. Illustration of origin, nature and solutions to MRB TBFIs

SIX GROUPS OF IDENTIFIED TRANSBOUNDARY FLOOD ISSUES RELATED TO

1. **floodplain development within the Mekong Delta (upstream-downstream and vice versus);**
2. **development in upstream of the Lower Mekong Basin that has an impact on the Mekong Delta (upstream-downstream);**
3. **hydropower developments in the Upper part of Mekong Basin (upstream-downstream);**
4. **hydropower project development and operation in the Se San, Srepok, and Se Kong river basins (upstream-downstream);**
5. **bank protection and port development, sand excavation, dam-operation communications in the upper reaches of the Mekong mainstream (left bank – right bank and vice versus); and**
6. **increased flooding on tributaries in northwest Cambodia (upstream-downstream);**

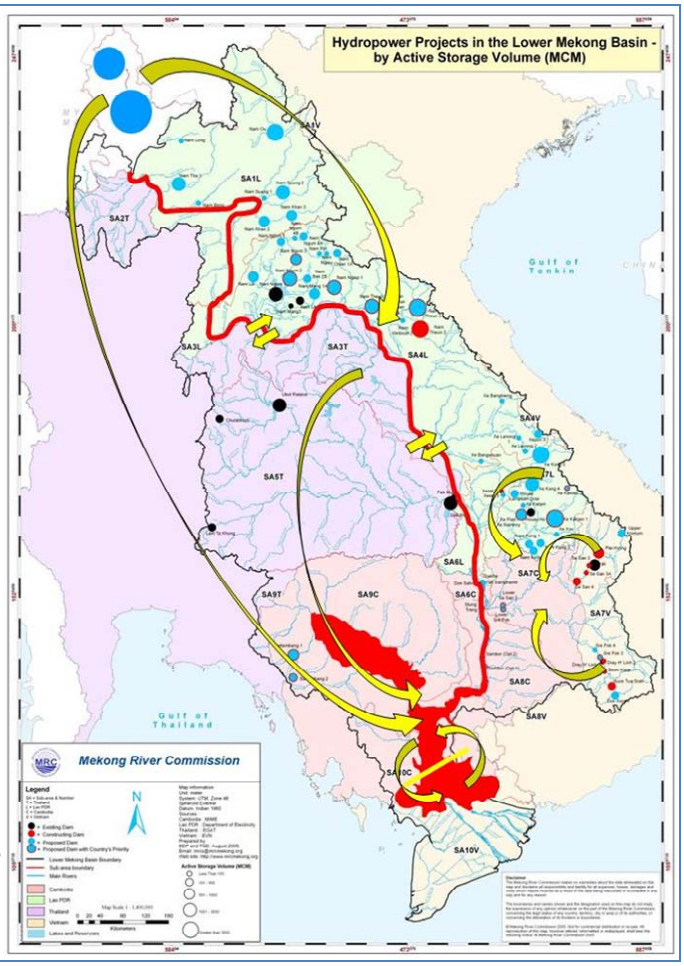


Figure 2. Six groups of regional TBFIs

In the course of TBFI identification, the member countries emphasised that technological and knowledge-related constraints appear to be most important, followed by policy, governance and institutional constraints to effectively addressing and resolving transboundary flood issues, differences and disputes (TBIDD). The countries suggested a strategic approach for addressing transboundary flood issues:

- to build on existing bilateral mechanisms supported or facilitated by the MRCS in general and Component 3 in particular;
- to share experiences and lessons learnt from bilateral mechanisms, expanding them to the multilateral and regional level where appropriate;
- to strengthen multilateral mechanisms such as the Mekong dialogue partnership by providing suitable tools and services from the MRCS (relating to Upper Mekong Basin developments and global concerns associated with climate change).

MANDATE AND ROLES OF THE MRC AND MRCS AND OPTIONS FOR THE MRC MEMBER COUNTRIES IN ADDRESSING TRANSBOUNDARY FLOOD ISSUES, DIFFERENCES AND DISPUTES

Transboundary issues are defined as issues between two or more sovereign nations, each with its rights, interests, responsibilities and obligations, due to their status under international law. Similar impacts occur within a nation, where national laws, policies and practices are employed.

International law and the UN Charter provide a framework for addressing shared water resources and the rights and obligations of sovereign nations (transboundary issues). Their sources include treaties between nations; conventions proposed by the UN and regional bodies and approved/adopted and ratified by the requisite number of the respective constituency; and widely accepted international practices, often articulated in judicial decisions such as by the International Court of Justice. General international law and practice has and can be reliably applied to address contentious issues, conflict avoidance and dispute resolution through various approaches or mechanisms amongst the states of an international river basin or international watercourse, especially where a water treaty has not already been entered into by all or some of the states, or on matters not covered by the treaty.

The four MRC Member States have, in addition to general international law and practice, the 1995 Mekong Agreement, which provides a legal framework for cooperation in the development and management of the water and related resources of the Mekong River Basin. This can be used to address and resolve differences and disputes that might arise between members of the MRC.

The 1995 Agreement provides the MRC Council and Joint Committee (JC) with a clear mandate to address differences and disputes. It is likewise clear that the MRCS has no clear mandate or role for directly engaging in dispute resolution through negotiation, conciliation, mediation or arbitration unless it is specifically granted such authority by the Joint Committee. Figure 3 gives a brief framework on how the1995 Agreement addresses TBIDDs.

It is clear that the four MRC Member Countries have two distinct options for addressing incidents perceived or understood to have been caused by the actions of another member country/ies and which have caused a significant adverse impact or substantial damage. It or they can either pursue the matter under the provisions of the 1995 Agreement, or pursue the matter on a bi-lateral basis involving the concerned parties. The latter would be addressed on a government-to-government basis through the respective ministries of foreign affairs. The former would be pursued under the provisions of the 1995 Agreement. In fact, a combination of the two options may be applied as well.

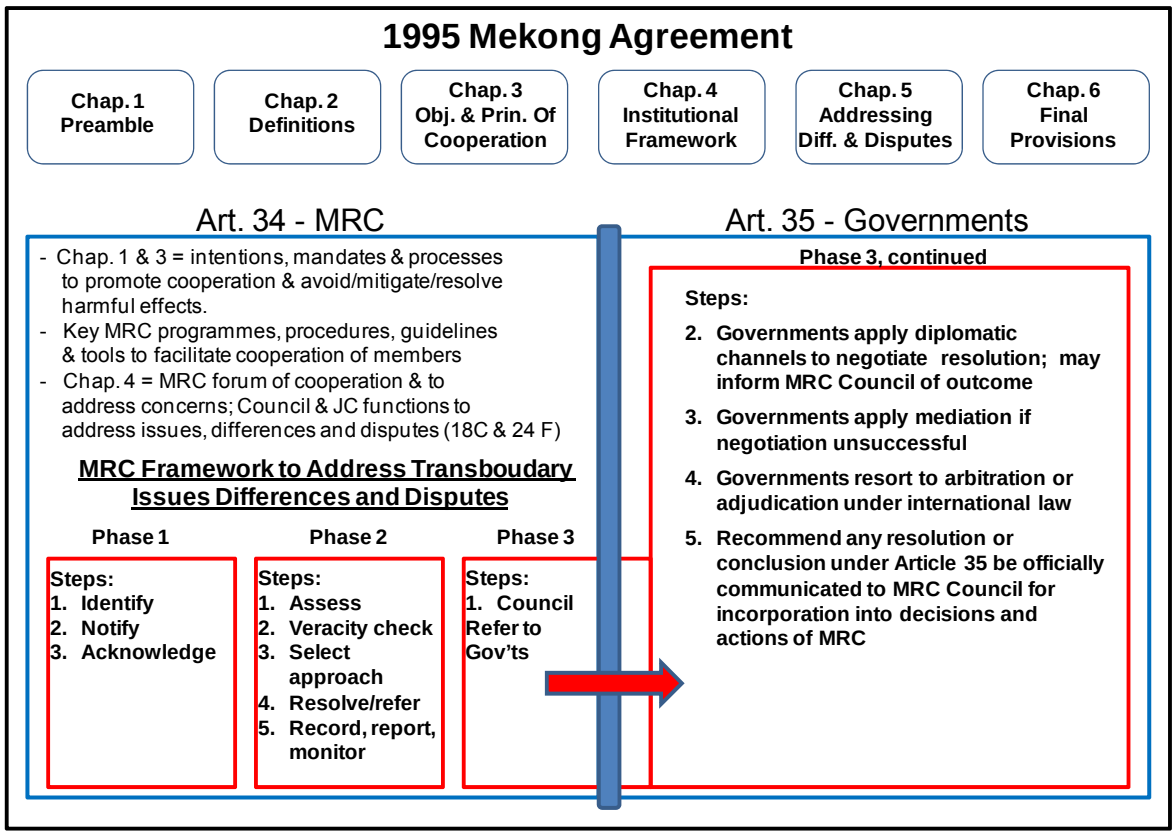


Figure 3. Framework for addressing Transboundary Issues, Differences and Disputes

COMPONENT 3 OF FMMP IN ENHANCING COOPERATION AND STRENGTHENING CAPACITY IN ADDRESSING TBFIs

It is very clear that the MRCS has an important role in supporting the Council, JC and the Member Countries by gathering, assessing, and analysing data and information and report preparations in a routine manner. It may also be specifically requested by the JC to conduct other forms of analyses, set up meetings, field trips, or to provide potential independent experts or organisations to assist in addressing development or conflict issues. Certainly the role of the MRCS is important in facilitating the enhancement of cooperation and avoidance or mitigation of incidents that may give rise to differences and disputes.

In the process of identifying the TBFIs, the member countries grouped the main constraints to better addressing issues, differences and disputes in three areas:

- *knowledge-related* constraints limit access to reliable information on structural development plans including standard design criteria and policies. Better access to and operation of appropriate tools would help to improve understanding of causes and effects;
- *policy, governance and institutional* constraints refer to differences in administrative, institutional and policy frameworks in the four Member Countries;
- inadequate *financial and economic* resources are another important constraint. In the Lao PDR, for example, joint studies of bank erosion require considerable funding for which budget allocation is insufficient.

The support required from MRC to the member countries is presented in two groups: Technical and administrative support.

Technical support would focus on:

- information and knowledge generation and exchange to improve factual evidence of

causes, effects and impacts. This includes science-based clarification and awareness raising, information exchange, joint fact-finding missions and studies, and harmonisation of policies and regulations;

- development and application of tools to reduce complexity so that causes and effects become sufficiently clear to allow effective response strategies to be identified. The suitability of tools would be demonstrated and tested within specific pilot areas and or projects;
- capacity building in impact assessment to provide a framework and develop analytical capacity for interested and value-based discussions on trade-offs between beneficial and non-beneficial impacts. The underlying assumption here is trust and confidence among the parties involved.

Administrative support is needed to:

- ensure adequate stakeholder participation with senior technical and administrative representatives of line agencies, including national and provincial levels if required;
- to develop and agree on processes and procedures which provide sufficient scope for factual and information-based discussions that result in agreed strategies and actions;
- ensure progress, continuity and sustained interest in the process through awareness raising, conflict prevention, management and funding.

From the above findings, Component 3 of the FMMP was developed to strengthen cooperation and enhance the capacity of the MRC to address differences and disputes in transboundary flood issues. The Member States suggested that Component 3 ought to include three outputs:

1. information generation;
2. awareness raising and knowledge and skills building;
3. toolbox development.

Output 1 'Information Generation' will be implemented firstly with activities on identification of transboundary flood issues from national and regional perspectives. The common understanding and agreement on the regionally concerned transboundary flood issues in the Mekong River Basin provide background information and serve as fundamental requirements for all other activities of Component 3. A proper understanding of the transboundary flood issues will be facilitated by making available documentation, such as applicable 'best' practices, instruments and case studies relating to all suitable options for addressing differences and disputes in transboundary issues and natural resources management. Information generation will be documented and distributed to the Council and JC members, MRCS, the NMCs, relevant national line agencies and, where appropriate, to a wider audience, including resource managers, civil society organisations, regional institutes and universities[1]. The compiled reference material will form part of the toolbox to be used by the MRC in addressing differences and disputes. The materials will also serve as input for the general awareness raising, knowledge and skills building activities under Output 2.

Output 2 'Awareness Raising and Knowledge and Skills Building' will start with clarification of the MRC mandate in transboundary flood issues in addressing differences and disputes. The materials developed under Output 1 will be complemented by more specific conflict management and resolution knowledge, tailored to the MRC environment. This will be used for development and implementation of the activities on general awareness raising, knowledge and skills building. Implementation of pilot studies will improve the result of general awareness raising, knowledge and skills building activities and build practical knowledge, skills and mutual trust for Member States and the MRCS. Implementation of pilot

[1] In line with the MRC information dissemination policy

studies activity will also be supported by the technical and administrative tools to be developed under Output 3.

Output 3 'Toolbox Development' aims at the development of a set of technical and administrative tools. These will be developed based on the requirements set out by relevant activities in Outputs 1 & 2. It should be noted that the establishment of the administrative tools activity strongly interacts with the implementation of pilot studies activity. The preliminary outcome of the administrative tools activity will be used as guidance for pilot studies activity, and lessons learnt from the pilot studies activity will help improve the established administrative tools. A brief illustration of the Component 3 design is presented in Figure 4.

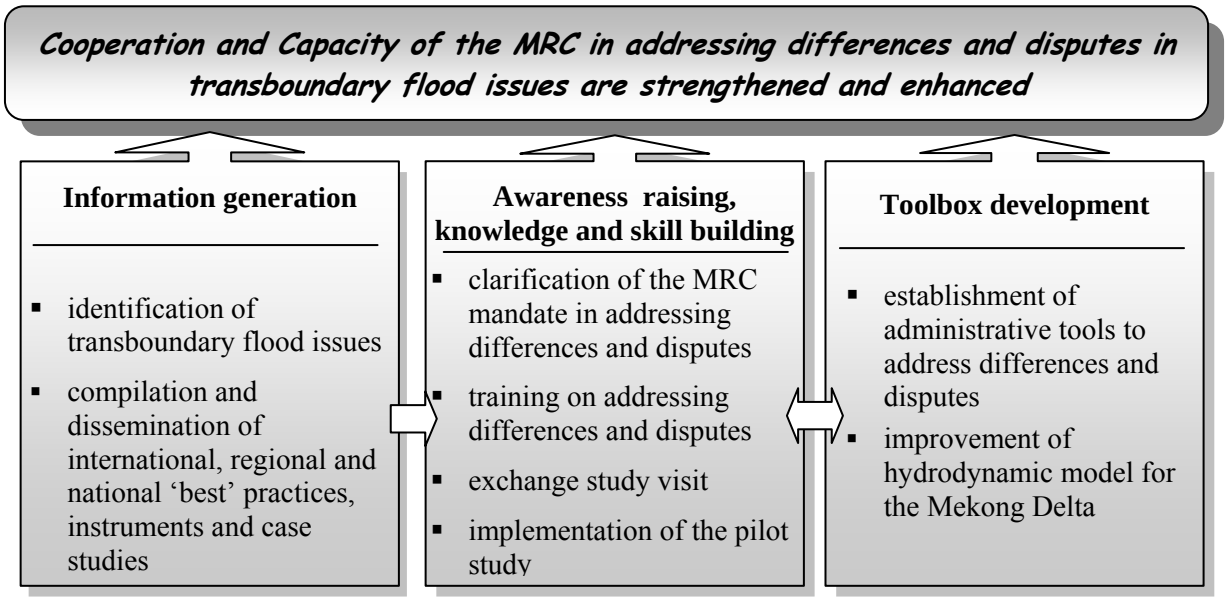


Figure 4. Basic design of Component 3

PRESENT STATUS AND FURTHER DEVELOPMENT OF COMPONENT 3

Component 3 has made good progress in 2007 and early 2008 in developing relevant MRC reference materials through the application of an intensive consultation process with the member countries. The Component has initiated implementation of a nine-month training and capacity building programme, which has the clear objectives of raising awareness and building knowledge and skills. The first phase of this programme will address the regional level, including the NMCs and line agencies dealing with transboundary issues. During Phase 1 exchange visits and training will be carried out in other river basins where experience has been developed in addressing transboundary issues (preferably flood) issues. One of the most interesting elements of the training and capacity building programme (but most complex as well) is the implementation of one or more pilot studies. During Phase 2 of the programme, specific focus will be placed on training and capacity building at national levels.

It is expected that the implementation of this Component will create a level playing field for participants, allowing them to work together closely and to apply a technical and practical approach. Such a joint setting will allow participants to build trust and confidence, which are conditions for the further development of the framework for addressing TBIDD. It became clear during the initial implementation period of Component 3 that each of the member countries is solidly committed to the scope of the component. It is therefore expected that with respect to addressing transboundary flood issues, Component 3 will help the Member States face the challenges of the future.

INTEGRATED FLOOD MANAGEMENT IN THE CONTEXT OF REGIONAL TO GLOBAL INTEGRATED OBSERVING AND INFORMATION SYSTEMS OVERVIEW OF CURRENT ACTIVITIES OF THE WORLD METEOROLOGICAL ORGANIZATION

WOLFGANG E. GRABS

World Meteorological Organization (WMO), Geneva, Switzerland

SUMMARY

Integrated Flood Management (IFM) is a development policy concept aiming at minimizing the losses of life from flooding and at the same time maximizing the efficient use of floodplains within the context of poverty alleviation and sustainable development. In this context, flood risk management aims to reduce risks associated with poverty, lacking access to resources, food and livelihood insecurity. The IFM concept also anticipates that climate variability and change has the potential to further exacerbate flood risks, which are already rising due to factors such as population and economic growth and large-scale land-use change. Here, the IFM concept offers a series of potential climate variability and change adaptation measures. The IFM concept has been successively developed and put into practice through the Associated Programme on Flood Management (APFM) of the World Meteorological Organization (WMO) in collaboration with the Global Water Partnership (GWP). After establishing and promoting the principles of IFM in international, regional and national forums, conducting various pilot projects and providing an overview of current flood management practices around the globe, the Programme has shifted its focus to support implementation of the concept in flood prone developing countries. This has lead to the establishment of a diversified capacity building package for flood managers and policy makers and the establishment of the 'Flood Management Tools Series' instrumental in building in-country capacities to put the IFM concept in its multi-disciplinary approach on the ground. Presently, the programme develops an IFM Help-Desk mechanism, which will be the central element in ensuring a demand-driven approach to implementing the IFM concept as the operational arm of the programme to respond to countries' needs in Integrated Flood Management.

Integrated flood management, especially in a transboundary context such as in the Mekong river basin, with its very diverse requirements for data and information is just one component amongst a multitude of WMO Programmes that rely on the availability and access to hydrometeorological, environmental and socio-economic data and information on national and regional levels. The response to diverse data and information requirements is the on-going development of WMOs Integrated Global Observing System (WIGOS). This is a comprehensive, coordinated system of observing systems that is based on all WMO Programmes' observational requirements. It ensures availability of required data and information and facilitates access through the WMO Information System (WIS) according to identified temporal, geographical and organizational requirements. These include real, near-real time and delayed modes to all required information in respect of existing data sharing policies. Additionally, it helps ensure high data quality standards and benefits from archival and technological innovations.

Amongst the WIGOS components are the Global Observing System (GOS) of the World Weather Watch; regional, river basin and global hydrological networks including the World Hydrological Cycle Observing System (WHYCOS) of which Mekong-HYCOS is one component; the climate component of atmospheric, oceanographic and terrestrial observing

systems contributing to the Global Climate Observing System (GCOS) observing requirements and space-based observing systems including meteorological satellite constellations, and other components of the space-based observing system serving the needs of operational and research applications.

The carrier of all data and information on regional and global levels are information management systems including telecommunication systems that make data and information accessible to a multitude of users. WMOs Information System (WIS) will provide the solution for the information exchange needs of National Meteorological and Hydrological Services (NMHS), relevant non-NMHS agencies/users, commercial providers, research facilities, and international programme centres. It will offer automated collection and dissemination of information (e.g., observations and forecast products); timely delivery of data and products (appropriate to requirements); and ad-hoc information discovery/access/retrieval services. In particular, WIS will enhance the visibility and importance of the NMHSs in their respective countries. The NMHS will gain through improved forecasting/warning services and a faster and more cost-effective exchange of operation-critical information and in particular also to new data and products, which will enhance its own operations. The national centres will also be able to provide critical data and information to other national agencies/users dealing with disaster mitigation, agriculture, energy and water management, amongst other sectors. The national centres will provide information, e.g., warnings, advisories, selected measurements, etc., and help discover, select and channel relevant information to the users, either ad hoc, or in reply to a non-real-time request.

Thus, NMHSs will gain significantly from a strengthened role as national service providers and the ability to 'push' to national users critical information including warnings, advisories, selected measurements and observations.

In closing, the concept of Integrated Flood Management provides an example for innovate approaches to flood management, going far beyond traditional approaches that focus mainly on flood defence options. It also shows the huge requirement for data and information that could be supplied through the operation of integrated observing systems using WIGOS and innovative information systems including WIS, which provide access to data and information related to all programmes of WMO.

QUALITY ASSESSMENT OF FORECASTS

ERICH J. PLATE AND FALK LINDENMAIER

Universität Karlsruhe, Karlsruhe, Germany

ABSTRACT

People living in large parts of the Mekong delta rely on regular flooding for the fertility of their farms and for their irrigation water needs. Therefore flood protection cannot consist of dikes and dams, but must allow natural drainage and flooding. Protection activity must concentrate on protecting people and their livestock. For this purpose the most effective measure is early warning. Forecasting is the important first step in the early warning procedure, and the development of an efficient forecasting system is one of the major challenges. Each country along the Mekong relies on some type of forecast, and it would be good if a criterion was available by means of which one could compare the performance of flood forecasting models. It is the purpose of this paper to review different types of criteria and assess their merit for use in forecasting situations. The gages at Kratie and Pakse for the season 2005 are used as examples.

INTRODUCTION

The development of quality criteria has a long tradition in hydrology, where models always have to be tested against data, because the fundamental fluid mechanical aspects of rainfall conversion into runoff, which leads to floods, are obscured by random components generated due to uncertainty of assessing the rainfall distribution over the basin, the inherent natural variability of the runoff formation of the basin, and scarcity and accuracy of data against which to calibrate models. The hydrologist providing design information for flood protection works is well aware of the fact that his calculations contain large error margins, which is to be taken care of by the designer by means of a suitable safety factor. In practical applications for designing flood protection structures, such as dikes or dams for retention basins, the safety margin is included by adding freeboards to the design height of the structures. The hydrologist strives to cover the physical process as accurately as possible, in order to keep the model error, which he can control, as small as possible. The objective is to avoid excessive over-design, or when the model is used for preparing hazard- or risk maps, to avoid identifying overly cautious risk zones. Furthermore, changes in land use or consequences from the development of a flood protection system can only be evaluated by means of hydrological and hydraulic models. The result is a model, which is calibrated against as many data as possible. For example, in consultancy work with the IHW model developed at the Institut für Hydrologie und Wasserwirtschaft, Institut for Hydrology and Water resources Planning of the University of Karlsruhe we always test extreme value statistics from hydrological rainfall - runoff models, generated by using rainfall of different recurrence intervals as input, against existing stream gage statistics for extreme floods (Plate et al., 1988).

The situation for flood forecasting is quite different. The objective of flood forecasting is to obtain an estimate of future discharges, or more often water levels, which is as accurate as possible, without regard for the physical accuracy or completeness of the model used for doing the forecast. Forecasting models are tested in every season against their performance. If the forecast is not good enough, people will not rely on the forecasts and essentially the forecast becomes useless. On the other hand, the physical model on which the forecast is based is of secondary importance. If a rainfall - runoff model gives better results than empirical approaches

based on time series analysis, such as a regression model or an artificial neural network developed between upstream and downstream gages, then it should be used. If an empirical model is giving better forecasts, then it should be preferred. The decision on which model to be used should, however, not been made in an arbitrary manner, but by using a criterion which allows the comparison of the performance of different forecast models. It is the purpose of a project initiated by the University of Karlsruhe, in cooperation with the Mekong River Commission Secretariat (MRCS), in the framework of a more general project funded by the German Ministry of Science and Technology to develop such a criterion. First results of this project will be presented. The model used for forecasting is the Streamflow Simulation and Reservoir Regulation (SSARR) model for the Mekong (Tanaka, 1999, Apirumanekul, 2006, see also Plate and Insigsiengmay, 2005) and the historical data of observed water levels, as provided by the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) in Phnom Penh.

UNCERTAINTY OF FLOOD FORECASTING SYSTEMS

Uncertainty evaluation is the daily problem of the hydrologist, both in design and in forecasting. The actual performance of a design is never really tested, because who can really tell the difference between a 100-year flood and the 150-year flood? So to overcome consequences from inaccurate estimates, one introduces safety factors, such as freeboards of dikes or dams. When a safety margin is added to the design level, which was determined from a statistical analysis, the probability statement inherent in the concept of a statistical design level is obliterated, the actual failure probability is lowered and an intuitive rather than an exact safety concept is satisfied. The value of the statistical analysis lies in protecting against unreasonable design values.

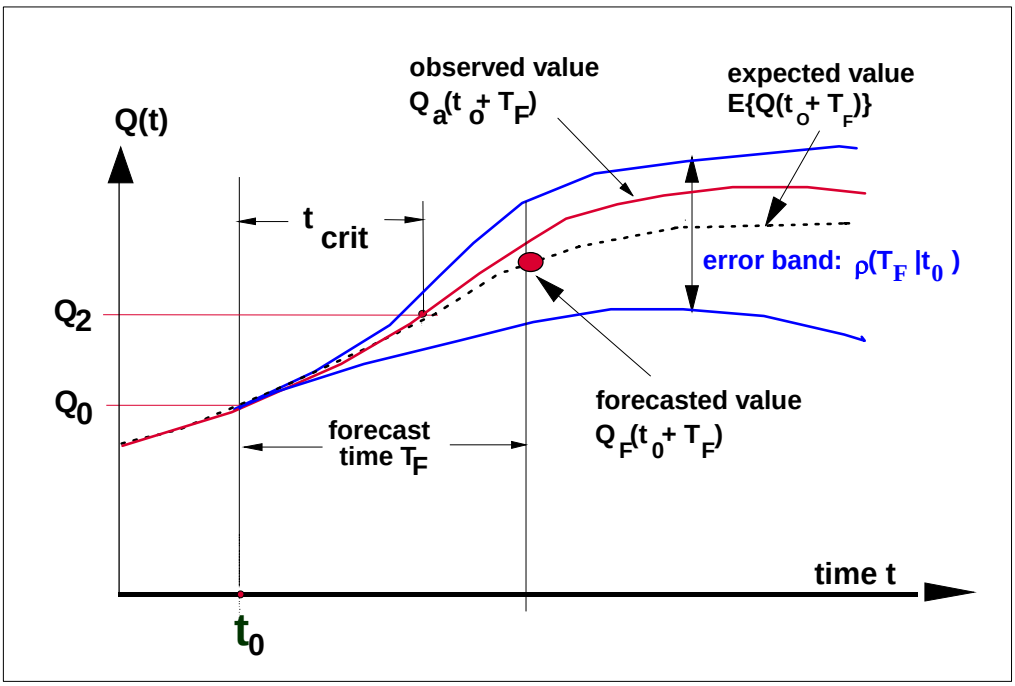


Figure 1. Defining the forecasting situation

From a theoretical point of view flood forecasting is the task of determining, on the basis of past experience and data obtained before time of the forecast, the best estimate for a flood

level in a given river. This is a classical problem of decision-making under uncertainty (Loucks and van Beek, 2005). As illustrated in Figure 1, this implies that at some time t_0 a forecast is to be made for future development of a time series, up to the forecasting time T_F. Because the forecast is made with incomplete knowledge of the future, it is an estimate only, and a statistical error band has to be accepted. In most cases error bands will increase with time T_F. For long times T_F the forecast will no longer depend on the initial time point t_0, but becomes independent of the time. This is the situation of the design statistics, where the extreme values of the time series are used to infer the long-term behaviour of the time series and to identify particular extreme situations, such as the 100-year flood.

DESIGN OF A FORECAST MODEL

The experience on the Mekong indicates clearly that there exists also an important difference between the design of forecasting models for flood forecasting and the actual performance of the system. For designing the forecasting system we want to obtain a system which extends a time function, say x(t), into the future. Information from which to infer the future course of time function x(t) is available, at least from the course of x(t) to the present ($t = t_o$, yielding x_o), or from measured rainfalls. During the design stage, some past sections of x(t) are known ahead of time, so that the model can be calibrated. In contrast, for the forecast application the future is unknown, and can only be inferred from data of the past. This indicates that forecasting has two different aspects: model design and calibration, and model application and adjustment to reality.

Model development of the forecast model starts with an initial value x_O at which the forecast is assumed to start. The forecast model is then used in the hindsight mode, i.e. the model is adjusted to fit the historical data. Flood forecasting models developed in such a way can be of different types, ranging from simple regression models (for downstream forecasts for large rivers, such as used by the MRC downstream of Phnom Penh, (Apirumanekul, 2006) to refined rainfall- runoff models for small catchments, to complex models for large rivers, such as suggested by Plate (Plate, 2007). In order to incorporate rainfall information the design problem includes the classical hydrological problem of fitting a suitable rainfall - runoff model to a specific situation, for which the data are given. However, the forecasted discharge, which is obtained from rainfall - runoff modelling, is an intermediate quantity only, because the quantity to be forecast is the stage, i.e. the water level at the points of interest along the river. Vice versa, the data to be calibrated against usually also are stages, from which design discharges have to be inferred from hydraulic rating curves, which also have errors - it is well known, for example, that stage discharge curves for the rising part of a flood wave are different from those of the falling branch.

All models have in common that they need parameters, which usually cannot be derived from first principles but have to be inferred from experimental data, i.e. observations. Such observations are subject to random measurement errors, and an error term has to be used when writing these terms. There are in addition errors due to the fact that the forecasting model is not representing the exact reality, but it is a simplified abstraction of the reality. Differences between reality and modelled reproduction of reality yield another error term. As a consequence, we must expect that no model is completely accurate, and therefore we have to estimate the parameters of the models in such a way that a best fit of observed versus calculated, i.e. forecasted values are obtained.

For design of a forecast model we must determine the model parameters from an optimisation procedure. Let the parameters of the forecasting model be identified by the symbols A, B, C,…. In the language of operations research, this means that we have to define an objective function Z that has to be optimised. It is common practice to use the rms error, or the standard deviation of the observed value x_{ob} minus the forecasted value as objective function. This is different for each forecast interval. We define the time in discrete steps $t = i \cdot \Delta t$, and

the forecast interval becomes $T = m \cdot \Delta t$. The forecast for time interval t+ T is $x_f(i+m)$. We then write the objective function for each time step m:

$$Z(A, B, ... \Big| m) = \sum_{i=0}^{i\,max} \left[x_{ob}(i+m) - x_f(i+m)\right]^2 \tag{1}$$

and for all time steps we obtain:

$$Z(A, B, ...) = \sum_{m=1}^{m\,max} \left\{ \sum_{i=0}^{i\,max} \left[x_{ob}(i+m) - x_f(i+m)\right]^2 \right\} \tag{2}$$

This is the objective function to be minimized, i.e. we have to determine that set of parameters which satisfies the condition:

$$Z^*(A, B....) = \min_{A,B...} \left\{ \sum_{m=1}^{m\,max} \left\{ \sum_{i=0}^{i\,max} \left[x_{ob}(i+m)\right] - x_f(i+m)\right]^2 \right\} \right\} \tag{3}$$

where $x_{ob}(i)$ is the observed quantity after time $t = m \cdot \Delta t$ (assuming a discrete time in steps Δt, so that $t = i \cdot \Delta t$ is the time interval from the beginning of the forecast (i.e. after x_{ob} exceeded a critical value, at which forecasting starts) to the end of the forecast, which occurs at $t_{max} = i\,max \cdot \Delta t$. The parameter set should correspond to the whole period of forecast, although it could be possible also to get an individual set of the results for each value of m.

FORECAST QUALITY

Although the criterion Equation (3) results in the optimum solution under given conditions of a model, i.e. for a given model structure and given data base, there is no indication how good is the forecast obtained from the model. A criterion of the quality of the forecast, which optimises the objective function, Z is obtained if it is seen relative to a potentially better method of forecasting. A quality criterion often used in hydrology is the criterion of Nash and Sutcliffe (1970), which when adapted to the forecasting case and denoted as CNS (m) reads:

$$QNS(m) = 1 - CNS(m) = \frac{\sum_{i=io}^{i\,max} [x_{ob}(i+m) - x_f(i+m)]^2}{\sum_{i=0}^{i\,max} [x_{ob}(i+m) - x_{av}]^2} \tag{4}$$

where x_{AV} is the average value of the quantity x over the time from $i = i_0$ to $i = i_{max}$. It is obtained from:

$$x_{AV} = \frac{1}{n} \sum_{i=0}^{i=i_{max}} x_{ob}(i) \tag{5}$$

Note that this quantity depends on the forecasting time, expressed through parameter m.

The original Nash-Sutcliffe criterion was designed for the whole time series and essentially is a measure of the contribution of forecast error (the numerator of Equation 4) to the variance (the denominator of Equation 4) of the total record. For a perfect fit, the numerator is zero, whereas for a fit, which is no better than the average value the ratio, QNS(m) becomes 1 or larger. By subtracting QNS(m) from 1 the direction of the criterion is reversed, and a good fit, in Nash - Sutcliffe terminology is a value close to 1, a poor fit will lead to a criterion CNS(m) ≤ 0, whereas for QNS(m) the opposite is the case. As adapted to forecasting the Nash Sutcliffe criterion implies that we start the forecast with no information except that obtained from ranking all measured values of forecasts. In that case, the best estimate of the future value is the mean value x_{AV}.

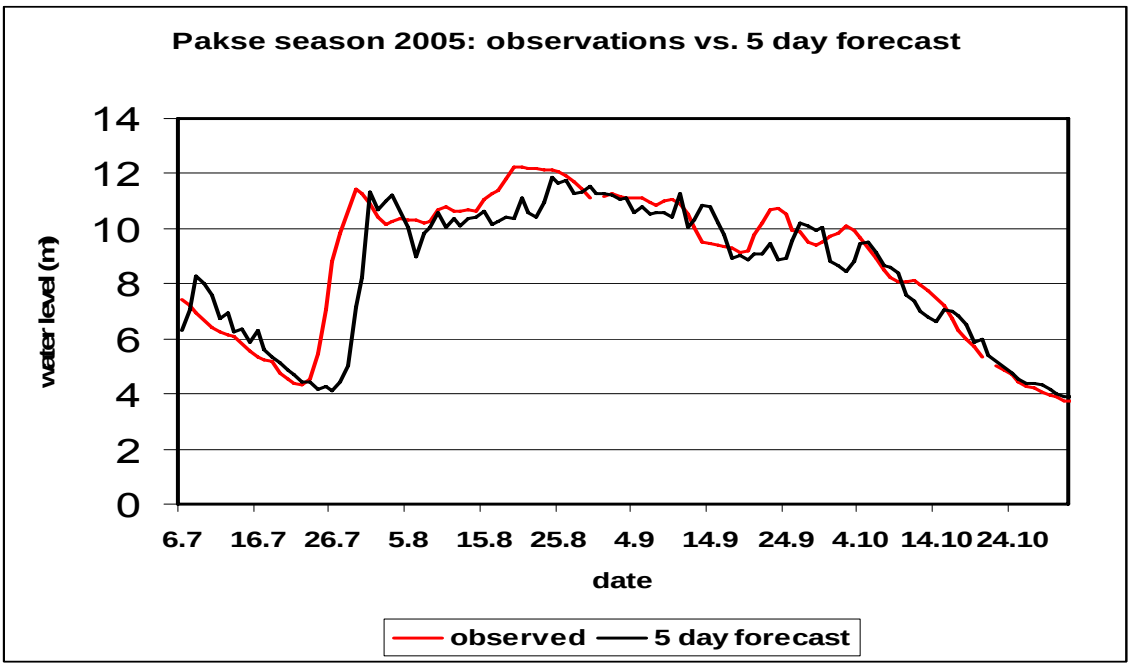


Figure 2. Plot of five day forecast versus actual data: Pakse, flood season 2005

For illustration, an example of a 5-day forecast is shown as function of time in Figure 2. The example forecasts are made by means of the currently available model SSARR for station Pakse, for the 2005 season. From Figure 2 it is seen that a criterion will depend on where beginnings and end of the season are located on the time axis. Because the season starts when the Monsoon rains start, the initial rise of the water surface will be steep and the forecast reaches an early maximum, while later on the deviations from observed values are much smaller. It is fairly obvious that the very large jump during one week from about 4.20 m to 11.20 m cannot be forecasted from the time series alone, additional information from rainfall forecasts or from upstream stations on the river must enter.

Table 1. Nash-Sutcliffe criterion applied to Pakse gage readings for the 2005 season

	Nash-Sutcliffe									
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
Sum:	8.25	906	28.5	902	65.7	900	120.	898	180	897
QNS(m)	0.99		0.97		0.93		0.87		0.80	

In spite of this the application of the CNS(m) criterion to the Pakse data for the season of 2005, starting from July 1 to the end of November yields the favourable results of table 1. In table 1 D(m) is the numerator and E(m) the denominator of QNS(m), as expressed in Equation 4. The sum is extended over the whole season. The quality of the forecast appears to be very good indeed, yielding values close to 1+ - much in contrast to the evidence, which is seen by

looking at the plot of forecasted values and observed values of Figure 2.

A better quality criterion is obtained if we use the fact that at time t_0 we have already some information available, at least the value of the time series to be forecasted at the present time $t = t_0$, as well as earlier values. Let us first look at what happens if we use the present value $x_0(i)$ only. It is evident that for short times (short in relation to a critical time, which depends on the size of the river basin) the requirements for complexity of forecast models are not very high – because the discharge cannot have discontinuities, for physical reasons. If there is no other information available, the best forecast for the near future is to forecast the value at time t_0+T_F, i.e. at $i + m$, as being equal to the value at t_0.

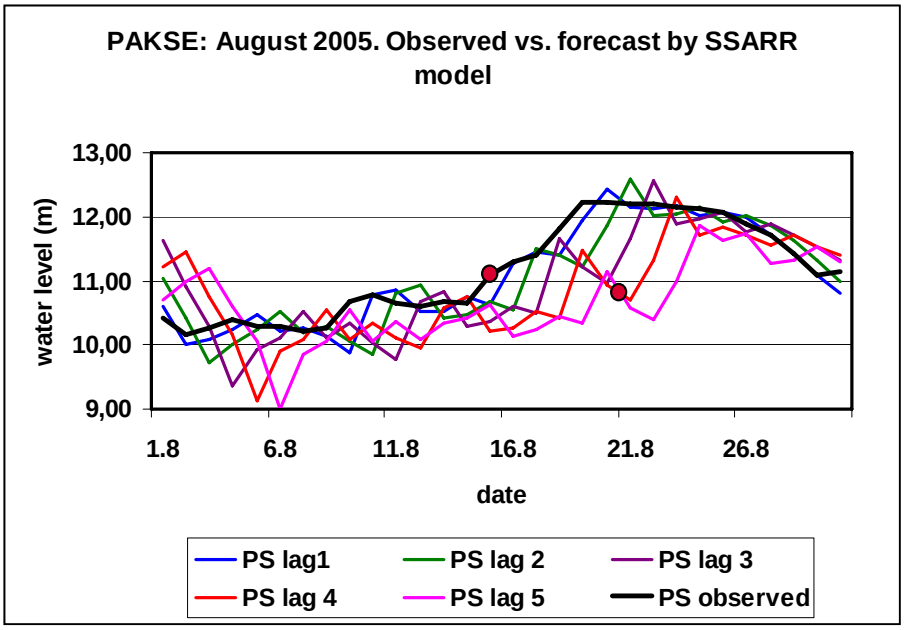


Figure 3. Gage Pakse. August 2005: forecast calculated with the SSARR model.

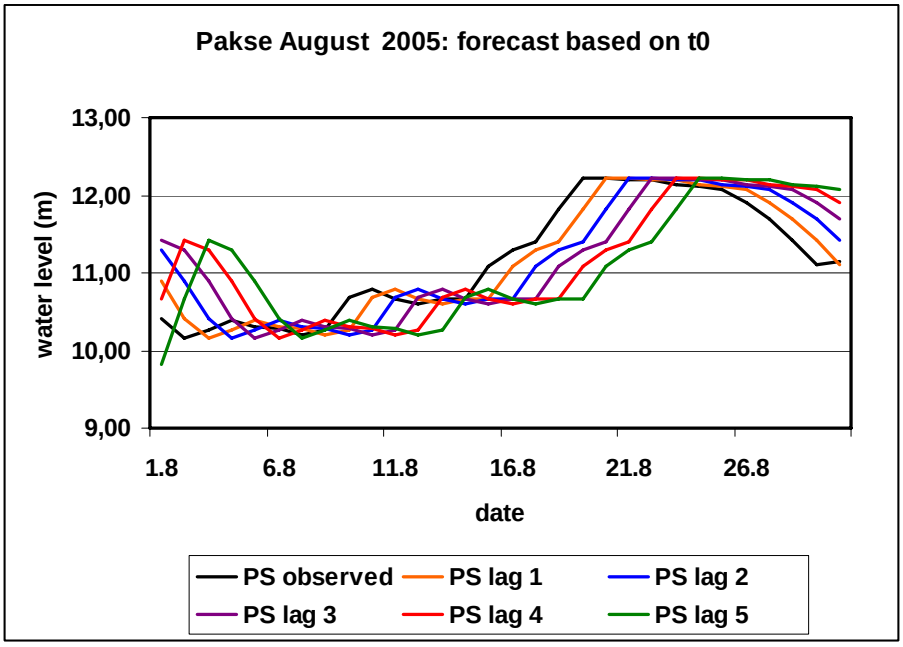


Figure 4. Gage Pakse. August 2005 data: taking $x_0(i)$ as forecast versus observed data.

In Figures 3 and 4 the forecast using the SSARRS model and using the no information model with forecast equal to $x_o(i)$ are shown for Pakse, using the data of August only. Forecasts are shown as family of curves. The figures must be interpreted from one point $x_o(i)$ on the observed gage where a forecast is made for different forecasting times, represented by the other curves. For example, on August 16 we observe a value of 11.30 m, indicated by the red dot on the left in Figure 3 on the observed curve. We make a five days ahead forecast to obtain the right red dot on the lag 5 curve, which has a value of 10.58 m. This value has to be compared with the actual value on the observed curve, which has a value of 12.19 m.

It is seen by comparing Figures 3 and 4 that the forecast using $x_0(i)$ is a reasonable first approximation, in particular for small delay times. The performance of a forecast model, expressed through a forecasted value $x_f(i+m)$ after time $T_F = m\,\Delta t$ should be judged relative to this value. This implies that the deviation of the observed value $x_{ob}(i+m)$ from the present value $x_0(i)$ should be large relative to the deviation of the observed value from the forecasted value $x_f(i+m)$, i.e. from $x_{ob}(t+T_F) - x_o(t+T_F)$. In terms of quadratic deviations (to eliminate the need for sign corrections) we express this condition quantitatively by an index similar in structure to the NS criterion:

$$QI_0(m) = \frac{\sum_{i=io}^{i\,max} [x_{ob}(i+m) - x_f(i+m)]^2}{\sum_{i=0}^{i\,max} [x_{ob}(i+m) - x_0(i)]^2} \tag{6}$$

for which during calibration the sums have to be taken at each time $t = i \cdot \Delta t, \quad i = 1,2,...i_{max}$ for each m, i.e. for each $T_F = m \cdot \Delta t$, where Δt is the time increment. A small value of $QI_0(m)$ indicates good, a large value poor performance, i.e. if $QI_O(m)$ is close to 1, performance of the forecast is not better than taking the value of today (at time t) as forecast for the value at T_F.

Table 2. Kratie season 2005: quality criterion Equation 6 applied to SSARR forecasts.

Kratie season 2005: comparison of SSARR model with equation (6)										
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
Sums	1.58	24.5	9.54	88.7	38.1	178	91.5	280	162	387
Quality	0.06		0.11		0.21		0.33		0.42	

Table 3. Pakse season 2005: quality criterion Equation 6 applied to SSARR forecasts.

Pakse season 2005: comparison of SSARR model with equation (6)										
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
Sums	7.60	16.1	27.8	57.1	65	113	119	178	179	24
Quality	0.47		0.49		0.57		0.67		0.74	

An application of this criterion to the Mekong for station Kratie is shown in Table 2, where D(m) is the numerator and E(m) is the denominator for the m-day ahead forecast. The data are taken for the whole season from 1 July to 31 October. For short lags, the forecast by means of the SSARR model appears to be quite good. For Pakse, the same criterion is somewhat less satisfactory, yielding the values of Table 3. However, one must realize that the performance criterion is very much dominated by the large jump in water level around the end of July. This is evident if we decompose the squared sums into the individual terms, as is illustrated in Figure 5 and 6. For better illustration the vertical axis is scaled logarithmically.

It is seen from Figures 5 and 6 that whereas the dominant influence of the squared deviations comes from the late July jump in value, later fluctuations of the SSARR forecast are due to oscillations, which are not followed by the x0 model. Consequently, the forecast for

August is as good for the xo forecast as for the SSARR forecast. Indeed, if we calculate the quality criterion Equation 6 applied to the SSARR model only for August 2005, corresponding to the records of Figures 3 and 4, we find in Table 4 that the SSARR model is actually performing less well than the xo model, although the differences of observed and forecasted models generally are small, as is evident from the small sums of Table 4 in comparison to values of Table 2 and 3.

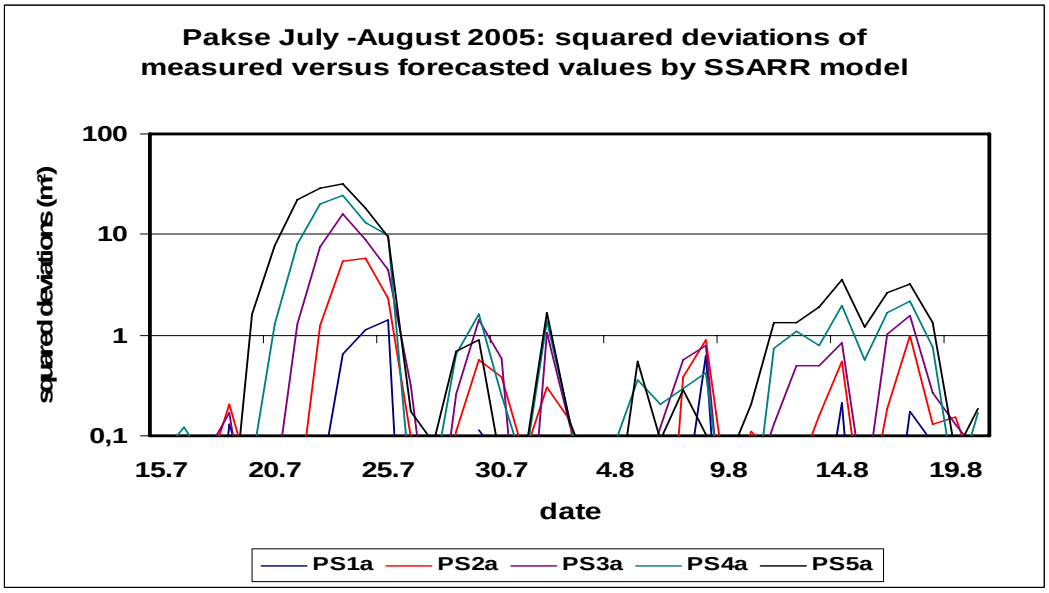


Figure 5. Pakse August 2005: squared deviations for SSARR model (logarithmic scale for better illustration)

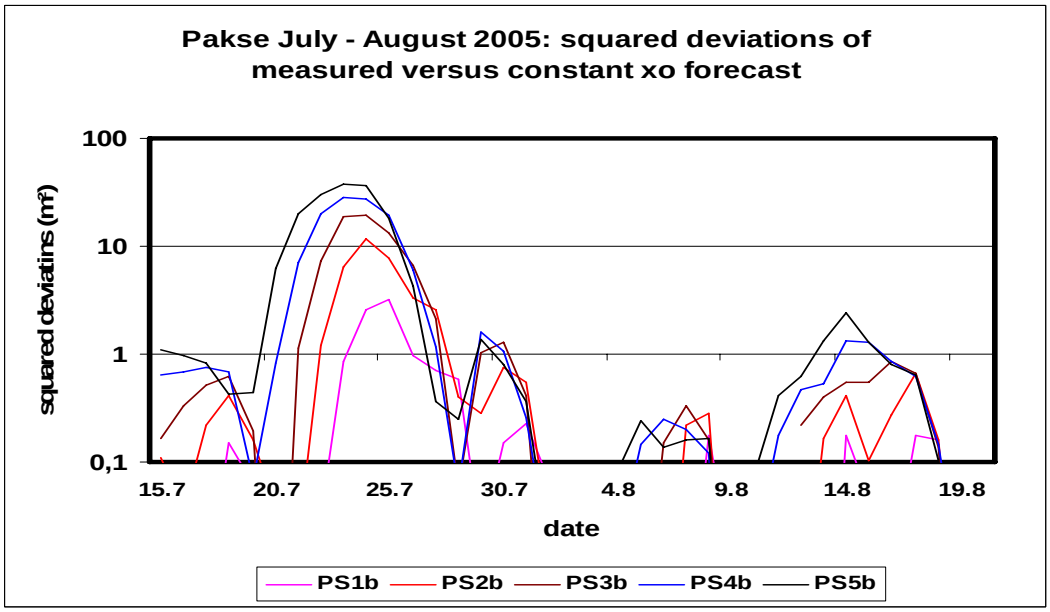


Figure 6. Pakse August 2005: squared deviations for x0 model (logarithmic scale)

Table 4. Pakse August 2005: quality of forecast with SSARR model.

Pakse August 2005: quality criterion equation 6 applied to SSARR model										
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
Sum	1.60	1.18	4.77	3.33	8.54	5.85	13.58	8.88	20.92	12.18
Quality	1.36		1.43		1.46		1.53		1.72	

MODEL IMPROVEMENT POSSIBILITIES

The results presented so far are only used for illustration; a complete evaluation of the performance of the SSARR model is not yet done. Nevertheless it might be useful to consider possible ways to improve the present model on the basis of available information of measured data. The first alternative is to use the result from table 4 and attempt to improve the forecast based on the available time series x(i) only. Using x_0 as forecast yielded fairly good results, and it was thought that further improvements could be obtained if instead of keeping x_o constant, one uses an extrapolation of the trend of the observed time series into the future for time intervals m Δt by means of a Taylor series expansion. This yields:

$$x(t+m\cdot\Delta t) = x_o(t) + \frac{\partial x}{\partial t}\cdot m\cdot\Delta t + \ldots \Rightarrow \qquad x_o(i) + \frac{x(i-1)-x_o(i)}{\Delta t}\cdot m\cdot\Delta t = x_1(i+m) \tag{7}$$

for which the quality criterion becomes:

$$QI_1(m) = \frac{\sum_{i=io}^{i\,max}[x_{ob}(i+m) - x_1(i+m)]^2}{\sum_{i=0}^{i\,max}[x_{ob}(i+m) - x_0(i)]^2} \tag{8}$$

Application of this criterion to the data of Pakse yields the result of Table 5. For the first two lags the model performs better than the xo forecast, but for larger distances it no longer works well: the large addition of a linear term causes the forecast from this model to regularly overshoot the actual value. Consequently, this improvement is not very useful for long term forecasting, but it may help for short times, because it reduces the effect of the large jump.

Table 5. Pakse season 2005: Performance of x_1 model.

Pakse season 2005: comparison of x0 model versus criterion equation (8)										
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
Sum	7.83	16.5	39.6	57.0	107	113	227	177	401	244
Quality	0.47		0.69		0.95		1.28		1.64	

A second possibility for the improvement of the model on the basis of available information from the SSARR model is to use the fact that the SSARR model seems to cause significant fluctuations, as is evidenced in Figure 3. The oscillations of the SSARR model are not followed by the x_0 forecast model, which is the reason for the poor performance of criterion Equation 6 for the August season. A possibility of reducing the oscillations is to combine the forecast of the SSARR model x_f (i+m) with the value x_o(i) to obtain some damping of the fluctuations. The criterion adapted to this case becomes:

$$QI_{mod}(m) = \frac{\sum_{i=io}^{i\,max}\{x_{ob}(i+m) - \frac{1}{2}[x_1(i) + x_f(i+m)]\}^2}{\sum_{i=0}^{i\,max}[x_{ob}(i+m) - x_0(i)]^2} \tag{9}$$

When this criterion is applied to the season of 2005 to the data of Pakse (or Kratie)

significant improvements are obtained, in particular for large lags, as can be seen from Table 5. However, this improvement is mostly accomplished for the big jump of end of July. If one concentrates on the results of August only, one finds that the quality of the forecast by this model is about the same as the quality of forecast without any information except x(i). This is seen from Table 6.

Table 5. Modified SSARR model performance compared with Eq.6 for Pakse, 2005 season

Pakse season 2005: comparison of modified SSARR model versus criterion equation (6)										
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
Sums	13.3	16.7	29.1	57.9	13.7	115	13.6	180	19.3	246
Quality:	0.80		0.50		0.12		0.08		0.08	

Table 6. Modified SSARR model compared with Equation 9 for Pakse, August 2005.

Pakse august 2005: modified SSARR model versus criterion equation (6)										
	D(1)	E(1)	D(2)	E(2)	D(3)	E(3)	D(4)	E(4)	D(5)	E(5)
sums	1.16	1.18	3.56	3.33	6.32	5.85	9.84	8.88	14.01	12.18
quality	1		1.1		1.1		1.11		1.15	

CONCLUSIONS

The paper is exploratory in nature. We have at this time only worked with data sets from Pakse and Kratie, as we are looking first of all to identify a means of quantifying the value of improvements of the SSARR model. The quality criteria for the cases considered for both these stations show that the largest uncertainty arises from forecasting the large changes of water level at the beginning of the monsoon season. Obviously, this uncertainty can be reduced only if rainfall (or weather) information is included in the forecast. Apart from this we have found that for short term forecasting (one or two days ahead) an approach using either the value at the day of forecast or the average of the day of forecast and the forecasted value yields better results than the original SSARR model.

Our next steps will be to explore the possibility of the models described above for all stations upstream of Phnom Penh. We shall further try to develop a criterion by means of which we can better evaluate the performance of the forecast. We hope to report further progress at the next forum.

REFERENCES

Apirumanekul, C., 2006. Flood forecasting in the Mekong River Basin: an improvement plan for the flood forecasting system. International Conference on Mekong Research for the People of the Mekong, 18 -21 October, Chiang Rei, Thailand

Loucks, D.P. and E. van Beek, 2005. Water Resources Systems Planning and Management. UNESCO Studies and Reports in Hydrology. UNESCO Publishing. UN (2006): Water: a shared responsibility. The United Nations World Water Development Report 2 UNESCO & Berkhahn Books, 436 pages

Nash, J.E. and J.V. Sutcliffe, 1970. River flow forecasting through conceptual models. Part I — A discussion of principles, Journal of Hydrology, Vol.10 , pp. 282–290.

Plate, E.J., 2007. Early warning and flood forecasting for large rivers with the lower Mekong as example. Journal of Hydro-environment Research Vol.1 pp. 80-94

Plate, E..J. and T. Insigsiengmay, 2005. Early warning systems for the Lower Mekong River. Water International, Vol.30, pp.99-107

Plate, E.J., J. Ihringer and W. Lutz, 1988. Operational models for flood calculations. In: Journal of Hydrology, Vol.100, 1988, pp. 489-506

Tanaka, H., 1999. Flood forecasting of the Mekong River in 1997. In: FAO/RAP Publication 1999/14, FAO Bangkok, pp. 109-117

FLOOD RISK FORECASTING FOR POORLY GAUGED BASINS IN THE MEKONG RIVER BASIN USING A DISTRIBUTED HYDROLOGICAL MODEL AND A SATELLITE DERIVED PRECIPITATION DATASET

JUN MAGOME, KAZUHIKO FUKAMI, HIRONORI INOMATA AND KUNIYOSHI TAKEUCHI

International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO, Public Works Research Institute (PWRI), Tsukuba, Ibaraki, Japan

ABSTRACT

In order to achieve effective flood risk forecasting for poorly gauged sub-basins in the Mekong River Basin, the feasibility of using a currently available distributed hydrological model and satellite-based precipitation datasets coupled with a simple statistical approach is discussed in this paper. A physically based distributed hydrological model, the YHyM/BTOP model, was used in this paper to simulate at any grid for the whole Mekong River Basin, including poorly gauged basins. Historical discharge data for the past 29 years were reconstructed and archived with validation using ground-based observed hydro-meteorological data with other public domain datasets as input. A preliminary study on the real-time flood risk assessment interpreted from the percentile of simulated discharge from the discharge database referring observed river discharge is consequently conducted utilising satellite-based precipitation datasets Global Satellite Mapping of Precipitation (GSMaP) and Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) data. Simulated discharge by the YHyM/BTOP model using satellite-based precipitation generally represents the trend of observed discharge well and the possibility of real-time flood risk assessment was well demonstrated.

INTRODUCTION

The Mekong River basin, especially the Lower Mekong River basin (LMB), is known for frequent flood inundations occurring almost every year. Therefore, more than half of the LMB residents are living with floods, and are partly benefited through fisheries and agricultural gains in the flood plain (Mekong River Commission (MRC), 2003). However, huge environmental, social and economic damages are also caused frequently due to heavy rain and strong tropical storms. These flood disasters often affect not only the immediate surroundings of the main river channel but also broad sub basins, e.g. the tropical storm Xangane in October 2006 (Mekong River Commission (MRC), 2007; Dartmous, 2008). Thus, flood risk forecasting for these sub-basins in the Mekong River Basin is a priority issue in developing an efficient flood disaster management system for the entire basin. Therefore, a grid based distributed hydrological model, capable of simulating and forecasting flood risk at any given location in the basin based on the river discharge, is required. In addition, real time and short to mid-term flood forecasting are also important in order to reduce the economic and social losses by effectively disseminating the flood forecasts to the residents in these regions by local water management sectors. For effective flood risk forecasting, especially in poorly gauged sub-basins, in the Mekong River Basin, the lack of hydro-meteorological data and difficulty in accessing and collecting these data are serious issues and it is strongly desired to overcome the lack of data using satellite derived datasets. For the flood risk assessment, precipitation data is the most important input data in the hydrological simulations. At present, various kinds of satellite derived precipitation

datasets, e.g. GPCP1DD, CMORPH, PERCIANN, SCaMPR, are developing and stating to provide data through the web/ftp site. Despite these precipitation dataset has been available, there have been no sufficient research carried out for flood risk forecasting not only in gauged sub-basin but also in poorly gauged sub-basins in Mekong River Basin. In this study, the feasibility of flood forecasting using a currently available distributed hydrological model and satellite delved precipitation datasets by means of a statistical approach has been studied. YHyM/BTOP Model is applied and historical discharge data for the past 29 years were reconstructed and archived through simulations using available ground-based observed hydro-metrological data, with other public domain datasets as input. Consequently, a preliminary study on the real-time flood risk assessment utilising satellite derived precipitation datasets for short- to mid-term forecasts is conducted using as GSMaP (Global Satellite Mapping of Precipitation) and TMPA (TRMM Multi-satellite Precipitation Analysis) data.

YHyM AND BTOP MODEL

Grid-based integrated distributed hydrological model YHyM originally developed at the University of Yamanashi (Japan) and BTOP model (The block-wise use of TOPMODEL) as its core module had been started to develop specially for large river basin from 1998 (e.g. AO et al., 1999, Takeuchi et al., 1999, 2007; Zhou et al., 2006; Hapuarachchi et al., 2007). In this study, the latest version of the YHyM and BTOP model has been applied.

The YHyM is an integrated hydrological simulation system, which consists of core 'BTOP model' as described below and advanced sub models. These sub modules are meso-scale precipitation module, a potential evaporation module, a snow accumulation/melt module, frozen soil module, sub-surface model, sediment movement module, inundation module, water quality model and water use/control module (dam, irrigation) and each sub-modules are able to select based on object of application of model. In this application, potential evaporation model and snow accumulation/melt model are used together with core model for simulation for Mekong River basin. Furthermore, Muskingum-Cunge Method (Cunge, 1969, Takeuchi et al., 1999, Ao et al., 2000) is mainly used. The core 'BTOP model' is formed by topographic model, runoff generation model, flow routing model and parameter identification module. For runoff generation concept is an extension of the original TOPMODEL (Beven et al., 1979, 1992) to large river basins. This extension was made by redefining the topographical index by using an effective contributing area per unit grid cell area instead of the upstream river basin area per unit contour length and introducing a concept of mean ground water travel distance. Furthermore, transmissivity parameter was also replaced by a groundwater dischargeability which can provide a link between hill slope hydrology and macro hydrology. Yet the BTOP model uses all the original TOPMODEL equations in their basic form (Takeuchi et al., 2007).

DATA USED AND MODEL APPLICATION

Model parameters and required data to apply the YHyM/BTOP model are listed in Table 1 and Table 2. The whole basin is divided into nine sub-basins considering the natural sub-basins and the Köppen climate classification data (e.g. Kottek et al., 2006). The simulated spatial resolution of grid cells is 2' x 2' (about 3.6 km x 3.6 km) and the temporal time step is one day. At each time step, the water balance is updated at the end of the day and all the rainfall is considered as input at the beginning of the day regardless of the temporal distribution of the event. In the calibration process, the observed discharge from 11 gauging stations and the precipitation measured at 65 gauging stations over the basin are used (Figure 1). Spatially distributed monthly average potential interception and evapotranspiration, and daily snow pack and snowmelt are accounted for. However, the effects of dam operations, irrigation water use, and flood inundation are not considered in this study due to difficulty to obtain the data. In this

application, the model parameters including block-average Manning's roughness coefficient (n_0), drying function parameter (□), groundwater dischargeability (D) and its decay factor (m) are identified through trial and error calibration while the other parameters (Table 1) are guessed based on literature values and then slightly adjusted. The maximum storage capacity of root zone ($S_{rz\ max}$) is assigned to each grid cell based on the soil texture type and the root depth (d_{rz}) from the land cover map.

Table 1. Parameters of the BTOP model

Model component	Parameter	Extent
Runoff Generation parameters	Decay factor (m)	Block
	Drying function parameter (□)	Block
	Coefficients of dischargeability D ($D_{0\ sand}$, $D_{0\ silt}$, $D_{0\ clay}$)	Basin
	Soil freezing threshold temperature (T_t)	Basin
Routing parameters (Muskingum-Cunge)	Spatial discretization of a channel segment(□l)	Basin
	Temporal discretization of flow in a channel segments(□t)	Basin
	Block average Manning's coefficient (n_0)	Block
Snow model parameters	Threshold temperature of snow accumulation Basin	Basin
	Degree-day index	Basin
	Threshold temperature of snowmelt beginning	Basin
	Parameter for snow-pack yield method Basin	Basin
	Re-freezing coefficient Basin	Basin

Table 2. Basic data used in the Mekong River application

Type	Description	Source	Original spatial resolution	Remarks
Physical Data	Digital Elevation Model (DEM)	USGS-GTOPO30	30 s	Global data
	Soil Map	FAO-DSMW	0.25 deg.	Global data, 1995
	Soil Properties	FAO	-	USGS soil triangle (Rawls et al., 1982, 1985)
	Land Cover Type	GLCC/IGBP V2	30 s	Global data, April 1992 to March 1993
	Root depth	-	-	(Sellers et al., 1994, 1996)
	River width	-	-	Calculated based on the upstream area; (Lu et al., 1989)
	NDVI	NOAA-AVHRR	8 km	Monthly data, 1981–2000
Hydro-meteorological data	Precipitation (daily)	MRC	Gauged	65 stations, from 1972 to 2000
	Mean Temperature (daily)	MRC	Gauged	24 stations, from 1972 to 2000
	Cloud cover Daylight duration Diurnal temperature range Extraterrestrial radiation Vapour pressure Wind speed	CRU TS 2.0	0.5 deg.	Global, monthly data from 1901 to 2000. Used for he potential evapotranspiration model in YHyM
	Observed discharge (daily)	MRC	Gauged	11 stations, from 1972 to 2000.

Furthermore, GSMaP (Okamoto et al., 2005, 2007) and TMPA (Huffman et al., 2007)) datasets are used as a preliminary analysis of feasibility of flood forecasting using satellite based precipitation datasets with distributed hydrological model. Table 3 shows satellite-derived precipitation dataset used in this study. These dataset are now available through their web site.

In this paper, the results using GSMaP MWR (Kubota et al., 2007) and TMPA-3B42 V6 are shown. The GSMaP MWR products are made by combining GSMaP TMI, which is derived from TRMM/TMI satelliteborne microwave radiometers, and precipitation estimates from other microwave radiometers such as SSM/I, AMSR and AMSR-E. TMPA 3B42 V6 uses an optimal combination of 2B-31, 2A-12, SSMI, AMSR and AMSU precipitation estimates and finally scales to match the monthly rain gauge analyses used in 3B-43. Both precipitation datasets cover by 0.25x0.25 degree grid boxes every 3 hours.

Table 3. Used and tested satellite precipitation dataset

Name	Data period	Coverage spatial resolution	Temporal resolution
GSMaP, MWR (JST-CREST/GSMaP)	1998-2006	Global(N60-S60) 0.25	hr, d, m, cl
GSMaP, MWR+ (JST-CREST/GSMaP)	2003-2006	Global(N60-S60) 0.25	hr, d, m
GSMaP MVK (JST-CREST/GSMaP)	2003-2006	Global(N60-S60) 0.1	hr, d
GSMaP MVK+ (JST-CREST/GSMaP)	2003-2006	Global(N60-S60) 0.1	hr, d
TMPA3B42 V6 (NASA/GSFC)	1998-current	Global(N50-S50) 0.25	3 hr
TMPA3B42 RT (NASA/GSFC)	2002-current	Global(N60-S60) 0.25	3 hr (6 hour after)

hr = hourly, d = daily, m = monthly, cl = climatology

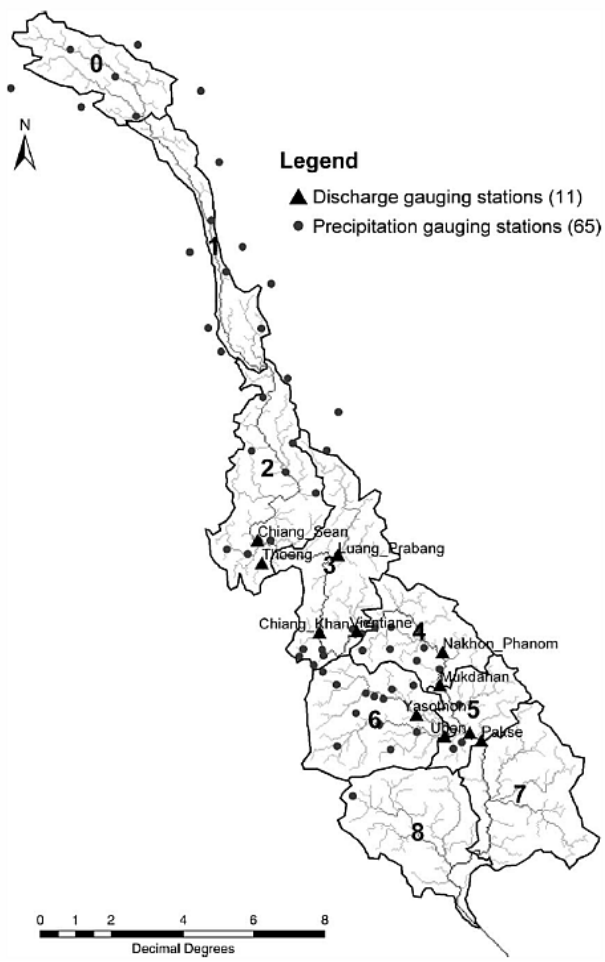


Figure 1. The Mekong River basin and hydrological gauging station used in this study

RESULTS AND DISCUSSION

Calibration and reconstructing of past 29 year discharge at any location

In this study, the hydrological data (daily data) from 1972 to 2000 are used for calibrating the model parameters in order to well detect the peak flow timing and not to underestimation of flood peak for flood forecasting purpose. Output results of YHyM/BTOP had been archived as database for every grid cell. The model performance (using gauged precipitation data) are validated selected stations for the calibration and validation periods, here as an example, simulated and observed hydrographs at Pakse (Figure 2) station during the period 1972 to 2000 is shown. The overall model performance in the validation period is good. The volume ratio and Nash-Sutcliffe coefficient are 107%, 85% respectively. In addition, the model accuracy have been checked in terms of other simulated elements such as potential evaporation, storage water in root zone, unsaturated zone and so on) at the other discharge gauging stations of some sub-basins, results are acceptable accuracy, which is extremely important for archiving these result to use the water resources management and planning through future analysis.

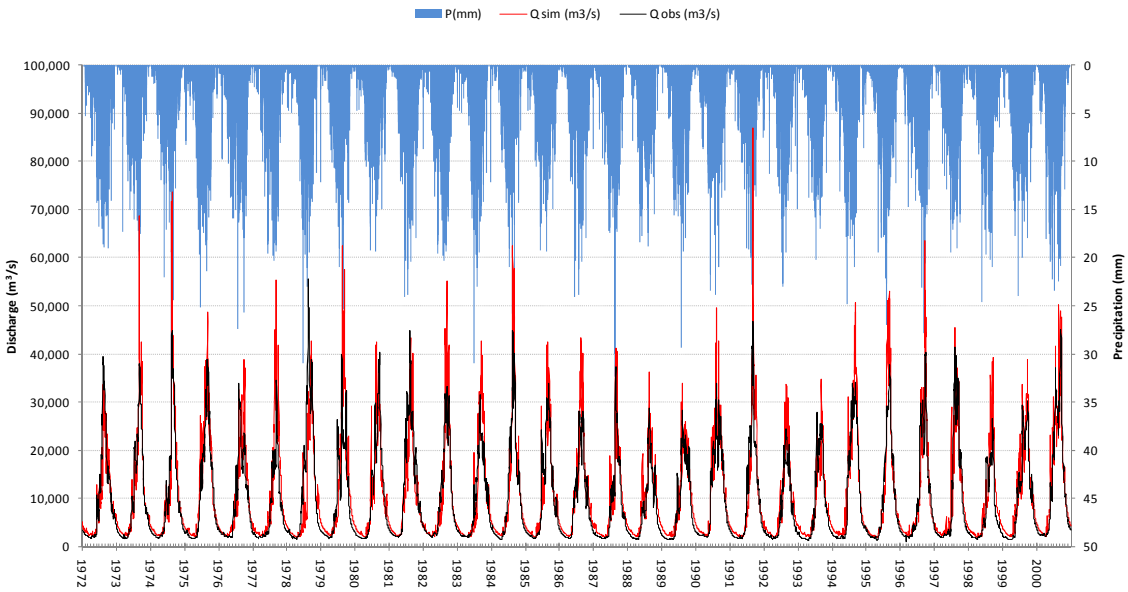


Figure 2. 29 year simulation result compared with observed discharge and precipitation. (1972 to 2000 at Pakse)

Applicability of a distributed hydrological model and satellite derived precipitation

In order to examine applicability of available satellite derived precipitation dataset and its subsequent effects to simulated discharge, satellite derived precipitation dataset listed Table3 were applied to YHyM BTOP model. From these precipitations, GSMaP MWR and TMPA-3B42V6 applications at Pakse gird results for 1998 to 2000 shown Figure4 and overall model performance is shown in Table 4. Even though results of GSMaP MWR were underestimated, TMPA-3B42V6 result is similar to the case using ground gauged precipitation data. The underestimation of discharge by GSMaP is caused mainly from under estimation of precipitation (Figure 5). However, general trend seems to be observed one. Therefore, simple correction method, used uniform correction coefficient for each grid value in GSMaP MWR based on ground gauged precipitation in order to keep basin average precipitation is applied. As a result, simulated discharge became similar Nash coefficient of TMPA-3B42V6 and case used

ground gauged precipitation data. Thus, it is able to consider that the pattern of the variation of discharge can be simulated even by only the satellite based precipitation dataset.

Evaluating feasibility of flood forecasting

As a preliminary study, the discharge value exceeded 90 percentile had been assumed and set as flood discharge and 80 percentile is set as alarm discharge based on 29 years discharge database described previous section and MRC information. Using these percentiles for each simulated discharge time series, probability of prediction (POD) was calculated. The results at Pakse grid are listed in Table 4. In case of flood alarm, all POD values are good like 68% (GSMaP-MWR), 89% (GSMaP-MWRM) and 81% (TMPA-3B42) compared to 87% (GP). A remarkable point is that even GSMaP-MWR case, which had bias also predicted relatively good about 70% of flood alarm level. For flood case, detection level were decreased, however their results would be better considering there is many uncertainty caused from input precipitation and other error, model parameter and so on. Thus flood forecasting by distributed hydrological model using satellite precipitation dataset is considered to be possible.

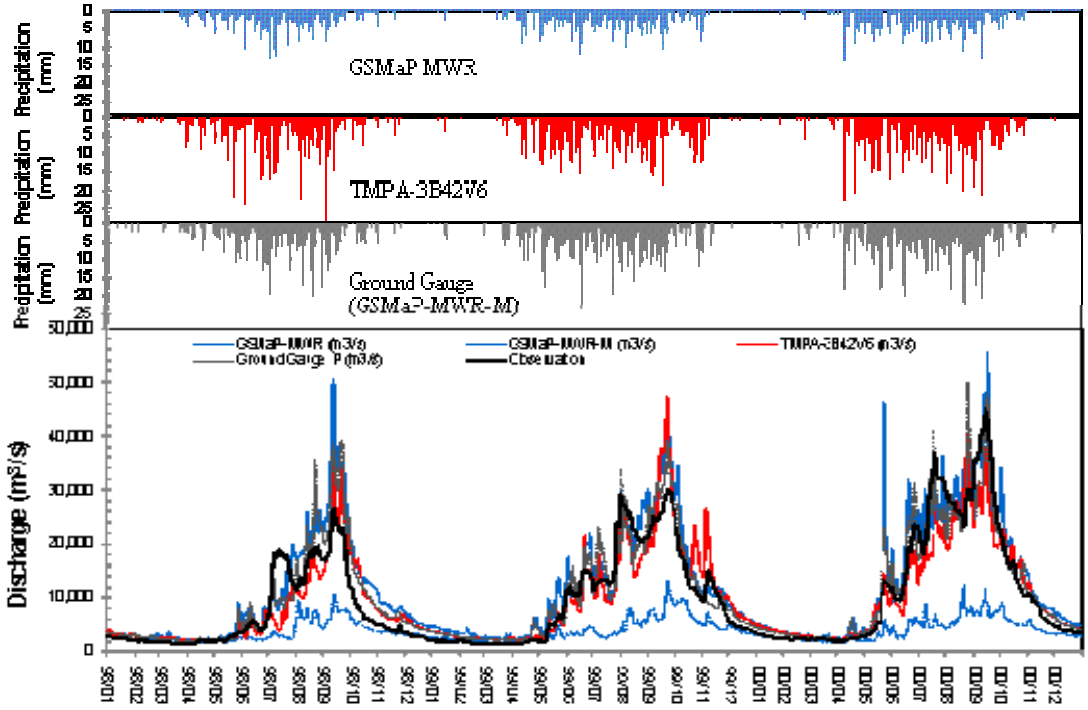


Figure 3. Simulation results by satellite precipitation dataset at Pakse for 1998 to 2000

SUMMARY

In this paper, latest version of YHyM/BTOP model was applied to whole Mekong River basin and historical discharge data for the past 29 years were reconstructed at all grid cell and archived using ground-based observed hydro-metrological data with other public domain datasets. Satellite-based precipitation datasets GSMaP and TMPA were applied to simulate discharge by YHyM/BTOP model. Overall trend of discharge is able to represent and possibility of flood risk assessment was indicated. An advantage of applying grid based distributed hydrological model is capability of simulating and forecasting flood risk at any locations even in sub-basin. Therefore, simulated discharge should be validated more at especially sub-basins of Mekong River basin obtaining more ground gauged data to compare. Development of correction method for satellite precipitation dataset is also required.

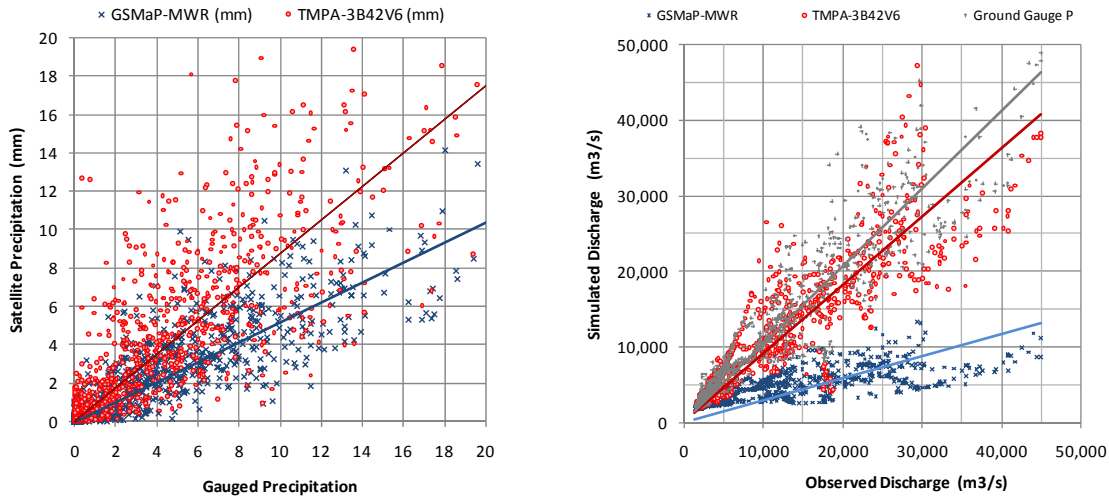


Figure 4. Satellite precipitation and simulated discharge compared to ground gauged precipitation (areal average) and discharge (Pakse for 1998 to 2000 daily matching)

Table 4. Discharge simulation performance and probability of detection of flood

	GSMAP MWR	GSMAP MWR-M	TMPA 3B42V6	GROUND GAUGE
Q simulated performance (volume ratio)	41%	121%	101%	110%
Q simulated performance (Nash-coefficient)	-95%	83%	78%	87%
POD(90 percentile : assumed flood level)	43%	65%	74%	70%
POD(80 percentile : assumed alarm level)	68%	89%	81%	87%

REFERENCES

Ao T, Ishidaira H, Takeuchi K, 1999. Study of distributed runoff simulation model based on block type TOPMODEL and Muskingum-Cunge method. Annual Journal of Hydraulic Engineering, JSCE 43: pp7-12 (in Japanese).

Ao T, Ishidaira H, Takeuchi K. 2000a. On problems and solutions of the Muskingum-Cunge routing method applied to a distributed rainfall unoff model. Annual Journal of Hydraulic Engineering, JSCE 44:139–144. (in Japanese).

Beven, K.J., Kirkby, M.J., 1979. A physically based, variable contributing area model of hydrology, Hydrol. Sci.Bull. 24-1, pp43-69.

Beven, K.J., Binley, A.M., 1992. The future of distributed models: model calibration and predictive uncertainty, Hydrol. Processes, 6, p279-298.

Cunge, J.A., 1969. On the subject of a flood propagation computation method (Muskingum method), Journal of Hydraulic Researches, Vol. 7, No. 2, p205-230.

Dartmouth Flood Observatory, http://www.dartmouth.edu/~floods

Hapuarachchi, H.P. Kuniyoshi Takeuchi, Maichun Zhou, Anthony Stuart Kiem, Mikhail Georgievski, Jun Magome4 and Hiroshi Ishidaira, 2008 Investigation of the Mekong River basin hydrology for 1980–2000 using the YHyM, Hydrological Processes, DOI: 10.1002/hyp.6934.

Hsu, K., X. Gao, S. Sorooshian, and H. V. Gupta, 1997. Precipitation estimation from remotely sensed information using artificial neural networks. Journal of Applied Meteorology, 36, ppz1176-1190.

Huffman, G.J., R.F. Adler, D.T. Bolvin, G. Gu, E.J. Nelkin, K.P. Bowman, Y. Hong, E.F. Stocker, D.B. Wolff, 2007: The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. J. Hydrometeor., 8(1), 38-55.

Huffman, G.J., R.F. Adler, M.M. Morrissy, D.T. Bolvin, S. Cutris, R. Joyce, B. McGavock, and J. Susskind, 2001. Global precipitation at one-degree day resolution from multisatellite observations, J.Hydromet., Vol. 2, pp36-50

Joyce, R. J., J. E. Janowiak, P. A. Arkin and P. Xie, 2004. CMORPH: A Method that Produces Global Precipitation Estimates from Passive Microwave and Infrared Data at High Spatial and Temporal Resolution. Journal of Hydrometeorology, 5(3), pp487–503.

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006. World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263. DOI: 10.1127/0941-2948/2006/0130.

Kubota, T., S. Shige, H. Hashizume, K. Aonashi, N. Takahashi, S.Seto, M. Hirose, Y. N. Takayabu, K. Nakagawa, K. Iwanami, T.Ushio, M. Kachi, and K. Okamoto, 2007. Global precipitation map using satelliteborne microwave radiometers by the GSMaP Project: Production and Validation, IEEE Trans. Geosci. Remote Sens.,Vol.45, No. 7, pp2259-2275.

Kuligowski, R. J., 2002. A self-calibrating GOES rainfall algorithm for short-term rainfall estimates. Journal of Hydrometeorology, 3, pp112-130.

Mekong River Commision, 2007. Annual Annual Mekong Flood Report 2006, http://www.mrcmekong.org/flood_report/2006/

Okamoto, K., T. Iguchi, N. Takahashi, K, Iwanami, and T. Ushio, 2005. The global satellite mapping of precipitation (GSMaP) project, the25th IGRASS Proceedings, pp3414-3416

Okamoto, K., T. Iguchi, N. Takahashi, T. Ushio, J. Awaka, S.Shige, and T. Kubota, 2007., High precision and high resolution global precipitation map from satellite data, ISAP Proceedings, pp506-509.

Seto, S., Yoshimura, K. and Oki, T., 2008. Dimulations of flood detection all over japan by using high-resolution satellite precipitation maps, Annual Journal of Hydraulic Engineering, JSCE 52: pp355-360 (in Japanese)

Takeuchi, K., Ao, T.Q., Ishidaira, H., 1999. Introduction of block-wise use of TOPMODEL and Muskingum-Cunge method for the hydro-environmental simulation of a large ungauged basin, Hydrol. Sci. Journal, Vol. 44, No. 4, p633-646.

Takeuchi, K., Hapuarachchi, P., Zhou, M.C., Ishidaira, H. and Magome, J., 2007. A BTOP model to extend TOPMODEL for distributed hydrological simulation of large basins. Hydrological Processes, DOI: 10.1002/hyp.691.

Zhou, M.C., Ishidaira, H., Hapuarachchi, H.P., Magome, J., Kiem, A.S., Takeuchi, K., 2006. Estimatingpotential evapotranspiration using Shuttleworth-Wallace model and NOAA-AVHRR NDVI data to feed a distributed hydrological model over the Mekong River basin. Journal of. Hydrol. Vol. 327, No. 1-2, p151-173.

IMPROVING THE METEOROLOGICAL NETWORK IN CAMBODIA

LONG SARAVUTH[1], KATRY PHUNG[2] AND BOB PENGEL[2]

[1]*Department of Meteorology, Ministry of Water Resources and Meteorology, Cambodia*
[2]*MRC Regional Flood Management and Mitigation Centre, Phnom Penh*

ABSTRACT

The situation of the meteorological network of Cambodia is problematic. Until recently years of economic hardship and the prevailing security situation meant that very few improvements were possible and parts of the system even fell into disrepair. Since 2007, an ambitious though still underfunded effort for improvement has been underway, and the first results are now evident.

Increased and targeted funding of the Cambodian Ministry of Water Resources and Meteorology has been used to bring the payment of the observers to a more reasonable level, and to pay them throughout the year, ensuring continuity of records. Government funds have also been used to repair and upgrade three important manual stations at Kompong Thom, Pursat and Battambang. For 2008 the Minister has approved 109 million Riel (4000 Riel is approximately 1 US $) to upgrade three more stations.

External funding is now used in a concerted effort with the Regional Flood Management and Mitigation Centre of the Mekong River Commission; the objective is to upgrade manual rainfall stations to enable daily delivery, and to establish new stations in order to improve the network coverage. The Japanese International Cooperation Agency provided very important support in setting up the GTS link (Global Transmission System of the WMO, or World Meteorological Organisation) and is conducting on the job training and support. A request for rehabilitation and upgrading of the network of automatic weather stations will be submitted through the WMO Voluntary Co-operation Programme.

While the road ahead is long and difficult, a number of important steps were taken, and the direction is now clear. With continued targeted assistance and sustained efforts from its motivated staff and management the Department of Meteorology (DOM) will be able to become a fully integrated and respected member of the international WMO community.

INTRODUCTION

The Department of Meteorology is part of the Ministry of Water Resources and Meteorology, and is the National Meteorological Organisation of Cambodia. It is the representative of the WMO, as Cambodia is a WMO member. The organisational chart is shown in Figure 1.

The head office is located in Dangkor District, Phnom Penh, near the national airport. Provincial offices are located in all provincial capitals. The DOM situation is problematic; until recently the prevailing security situation made access to stations difficult and years of economic hardship meant that there were serious budget constraints. Maintenance of the buildings and network was hardly possible for a long time, and very few improvements were realised. Parts of the system fell into disrepair, and new systems failed due to a lack of funding for operation and maintenance and the capacity of the staff to operate the systems. Since 2007 an ambitious, though still seriously underfunded effort for improvement is underway, and the first results are now showing. The connection to the regional hub of the GTS of WMO was an important step forward. The challenge now is to upgrade the meteorological network of Cambodia to ensure sufficient, timely and reliable data will become available in increasing quantities, to be shared with the world meteorological community through this GTS link.

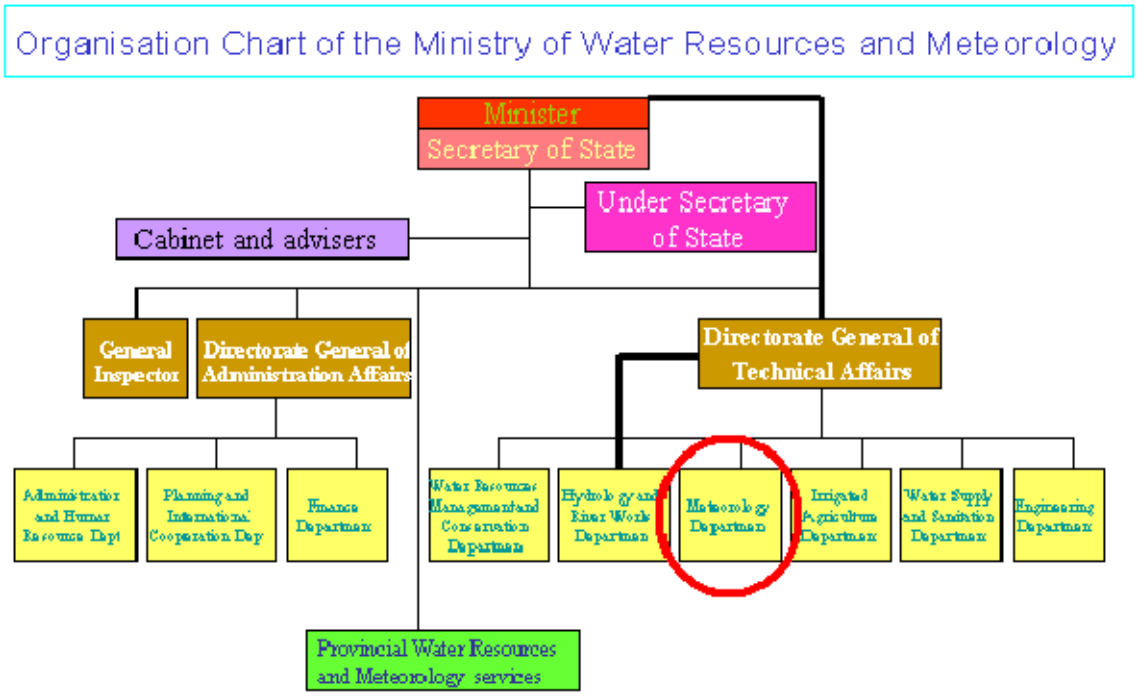


Figure 1. Organisational setting of DOM

METEOROLOGICAL NETWORK

The meteorological network of the DOM has 21 synoptic stations (Figure 2). The readings are collected by on-site observers and presently communicated to the head office in Pochentong by VHF radio or telephone. None of the 9 automatic stations is currently fully operational, and telemetry has not been installed. The 12 manual stations also have problems and lack instruments. The data of four of the synoptic stations are presently shared through the Global Transmission System (GTS) of the WMO.

The DOM has a total of 200 manual rainfall stations in the country, of which about 125 are operational. Rainfall data are 12-hour totals, read at 7.00 hr and 19.00 hr (0:00 and 12:00 GMT). For some of the stations the coordinates are not available. Observers are volunteers, who receive a small compensation for their important work. They live near the station and are trained regularly in the DOM office in Phnom Penh. Data from the manual rainfall stations are recorded in paper logbooks, which are send to the DOM head office every year. In general the dataset for one year is processed three to six months afterwards. DOM is presently working on digitising its valuable store of meteorological data; meteorological data collection in Cambodia started already in 1919.

The staff members have an adequate academic background but are in need of specific skills training to fully use the potential of available modern techniques of weather forecasting and systems like the GTS.

Analysis of the Hydromet Network in the Lower Mekong River Basin

The analysis of the rainfall network carried out under several projects (Mekong River Commission Secretariat, March 2001 and others) consistently shows that for Thailand and Viet Nam the average coverage is sufficient but the spatial distribution needs improvement. Mostly Cambodia and the Lao PDR suffer from inadequate network coverage. It is also mentioned that

‘the network operation and maintenance problems are serious in Cambodia and the Lao PDR’ while Thailand and Viet Nam need only limited support for operation and maintenance (O&M) (Mekong River Commission Secretariat (MRCS), 2001).

Figure 1. 21 Synoptic stations in Cambodia

Because capacity building was a major objective in recent hydrological network support projects, state of the art telemetry equipment and rainfall and water level loggers were installed. Because of the earlier mentioned lack of resources for O&M these projects and instruments have often been beset by problems. For instance, the Appropriate Hydrological Network Improvement Project (AHNIP) network, while 90% operational by late 2007, has been operating at a capacity of around 50% or less since mid-2006.

The objective may have been to move immediately to modern technologies; however, when evaluating the present meteorological networks it is clear that the situation in the Lao PDR and Cambodia is still far from ideal. To understand this one should consider the following observations:

- it appears that the responsible organisations in Cambodia and the Lao PDR do not have adequate funding to ensure proper operation and maintenance. Moreover, all spare parts have to be imported at considerable cost;
- the advantage of a data logger with telemetry is the fact that data can be read immediately or at high frequencies. However, for water level data at the main stream the daily fluctuations are usually not very big and it is considered that loggers provide limited advantages over reliable manual observations in these cases. Instantaneous rainfall data are important for small and quick-response river basins, but are not very useful for basin wide flood forecasting which takes place only once every day during the flood season. Higher frequency readings of rainfall are useful, especially when determining the model response of relatively small river basins.
- to date the number of automatic telemetry stations is far too low to provide adequate inputs for meteorological and hydrological models, even after the new Mekong Hydrological Cycle Observing System (M-HYCOS) project is implemented. This is

especially true for rainfall stations in Cambodia and Lao PDR;

- the overriding reason to introduce automatic telemetry stations in developed countries has been the rising costs of labour. Investment and maintenance costs are high; they are offset by much lower costs for operation. This advantage does not apply in Cambodia and the Lao PDR, where investment and maintenance is higher and observers are paid comparatively low salaries.

IMPROVEMENTS USING GOVERNMENT FUNDING

Increased and targeted funding of the Cambodian Ministry of Water Resources and Meteorology has been secured to bring the payment of the observers to a more reasonable level, and to pay them throughout the year, ensuring continuity of records. Government funds to the tune of 69 million riel have been used to repair and upgrade three important manual stations at Kompong Thom, Pursat and Battambang. For 2008 the Minister has approved 109 million riel to upgrade three more stations.

While progress is not fast, it is steady, and it clearly shows a changing attitude. Funding for upgrading the stations is now becoming available, and the funding for operation and maintenance is also steadily increasing. To ensure that the available budget is spent with priority on operation and maintenance of those assets that contribute most to the knowledge and understanding of the meteorological processes over Cambodia, new commitments, especially costly commitments to operate and maintain automatic stations, should be paced carefully and introduced slowly, in parallel with increased funding capacity of the Cambodian government.

OTHER IMPROVEMENTS

At the Regional Flood Management and Mitigation Centre of the Mekong River Commission the new Mekong River Flood Forecasting System (MR-FFS) is being implemented (Malone, 2007). This MR-FFS is based on hydrological models and uses mainly rainfall data and forecasts as input. The requirements of the DOM and the MRC-RFMMC are clearly aligned; therefore, under the 2007 Memorandum of Understanding between the MRC and MoWRaM both organisations have signed an agreement on cooperation in improving the DOM network in March 2008. This Agreement aims to significantly increase the number of rainfall stations which report daily to their respective head offices by using simple but robust and adequate technology.

Improvement of Raingauge Network

A detailed analysis of the situation regarding rainfall stations in Cambodia was made (MRC-

RFMMC, 2007a) in preparation of the improvement plan.

At the DOM, 21 stations report daily. To improve the network coverage it is proposed to upgrade up to nine old rainfall stations to daily reporting. Even then the network coverage shows large gaps. In order to fill these gaps, it is recommended to establish at least six new manual rainfall stations. The locations are selected by overlaying the map of available daily reported rainfall data with the map of villages, roads and schools in Cambodia. The proposed locations are accessible by road and in a village with a school. For the most reliable management, data collection and delivery new stations in remote areas should preferably be located at a school, and data collection and transmission should be done by the (head) teacher of this school. Overall, this means that at the DOM the number of stations that provide daily rainfall data can be increased from 21 to 36 using relatively simple and inexpensive methods. Figure 3 shows the daily reported rainfall stations in Cambodia (these include stations managed by the Department of Hydrology and River Works, also under MoWRaM).

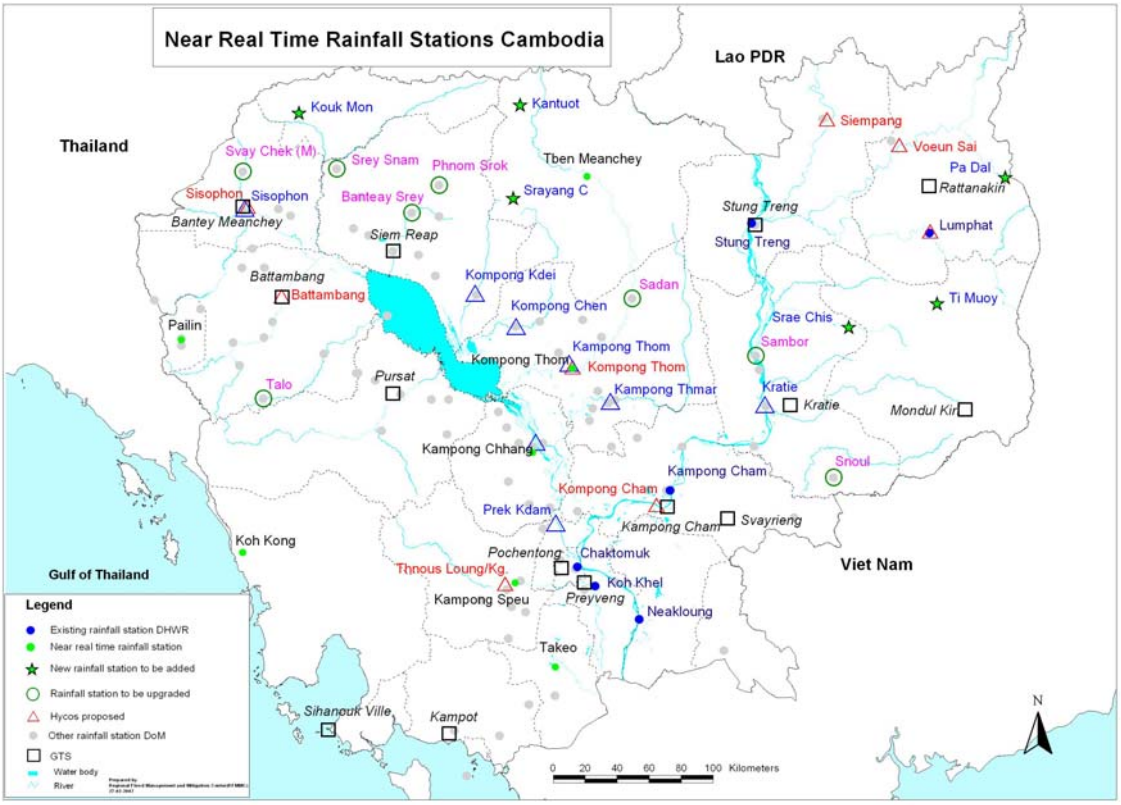


Figure 3. Map daily reported rainfall stations in Cambodia

At this moment (April 2008) a total of seven old rainfall stations have been upgraded to daily data delivery. This was done during three field trips in early 2008. During these trips the selected rainfall stations were visited; necessary repairs were carried out; the observers received mobile phones and were trained in using it to send twice daily observations by SMS to the DOM main office in Phnom Penh. In addition a total of seven locations were selected for installation of new daily report rainfall stations; four have already been installed, and the remaining three will be installed in May 2008.

Rehabilitation of automatic weather stations

The DOM of MoWRaM has nine Automatic Weather Stations (AWS) throughout Cambodia. The stations were installed by the JICA and the MRC between 2001 and 2003. The

AWS are all manufactured by Campbell Scientific and supplied from Australia. See Table 1 below for a summary of the stations.

Table 1. Automatic Weather Stations DOM-MoWRaM – status December 2007

#	Weather station – city/province	Installed	Inactive	Source
1	Pochentong	2002	2005	JICA
2	Pursat	2001	2002	MRC
3	Svay Rieng	2003	2004	JICA
4	Kampong Thom	2001	2002	MRC
5	Battambang	2003	2004	JICA
6	Flood Management and Mitigation Centre (Phnom Penh)	2003	2005	JICA
7	Stung Treng	2003	2004	JICA
8	Siem Reap	2003	2004	JICA
9	Kampong Som	2003	Still Working	JICA

Source: Department of Meteorology

These stations are all designed for solar-powered, stand-alone operation and to store the collected data inside the weather station logger until downloaded (Figure 4). The AWS installed by the two organisations (Japanese International Cooperation Agency (JICA) and MRC) differ in their instruments and configurations but all record the following parameters: rainfall, temperature, humidity, evaporation, wind speed and direction, barometric pressure, solar radiation and sunshine duration.

Figure 4. Battambang AWS

In order to get the AWS operational again a project has been formulated to recover and develop this existing automatic network of the DOM, and so to make a significant capital investment productive again, using limited means. The project covers firstly restoration of stations, training of staff to maintain the equipment and handle the data; and secondly developing the network through providing remote access to all stations and establishing central collection of the data at the Phnom Penh head office. This step would also include managing the data in a database, user-friendly presentation of the data and a connection with the MRC weather data storage system and the WMO GTS.

The proposal is based on the assumption that a small amount of resources will restore the valuable AWS network and provide central access and storage of the data. Current replacement

cost of all nine weather stations is approximately US$130 - 150,000. However, restoration would be a small percentage of the replacement cost. It is recommended that all the stations be networked for collection, presentation and utilisation of the data and maintenance of the equipment. Upgrading the software/hardware to network level with present technology is not expensive.

The improvement of the AWS network would greatly enhance the capability of the DOM and MoWRaM to report Cambodian weather data on the GTS network. It is part of the present effort to bring the capabilities of the DOM from the present level to a more acceptable international standard, and to further connect the DOM to the larger community of WMO members. It has the full support of the MRC-RFMMC. The expected outcome of the project would be the following:

1. the AWS network which is now idled will be operational again, salvaging an important earlier investment;
2. by adding remote access the availability and usefulness and reliability of the data will be much improved;
3. improved data availability will improve the DOM capacity to fulfil its mandated tasks related to weather forecasting and information dissemination;
4. the present very limited number of Cambodian synoptic stations reported on the GTS network can be significantly increased, adding to the step by step improvement recently seen. This will improve data and information support to regional and international meteorology programmes relying on GTS data; and
5. sustainability will be ensured by training of the DOM staff while limited funding for further support of the DOM by the consultant can be made available by other donors, which have already shown keen interest.

At this moment an application for WMO Voluntary Support Project funding is being processed; as this proposal has a very positive benefit/cost ratio and international impact it is expected that work can be started in 2008.

Global transmission system link

The GTS is the Global Transmission System of the World Meteorological Organisation. Members use the GTS to share synoptic meteorological and hydrological data. It is an essential part in the global meteorological system, and without it weather forecasts as we know and are used to would not be possible.

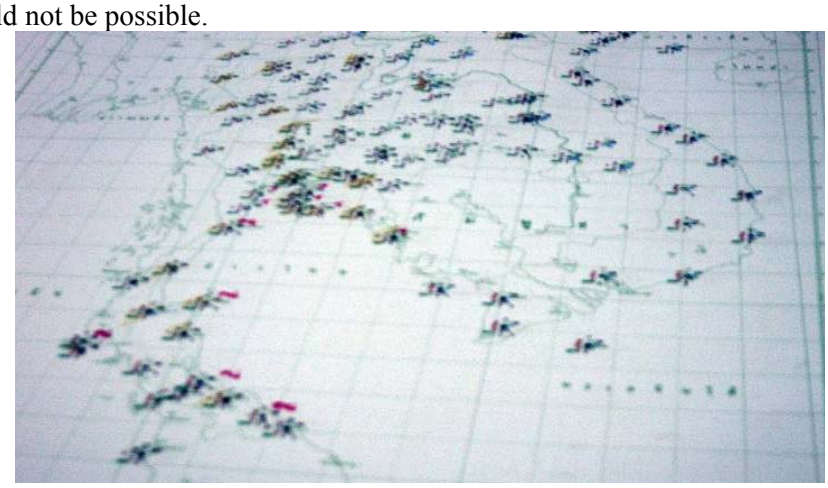


Figure 5. Cambodia is still a blank space on the weather map

The GTS connection of the DOM was established in January 2007 with assistance of JICA. The JICA continues supporting the DOM by organising trainings and by funding

consultants who have been assisting the DOM in further use of the GTS. Also, the connection fee through the Internet was paid for, for the period 2007-2009.

The GTS connection is of vital importance for the DOM: through the GTS it is possible to share the meteorological data from synoptic stations, like the nine AWS which are to be repaired and upgraded. By early 2008 Cambodia was still a blank spot on the world meteorological map, see Figure 5. The goal of the DOM is to remedy this situation by the end of 2008.

While sharing Cambodian data with the world meteorological community is very important, the DOM benefits even more by receiving the information available through the GTS. The following are highly relevant products that are accessible through or possible with the GTS:

- numerical weather prediction model products;
- tsunami and earthquake information;
- maritime forecasts;
- aerodrome forecast, aviation route forecast;
- meteorological satellite data;
- climatic data of the world;
- weather forecast for the major cities in the world;
- possibility to prepare 1 to 3 days forecast for each province 2 times every day;
- more attractive weather information through TV.

Still there are serious problems to solve. The lack of reliable electricity at the Phnom Penh head office is crippling: all the modern GTS equipment is useless without electricity. To remedy this, funding for renewal of the non-operational generator is being provided by the MRC-RFMMC. The internet connection is also a recurring problem, but this is now addressed and is expected to be much more reliable in the future. Funding for operation and maintenance is also still low, and limits the DOM in its plans for improvement.

CONCLUSIONS

It is recommended to continue upgrading existing historical (rainfall) stations by providing a simple but effective means of communication (SMS using a mobile phone) at short notice. For the agencies it is relatively simple and inexpensive to set up a new manual rainfall station; the logistics are more difficult as it concerns remote areas. Options for communication were discussed. While most of the hydro-meteorological institutes in the Mekong Basin and especially in Cambodia and the Lao PDR depended on VHF radio, the vast and ongoing improvement of GSM (mobile phone) coverage means that text messaging using a mobile phone by the observer is now a viable option. The text messages are automatically received by a modem linked to a computer at the agencies head office, and can be easily used, stored and forwarded. At this moment a successful pilot has been completed at the DOM and full implementation is underway.

As the sums involved are small, the MRC-RFMMC through the Cambodian National Mekong Committee has established an MOU under which the MRC-RFMMC is able to work directly with the agencies to improve their networks, and the agencies will deliver data directly to the MRC-RFMMC to be used as input for the Flood Forecast System. The first work plans for the DOM concerning three field visits for stations upgrading and improvement have been successfully carried out.

Though the focus of the MRC-RFMMC is on manual rainfall stations, the proposal to repair and upgrade the nine AWS has been cooperatively developed with strong support by all involved parties. Funding through the WMO-VSP is expected to be secured at short notice.

The AHNIP and proposed M-HYCOS system in Cambodia may in future provide real-

time data to the DOM and the MRC-RFMMC at higher frequencies. However, for the time being and considering all other constraints in the data delivery to the MRC-RFMMC, it is realistic to focus efforts on improving the delivery of flood forecasting input data on a dependable daily basis. For this purpose the daily manual reporting of the AHNIP and in future M-HYCOS stations will be sufficient; it is expected that the manual system will remain as a backup. If the MRC-RFMMC is to increase the frequency of its flood forecasting many more than the presently operational and proposed AHNIP and M-HYCOS stations are needed, and the focus should be much more than now on rainfall data.

REFERENCES

Malone, T. et al. 2007. Development of a flood forecasting database for the Lower Mekong River

Mekong River Commission Secretariat. 2001. Improvement of the Hydrometeorological Network (basin wide), Component 2 - Final Report Volume 1 - Main Report.

Regional Flood Management and Mitigation Centre, 2007a. Data Acquisition - Collection and Communication Improvement - Preparatory Mission to Cambodia

POTENTIAL OF SATELLITE ALTIMETRY FOR FLOOD MODEL ASSESSMENT

R.J.J. DOST[1], G. PARODI[1], T. RIENTJES[1] AND LE THI HANH[2]

[1]*International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, the Netherlands*
[2]*Department of Natural Resources and Environmental (DONRE) in Thua Thien Hue province, Hue city, Vietnam.*

ABSTRACT

A preliminary study was carried on the lower Mekong River to assess the potential of satellite altimetry to improve river discharge model calibration. Applications of satellite altimetry to lake and flood hydrology are innovative although its potential is not well assessed. A limitation to successful applications is the limited spatio-temporal resolution to observe variations of river level-fluctuations. New developments that focus on improving accuracies are advocated by the hydrologic society and new observation platforms such as the Surface Water Ocean Topography (SWOT) mission may be developed in the near future. Such initiatives also trigger the need to do further research after applicability of river altimetry such as performed in this study.

Radar altimetry pre-processing consists of the application of a retracking algorithm that is able to mask the responses of land features from the satellite footprint. This result in an average footprint water level referred to as a reference geoid and vertical datum. This process is done at the reception station.

The punctual information on altimetry was compared with the water levels at gauged stations available from a public database. The usage of the altimetry data in a simplified 1D hydraulic flow model (DUFLOW) in the Lower Mekong River improved the performance of the model slightly despite that spatial-temporal resolution of the data was low. The assessment of the model performance indicates that satellite based altimetry data has a high applicability potential in areas of data scarcity, this under the condition that altimetry data at higher resolutions becomes available.

During flooding the quality of altimetry data is expected to improve since the flooded area covers a major proportion of the satellite footprint and pixel size. In view of our preliminary results in this pilot study we conclude that more research is required where also multiple river sections must be considered that are characterized by various widths and topography's.

RADAR ALTIMETRY

The principle of radar altimetry is the emission of a radar wave towards a target and the analysis of the return signal from the target surface. By measuring time delays of a pulse to return to the sensor, the distance from the spacecraft to the surface (and thus the topography) can be calculated. In this manner, radar altimetry is a technique of measuring heights and measurements yields a wealth of other information that can be used for a wide range of applications (Rosmorduc et al., 2006).

The surface height is the difference between the satellite's altitude (the position on orbit with respect to an arbitrary reference surface) and the satellite-to-surface range (calculated by measuring the time taken for the signal to make the round trip).

Height = Altitude - (corrected) Range

Table 1 shows the main characteristics of a number of radar satellite missions. To accurately measure the height of a water surface, the target area size has to be equal to or larger than the altimeter footprint and therefore at the moment only large rivers can be measured. Also the revisiting time has to be reconsidered and altimetry applications in river hydrology as such are still limited. Future missions are expected to have higher revisit time and smaller footprint (such as 'cryosphere satellite', CryoSat 2 and the 'Surface Water Ocean Topography', SWOT) and as such radar altimetry has a high potential for river modelling in areas where data is scarce. In view of this prospective, this paper intends to evaluate the potential of radar altimetry water height data for use in river modelling and monitoring.

Table 1. Summary radar technical characteristics

Parameter	T/P	ERS-2	GFO	ENVISAT
Launch	10 August 1992	1995	1998	1 March 2002
Altitude	1,336 km	785 km	800 km	800 km
Beam width				1.3 degree
Footprint				1.7 km
Spatial sampling	~ 0.58 -2 km along track	~ 7 km along track		~ 7 km along track
Geometric resolution		8 km		19 km
Revisit time	10 days	35 days	17 days	35 days
Error	Range: 2cm / Orbit: 2-3 cm	Range: 3cm / Orbit: 7-8 cm	Range: 3.5cm	Range: < 4.5 cm / Orbit: 2-3 cm

Radar altimetry over land and water surfaces has a number of limitations by the complexity in the analysis of the returned waveforms. An altimeter waveform (radar echo) represents the histogram of the energy scattered by the ground surface to the satellite with respect to time (Bjerklie et al., 2003). Echos's are affected by the presence of several land surface reflectors and may show peaks and noisy signals in the histograms. To be able to estimate a height from a histogram, refined procedures known as altimeter wave form retracking are developed that analyse altimeter waveform to obtain better range of estimates than those obtained with on-board tracking algorithms.

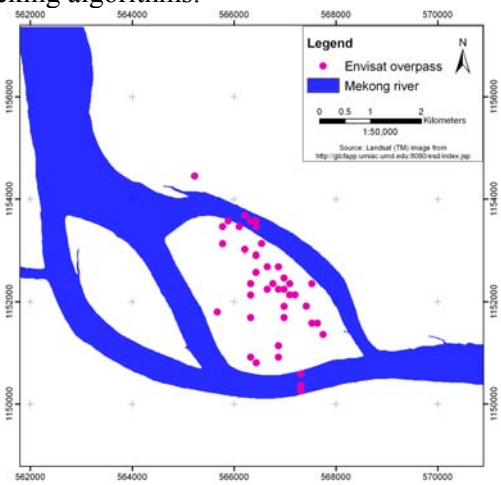


Figure 1. ENVISAT overpasses derived from ESA. Shows water mask in blue and ESA centred returns. See also Figure 5.

'Retracking is the term used to describe a group of non-linear ground processing estimation techniques which attempt to determine the tracker offset from the telemeters echoes,

and thereby estimate the range to the point of closest approach on the surface' (Rosmorduc et al., 2006). Several algorithms have been developed for the purpose of tracking the point of the altimeter radar echo waveform that corresponds to the effective satellite ground range to be measured and provides the correction to be applied to the onboard tracker estimates.

It suffices to know that 'retracking' is a specialized pre-process normally done at the radar processing centres and involves the use of a mask of the water surface required to overcome the difference in elevations that originate from the earth's undulating surface and thus serves to evaluate the mean altitude within the mask. This research makes use of the ENVISAT radar altimeter data and a mask of the area of interest (Figure 1) was sent to processing centre.

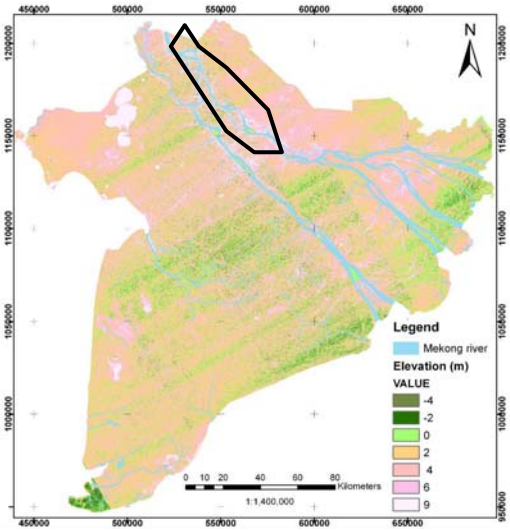


Figure 2. DEM in study area (Source: Shuttle Radar Topography Mission (SRTM)), and modelling sector

STUDY AREA

This research is conducted in the lower Mekong River Delta (MRD) because multiple ENVISAT overpasses are available and the width and length of the river sections are within the altimeter footprint with a range of 0.58 to 2 km (Koblinsky, 1993). In both main branches of MRD, there are around sixteen in-situ state observations available (Mekong River Commission, 2005) required for calibration and validation of the developed methodology. Figure 2 shows the Mekong Delta and the area selected for the research.

IN-SITU DATA COLLECTION AND PROCESSING

The data required for the research were collected from the field in 2007. Daily stream flow records (Graph 1), water level measurements at specified hydrological stations (Graph 2), evaporation and daily rainfall where collected from the Hydrometeorological Data Centre (HMDC) in Vietnam for the period 2002 - 2007 at 5 in-situ gauges and meteorological stations (Table 2 and Figure 3) namely Tan Chau, My Thuan, Cho Moi, Cao Lanh and Vam Nao station

Evapotranspiration data was also obtained from the HMDC but was available only for the year 2002 in Can Tho station. A number of cross-sections were identified in pre-fieldwork. These were measured at the selected gauging stations, at some river bends and the 'virtual stations' (position) of the radar altimeter data (Figure 4 to Figure 6) using the geo-referenced sonar sounding methodology of (Dost and Mannaerts, 2004). A fathometer connected to a Global Navigation Satellite System (GNSS) receiver was installed on a boat. The fathometer

uses a single frequency transducer of 200 kHz to measure the distance from sensor to river bottom with an vertical accuracy of 10 cm, while simultaneously the GNSS receiver records both the location coordinates and the depth measurement.

Table 2. Location of the gauges and meteorological stations in the area.

Station	North	East	River	Parameter
Tan Chau	592912.23	1197680.66	Mekong	Discharge, water level and rainfall
Cho Moi	544188.09	1166405.53	Mekong	Water level and rainfall
Cao Lanh	569310.49	1157079.13	Mekong	Water level and rainfall
My Thuan	598556.40	1135710.06	Mekong	Discharge, water level and rainfall
Vam Nao	540085.36	1168931.30	Vam Nao	Discharge, water level and rainfall

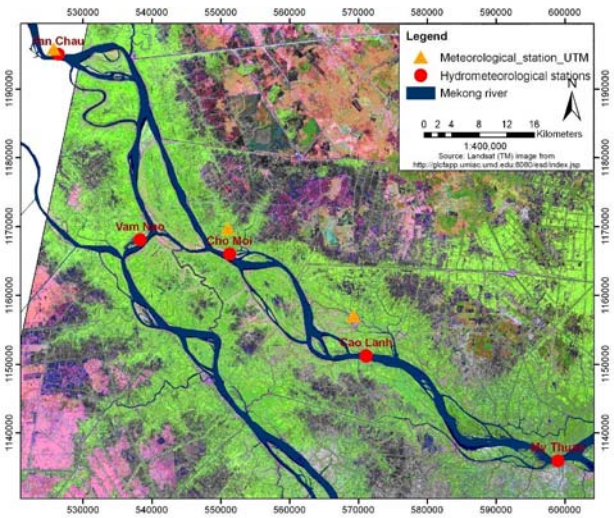
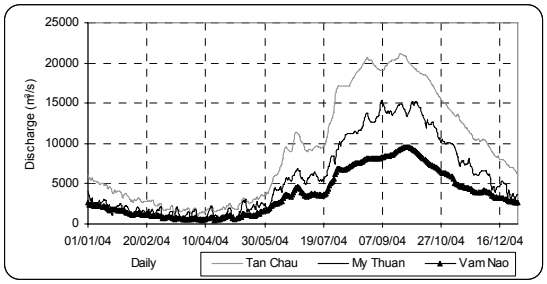
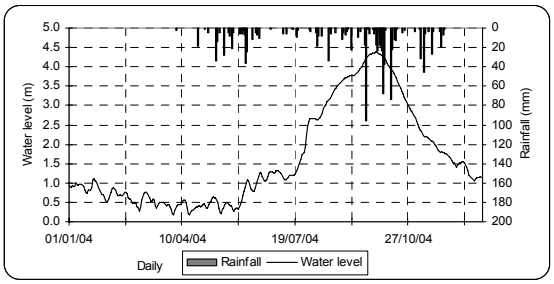


Figure 3. Location of the meteorological stations



Graph 1. Discharge records in Tan Chau, My Thuan and Vam Nao stations in 2004.



Graph 2: Rainfall and water level records in Tan Chau station in 2004

Altimeter data was obtained from the De Montfort University (UK) for the period from 20 October 2002 to 3 December 2006. The revisit period of ENVISAT is 35 days but some overpasses where not recorded and thus there are data gabs in the database. For this study the altimeter data was post-processed because the validation of the data with in-situ data from the Cao Lanh station revealed a correlation of R^2 = 0.87 (Graph 3) but also a systematic shift between the observation and radar altimetry data as shown in Graph 3.

The systematic shift is in the order of 2 meters and its cause could not be determined but might be caused by the use of different reference levels by the data providers. To correct the shift the average offset was subtracted:

$$\text{Altimeter}_{\text{corrected}} = \text{Altimeter}_{\text{original}}^{\text{time i}} - \left(\frac{1}{n} \sum_{j=1}^{n} \text{Altimeter}_{\text{original}}^{\text{time i}} - \text{Measured water level}_{\text{time i}} \right) \quad (1)$$

Where 'n' are stands for the number of dates with altimeter information.

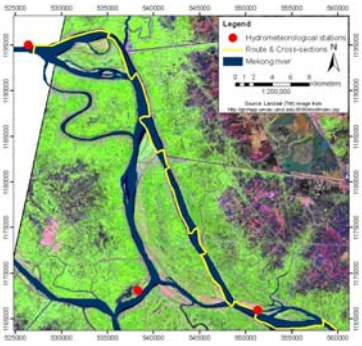


Figure 4. cross sections, upper.

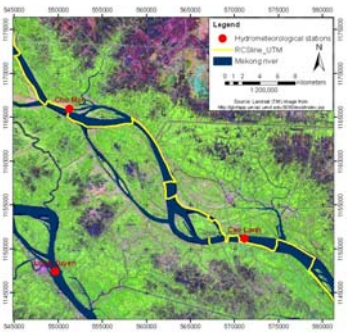


Figure 5. middle

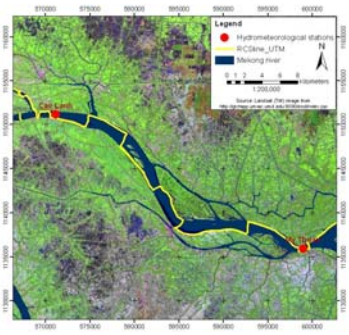
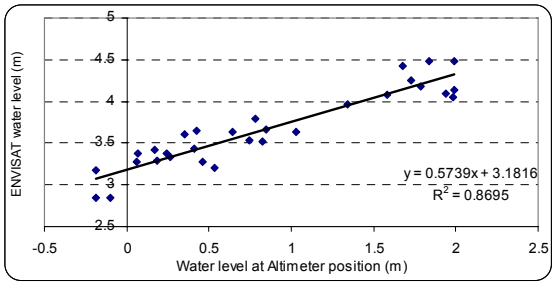
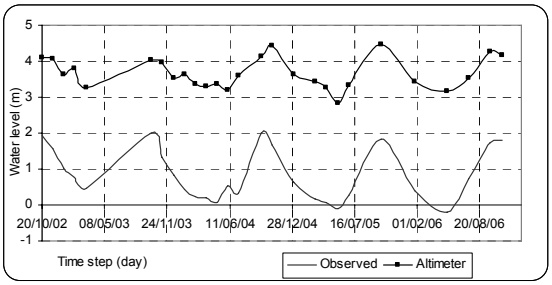


Figure 6. lower



Graph 3. Correlation of water level observation and altimeter data.



Graph 4. Time step of water level derived from ENVISAT compared with observation data.

At the 'virtual station' the linear regression formula in Graph 3 was used to interpolate from 35 days to daily data and input to model at Altimeter position.

DUFLOW MODEL AND SCENARIOS

Two different scenarios built in the hydraulic flow model DUFLOW are discussed with the objective to better understand the effects of inserting water levels derived from radar altimetry in river discharge modelling.

The so-called scenario manager in DUFLOW facilitates the definition of different scenarios which are based on a base scenario. The data for each additional scenario can be changed without affecting the data of the base scenario and thus the effect of the separate scenarios on the base model can be evaluated. Two types of scenarios were developed in DUFLOW, one using the input parameters with in-situ data only and one incorporating radar altimeter water level data. The main characteristics of these scenarios are described in Table 3.

Table 3. DUFLOW scenarios.

Scenarios	Boundary condition		RAM module		Added condition	
	Upstream at Tan Chau	Downstream at My Thuan	Sub-catchment 1	Sub-catchment 2	Outflow at Vam Nao	Internal boundary condition
Scenario 1 (first model)	Daily Discharge	Daily Water level	Inflow 1	Inflow 2	Daily Discharge	
Scenario 2	Same as Scenario 1 but the water level derived from ENVISAT is added as internal boundary condition.					

The implementation of the model represents a simplified scenario setup of a channel flow. The first scenario is setup with in-situ river discharge and water level measurements from four discharge/water level stations within the study area. The period of simulation was set to five years (2002 - 2006) which coincides with the ENVISAT altimeter data that was available.

Seven river cross-sections and three bending points respectively are inserted in the DUFLOW schematics (Figure 7). Channel roughness of the river was defined by using Manning's n and inverse to Manning-Strickler coefficient k = 1/n. In this case, the first value k = 28.57 (n = 0.035) was defined for natural river (Chow et al., 1988); k was adjusted after model calibration. The computation time step was set to 5 minutes. A detailed overview of the input values used is presented in Table 4.

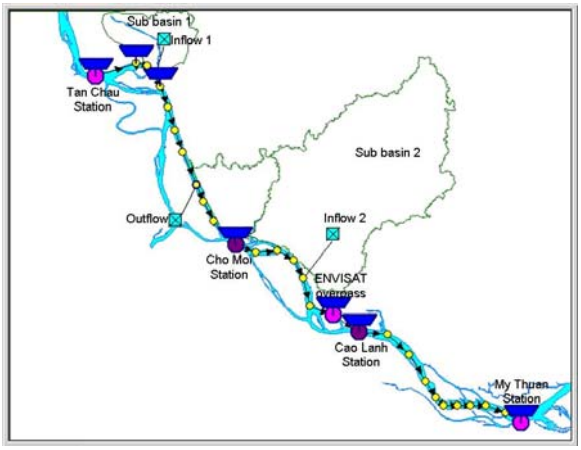


Figure 7. Schematic layout of the model for the Mekong River.

Table 4. Description model network and input parameters.

Object	Station	Input	Value/type
Upstream - node 1	Tan Chau	Boundary condition	Discharge
Middle node 1	Cho Moi		
Middle node 2	Cao Lanh		
Downstream	My Thuan	Boundary condition	Water level
Outflow	Vam Nao		Discharge (negative)
Sub-catchment 1 Rainfall Evapotranspiration	Runoff 1 Tan Chau Can Tho	Inflow 1 from RAM	91.6 km^2
Sub-catchment 2 Rainfall Evapotranspiration	Runoff 2 Cho Moi and Cao Lanh Can Tho	Inflow 2 from RAM	870.6 km^2 Average

A crude estimation was done to evaluate the inflow from the subcatchment due to lack of hydrological information. As such in the DUFLOW rainfall-runoff 'RAM' module, the surface was assumed 100% unpaved. The infiltration capacity Imax was calculated assuming that the kind of texture in the study area is sand. The crop factor f for a catchment area is determined as the mean crop factor per percentage of the surface. The depth between the average surface level and the average groundwater level is estimated and assumed being constant during the simulation period (in this case is 0.7). The soil moisture content is determined for the dominating soil type at saturation level (pF = 0), at field capacity (pF = 2) and at the wilting point (pF = 4.2). The moisture storage is determined as the product of the length of the unsaturated zone and the volume fraction. The input values are presented in Table 5.

Model calibration is commonly done manually by optimising the parameter values, starting with the given initial values, until the simulated variable fits with the observations.

Once calibrated, the model can be considered as the base/current condition scenario. In this study, calibration was limited to the adjustment of roughness coefficients in order to minimize the Root Mean Square Error (RMSE) between the modelled and measured water levels. There are no structures in the considered reaches and no further sections were surveyed. Manning's roughness coefficient for alluvial, sand bedded channels with natural vegetation (i.e. the Mekong mainstream) range from 0.025 to 0.05. In DUFLOW, the inverse of Manning's n, which is called Strickler-Manning roughness coefficient k in [$m^{1/3}$ s^{-1}] is defined. The results showed that a value of Manning-Strickler roughness equal to 27 $m^{1/3}$ s^{-1} is the best suited for the scenario. Water level data at Cho Moi and Cao Lanh station where selected for calibration purpose.

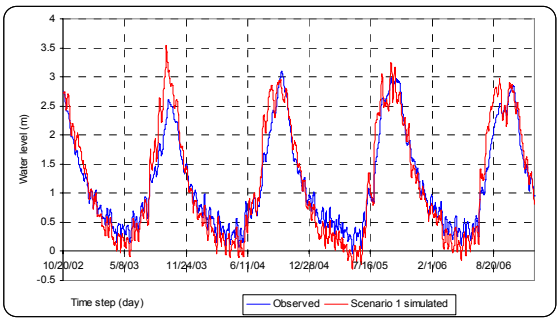
Table 5. Adopted values for the RAM module. For parameter explanations see DUFLOW RAM manual.

Parameter	Unit	Value	Parameter	Unit	Value
Max	[mm/day]	273.6	BL_{min}	[mm]	5
F	[-]	1	$P_{percmax}$	[mm/day]	10
F0	[mm]	314.3	C_{max}	[mm/day]	10
F2	[mm]	239.4	$K_{surface}$	[day]	2
F4.2	[mm]	46.9	K_{quick}	[day]	0.8
Phi0	[mm]	46.9	K_{slow}	[day]	1
LBv0	[mm]	50	B_{slow}	[-]	0.5
N	[-]	0.45			

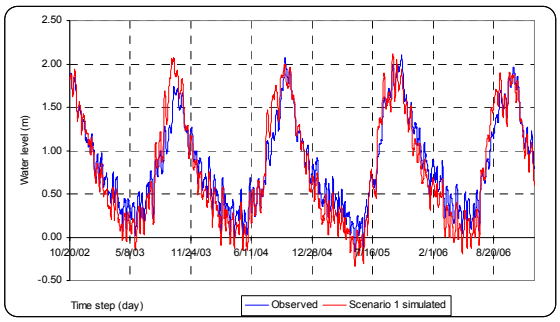
The second scenario is developed on the basis of the first scenario (using the same physical network and simulation period) with the addition of the radar altimeter water level data as internal boundary condition (Figure 7) at the location of a radar altimeter overpass.

RESULTS

When comparing the model results of the first scenario with the observed water levels it can be seen that the simulated levels, general speaking, match with the observed water levels (Graph 5 and Graph 6) although water level data show large variation by specific flow conditions and tidal influences. However, the tidal effects are experienced at a much finer time scale (1 hr) than the modelling time step 24hrs) and therefore cannot be readily visualized. The results indicate that there is a seasonal variation in the water level measurements where high water levels are observed in the period August to October with highest values in September and gradually decreasing levels till December. Water levels are therefore governed by seasonal variations and the rate of flow in the river.

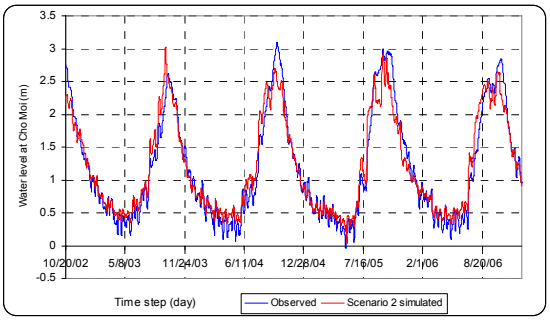


Graph 5. Water level of observed and simulated at Cho Moi stations (scenario 1)

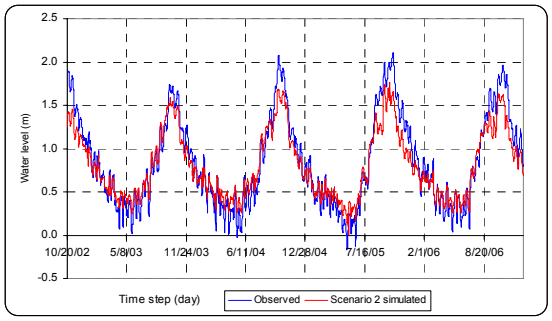


Graph 6. Water level of observed and simulated at Cao Lanh stations (scenario 1)

When evaluating the second scenario (Graph 7 and Graph 8), it can be observed that the peaks of simulation and observations are comparable but the lower flow shows deviations. The assumptions made of averaging the river cross-sections, errors of the observation (data) and lack of data such as evapotranspiration contribute to second order errors that might explain these differences.

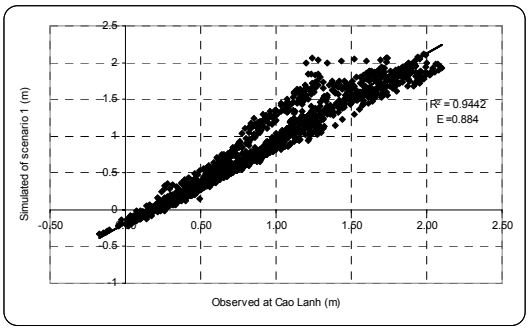


Graph 7. Water level of observed and Simulated at Cho Moi stations (scenario 2)

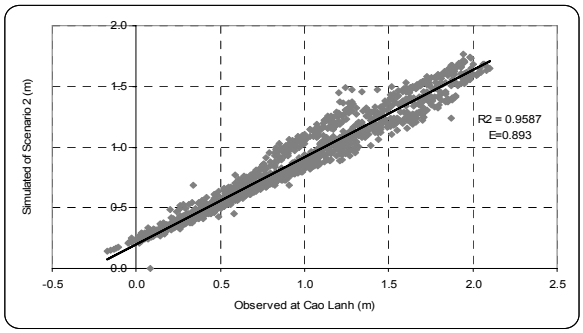


Graph 8. Water level of observed and simulated at Cao Lanh stations (scenario 2)

Regression analysis for the two nodes using the Nash-Sutcliffe R^2 and the correlation performance indicators are performed for the two stations. R^2 values and correlations for Cao Lanh station are presented in Graph 9 and Graph 10. Results for both stations in scenario 2 with additional altimeter data at both stations has been improved with R^2 results in Table 6.



Graph 9. Correlation R^2 and Nash-Sutcliffe at Cao Lanh station (Scenario 1)



Graph 10. Correlation R^2 and Nash-Sutcliffe at Cao Lanh station (Scenario 2)

These results show that the second scenario with additional altimeter data at both stations has a higher correlation with the in-situ data then the scenario without this additional data. This despite the fact that limited altimeter data was available with a large footprint, which seemingly indicates that altimeter data has the potential to improve river discharge modelling for river systems as large as the Lower Mekong.

Table 6. Summary of the correlation and Nash-Sutcliffe of two scenarios at Cho Moi and Cao Lanh stations

Location	Scenario	Correlation	Nash-Sutcliffe
Cho Moi (node 2)	1 with gauging data	0.94	0.89
Cho Moi (node 2)	2 with Altimeter corrected	0.94	0.93
Cao Lanh (node 3)	1 with gauging data	0.94	0.88
Cao Lanh (node 3)	2 with Altimeter corrected	0.95	0.89

CONCLUSIONS

This preliminary research shows that water levels estimated with radar altimetry have potential to be used as model input to improve the accuracy of the water quantity model of large rivers. When analysing the two different scenarios presented, it shows that the accuracy of the model using radar altimeter data has increased when compared with the model not using this data. A systematic shift was observed that might originate from the data sources which need to be evaluated. Due to the ENVISAT revisit time of 35 days the model used 36 days of radar altimetry data to represent a period of five year, which makes the number of radar altimeter observations small compared to the frequency of observed in-situ data.

The ENVISAT altimeter data used in this research has a 35 day revisit time, limiting the observation of rapid river water level fluctuations. Therefore by the low temporal resolution and large footprint can altimetry data only supplement in-situ data of large river systems. This research does however demonstrates that the use of river water levels derived with radar altimetry for discharge modelling has potential to improve river modelling accuracy when in situ data is scarce, this especially if the revisit time and footprint is reduced which is expected from future missions such as SWOT or CRYOSAT II..

During flooding the quality of altimetry data is expected to improve since the flooded area may cover large proportions of the satellite footprint and pixel size. In view of our preliminary results in this pilot study we conclude that more research is required where also multiple river sections must be considered that are characterized by various widths and topography's.

ACKNOWLEDGMENTS

This research could not have been done without the data provided by the Hydrometeorological Data Centre (HMDC) in Vietnam and the De Montfort University in the United Kingdom.

REFERENCES

Bjerklie, D.M., Dingman, S.L., Vorosmarty, C.J., Bolsterc, C.H. and Congaltonc, R.G., 2003. 'Evaluating the potential for measuring river discharge from space.' Journal of Hydrology 278(1-4): 17-38.

Chow, V. t., D.R. Maidment, and Mays, L.W., 1988. Applied hydrology. New York, McGraw-Hill.

Dost, R.J.J. and C.M. Mannaerts, 2004. 'Bathymetry generation using sonar and satellite imagery : poster.' Presented at ISPRS 2004 : proceedings of the XXth ISPRS congress : Geo-imagery bridging continents, 12-23 July 2004, Istanbul, Turkey. Comm. IV. poster.

Koblinsky, C.J., R.T. Clarke, A.C. Brenner, and H. Frey, 1993. 'Measurement of River Level Variations With Satellite Altimetry 'Water Resour. Res. 29(6): 1839-1848.

Mekong River Commission, 2005. 'Mekong-HYCOS_ Establishment of a Hydrological Information System in the Mekong River Basin.'

Rosmorduc, V. and Benveniste J., 2006. Radar Altimetry Tutorial.

FLOOD HAZARD IN SAVANNAKHET PROVINCE, LAO PDR MAPPING USING HEC-RAS, REMOTE SENSING AND GIS

M. K. HAZARIKA[1], A. BORMUDOI[1], S. PHOSALATH[2], V. SENGTIANTHR[3], L. SAMARAKOON[1]

[1]*Geoinformatics Centre, Asian Institute of Technology, Bangkok, Thailand*
[2]*Lao National Mekong Committee Secretariat, Lao PDR*
[3]*Environment Research Institute, Lao PDR*

ABSTRACT

Flood in Lao PDR is a yearly event causing damages to lives and property. It occurs mainly due to a heavy rainfall caused by south-west monsoon. Floods adversely affected the economic growth of the country by damaging the agriculture and other related economies. Savannakhet with a population of 120,000 is the second-largest city after the capital Vientiane and one of the main six flood affected provinces in the country. The other five being The Vientiane, Bolikhamxay, Khammouane, Attapeu, and Champasak. The Xe Champhone River is the main river of the Se Bangheing Basin. It is flowing through three districts namely Champhone, Atsaphang and Asaphone in Savannakhet province.

This study is aimed at preparing flood hazard maps for return periods of 10, 20 and 50 years in the Xe Champhone River. The length of river under study was approximately 153 km, starting at Donhean and ending at Ban Kengdone gauge stations. The depth maps were prepared using 1D hydraulic model HEC-RAS. Manning's coefficient of roughness was an input to the model depending on the land use class prepared from the Landsat-ETM image of the area during year 2000. Population per village was used for preparing the vulnerability map.

The hazard map showed the depth varies up to 12 meters for a 50 year flood event. The vulnerability analysis was carried out in the four districts of Atsaphang, Champhone, Xonbuly and Songkhone in the Savannakhet province for a 10 year flood. The vulnerability map showed that an area of 3,904 km^2 was under low vulnerability and approximately 35 km^2 was under the very high vulnerability. A total number of 66,994 people were directly affected by the 10 year flood event. An area of 196 km^2 of agricultural land and a forest area of 66 km^2 were affected by a 10 year flood. Likewise, a length of 259 km of road was inundated.

INTRODUCTION

Strong South West monsoon contributes to the flooding in LaoPDR every year from August to September. It usually occurs in the central and southern provinces. During the past 40 years, LaoPDR has been severely affected by flood in 1966, 1995, 2001 and 2002 (Anousone, 2005). Savannakhet province has a land area of 21,774 km^2 and a population of 120,000. Champhone district of this province is affected by each years flood severely. It adversely affects the agricultural production, fish cultivation and cause damage to infrastructures.

Flood model is one of the means to understand the behavior of flood in a particular area. Model simulation can provide flood depth and extent. With the increase availability of the computing resources and the development of new models, flood hazard maps can be prepared at a high resolution with better accuracy for preparedness planning. Flood vulnerability map can be also prepared by integrating infrastructure and population data with the flood hazard maps.

This study was aimed at preparing the flood hazard maps in Savannakhet Province for a return period of 10, 20 and 50 years with the help of Remote Sensing and GIS data as well as an

one-dimensional flood model called HEC-RAS. GIS was mainly used for flood vulnerability analysis for a 10 year flood.

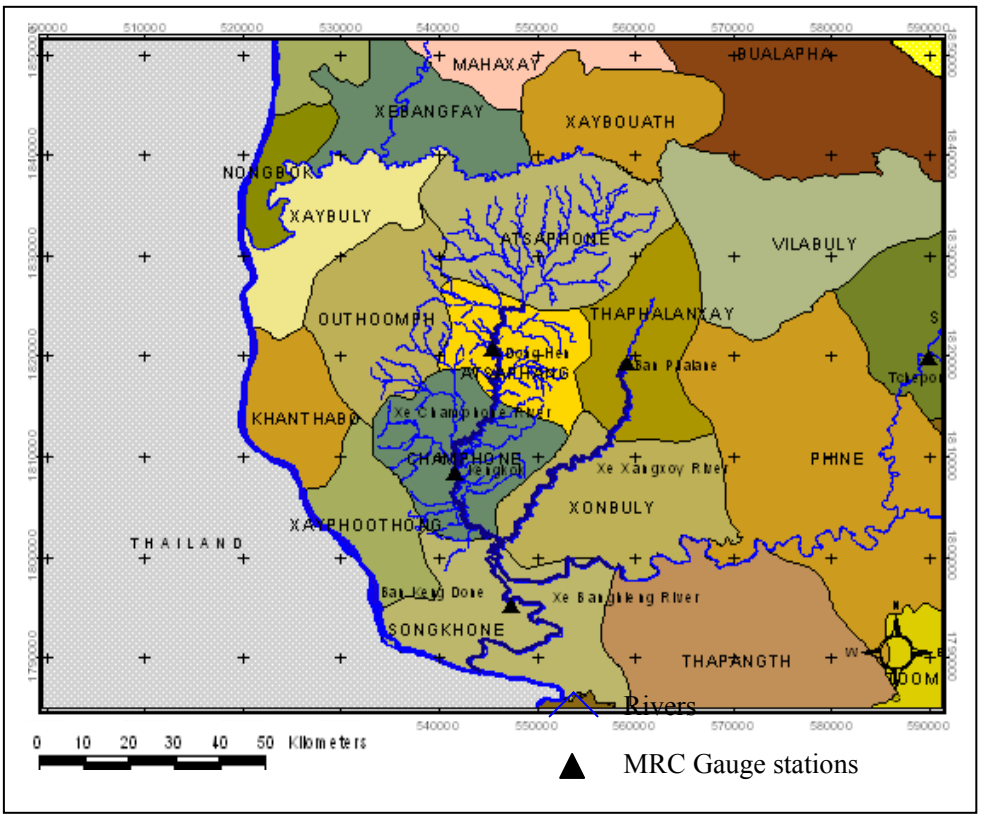


Figure 1. Study area

The study area extends about 153 Km of the Xe Champhone River starting from Donhean (upstream) to Ban Kengdone Gauge stations (downstream). It consists of three districts namely Champhone, Atsaphang and Asaphone in Savannakhet province. The geographical location of the study area is roughly in between 16º2´2.1 -16º35´12.5 N and 105º0´3.4 -105º39´17 E. For this study purpose, only one reach of the river that is the main Xe Champhone River is considered. The primary land use in this area is rice cultivation. The study area is covered by forest and shrubland in the north-east and the west. Generally, maximum rainfall occurs during July and August (240 - 330 mm/month).

OBJECTIVES

The main objective of the study was to develop flood hazard maps for return periods of 10, 20 and 50 years in Xe Champhone River in Savanakheth province, Lao PDR. Satellite data, river discharge data, and a hydraulic model called HEC-RAS.

DATA USED

Data used for the study were:

- satellite image of the study area of Landsat ETM acquired on date 04/11/2000 and ALOS/PRISM data acquired on 13/09/2006;
- contour 10 m interval;

- peak flow at upstream Donghean and downstream Kengdone with corresponding water levels;
- measured cross section along the river at 20 locations;
- population data of 2005 from National Statistics Centre, Lao PDR;
- river network, province, district and village boundary.

METHODOLOGY

Figure 2 shows the methodology for creating flood hazard and vulnerability maps. Digital Elevation Model (DEM) was created from the contour data of 10m interval as well as stereo pairs of ALOS/PRISM. The Triangulated Irregular Network (TIN) of the study area was prepared from this topographic data. Cross section data at 20 locations were adjusted with the help of the input geometry from the surveyed cross sections at these locations along the river. Supervised classification was carried out using the Landsat satellite image and a land use map was prepared. Based on the classes, Manning's roughness coefficients were given as an input to the model. Frequency analysis of the observed peak discharge at Donghean and Kengdone was carried out for a period of 16 years (starting from 1985 to 2000). A rating curve was prepared at the downstream Kengdone for the same period of time. Water levels for corresponding discharges were estimated with the help of the rating curve at the downstream station for 10, 20 and 50 year discharges. In the model, the upstream and downstream boundary conditions were the discharges. Steady sub-critical flow was carried out in HEC-RAS and the output was the flood hazard maps in terms of depths per pixel (pixel size 100 x 100 m) for the floodplain. Vulnerability analysis was carried out taking the population into account. Population per pixel was estimated based on weightage from the land use data. The final vulnerability map was prepared by taking into account the weighted population per pixel, land use per pixel and flood depth per pixel with classes as low, medium, high and very high.

RESULTS AND DISCUSSION

Figure 3 shows flood hazard maps 10, 20 and 50 year return periods which affects 629, 646 and 668 km^2 areas respectively. The depths greater 6m were considered as very high and the area having such a depth was found to be 179, 414 and 433 km^2 for 10, 20 and 50 year flood respectively as shown in Table 1. It was found that in the four districts, population of 66,994, 70,658 and 71,127 were affected by 10, 20 and 50 year flood. Similarly, from Table 3, a total length of 259, 265 and 278 km of roads were inundated by flood of 10, 20 and 50 year return periods respectively.

Table 1. Total area inundated

Flood depth range (m)	Total inundated area (km^2)		
	10 Yrs	20 Yrs	50 Yrs
Low (0-1)	37	45	50
Medium (1-3)	111	113	116
High (3-6)	302	74	69
Very High (>6)	179	414	433
Total	629	646	668

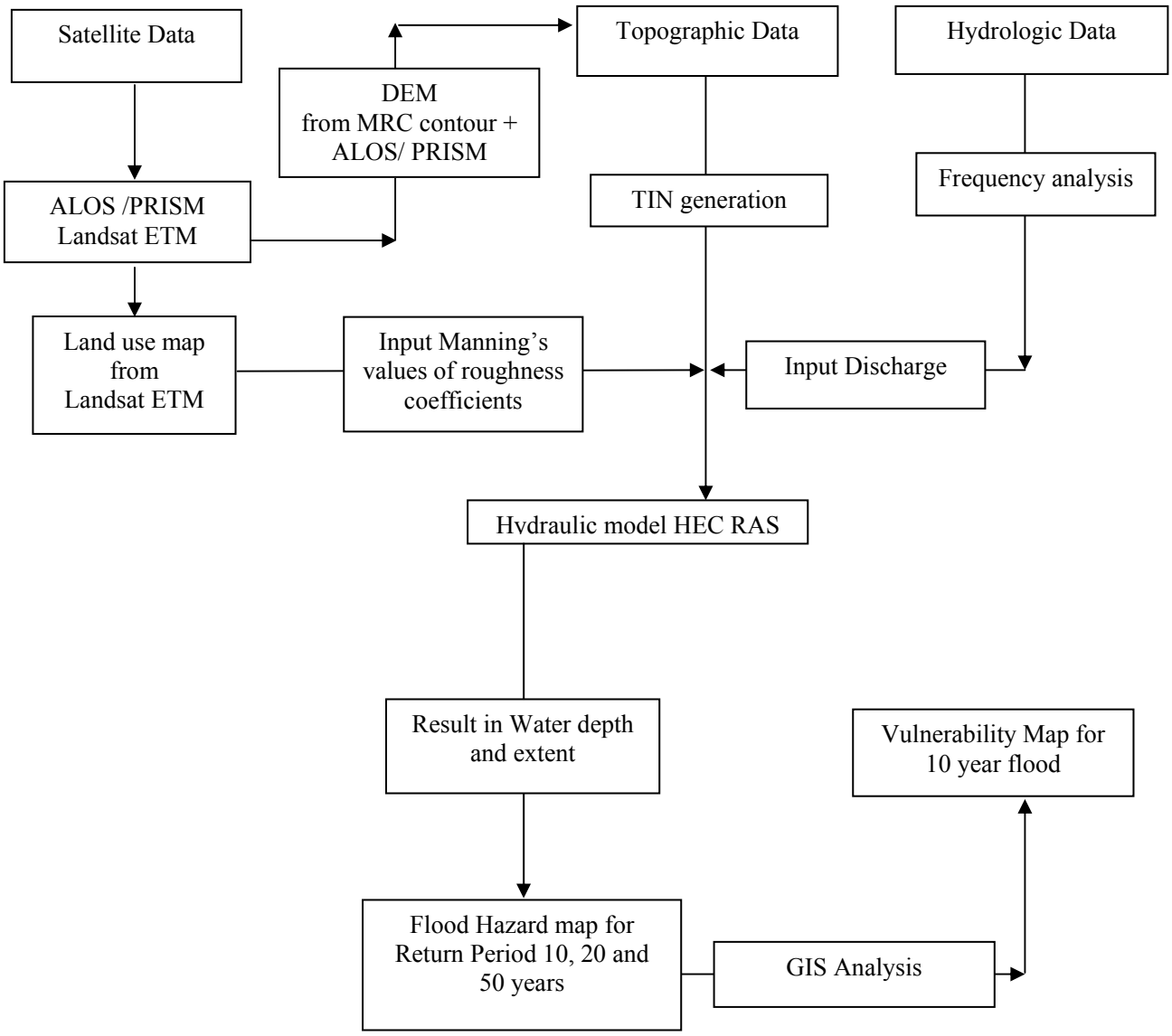


Figure 2. Flowchart of methodology

Table 2. Population affected

Districts	Total population affected for return period of		
	10 years	20 years	50 years
Atsaphang	8,130	7,796	7,796
Champhone	44,105	46,116	46,116
Xonbuly	5,668	7,655	7,955
Songkhone	9,091	9,091	9,260
Total	66,994	70,658	71,127

Figure 4 shows the flood depth in the study area for a 10 year flood. It was overlaid on the Landsat image acquired during the month of November. The model result was fairly matching with the extent of flood in the image. From the Figure, higher values of depths were found towards the upstream continuing till the middle of the river. Flood was extended towards the cultivating areas to the north-west and the south east.

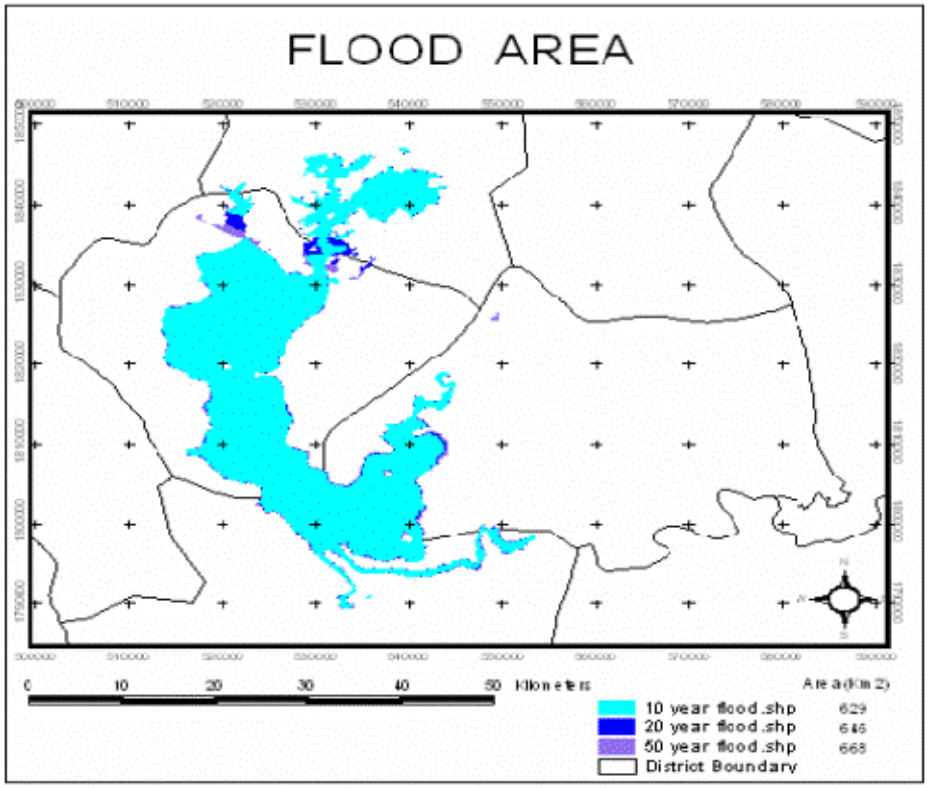


Figure 3. Results of 10, 20 and 50 years flood

Table 3. Length of roads affected

Roads	Total length of roads affected for return period of		
	10 years	20 years	50 years
National	4	4	5
Provincial	52	55	60
District	51	53	55
Rural	152	153	158
Total	259	265	278

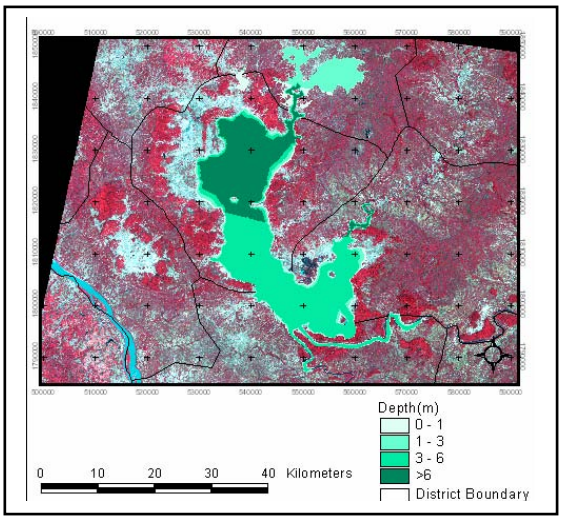


Figure 4. Flood depth

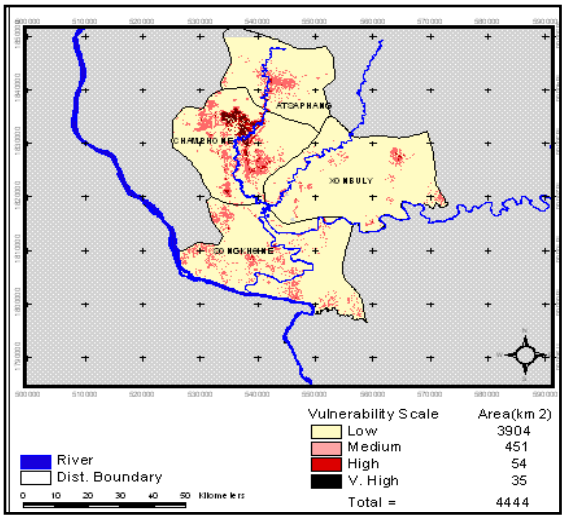


Figure 5. Vulnerability map

Figure 5 shows the vulnerability map for a return period of 10 years in the four districts of Champhone, Atsaphang, Xonbuly and Songkhone in a scale ranging from low to very high. Champhone was the most vulnerable district.

Table 4. Flood vulnerable areas

Vulnerability class	Total area (km^2)
Low	3,904
Medium	451
High	54
Very High	35
Total	4,444

Table 5. Land affected by flood

Land use	Total area (km^2)
Forest	66
Agricultural	196
Settlement	260
Grasslands	24
Rocks & Sand	1
Water Bodies	70
Total	617

From vulnerability analysis, it was found that for a 10 year flood, total vulnerable area is 4,444 km^2 as shown in Table 4 for the above four districts. Table 5 shows the total agricultural land inundated by a 10 year flood was of 196 km^2 with other land use area affected shown in detail.

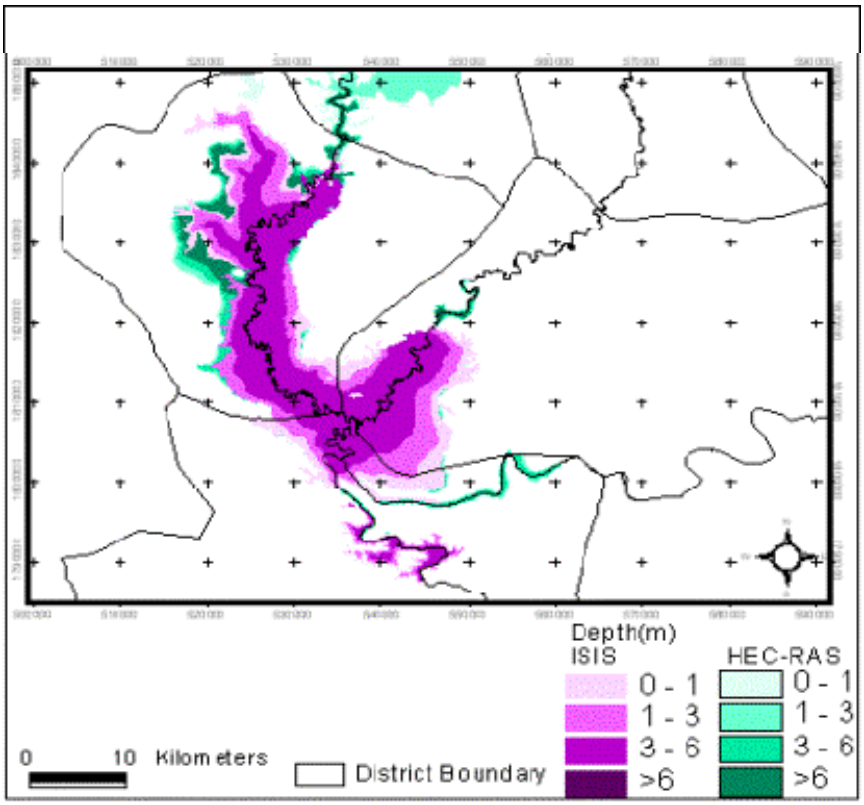


Figure 6. Vulnerability map

A visual comparison of the flood map with a flood map from ISIS mode is shown in Figure 6. The ISIS model generated flood map was obtained from the Mekong River Commission. A fairly good match was found in both the model results and a detail survey of the floodplains and the riverbed would help in generating a more accurate output. This study can be extended to the larger part of the basin which would be useful for flood preparedness planning in future.

REFERENCES

Anousone S.A., 2005. Concluding Report, Roadmap towards effective flood hazard mapping in Lao PDR, JICA Training Course on Flood Hazard Mapping.

Oudomchit, B.N., 2006. Flood forecasting system and flood management in Lao PDR, IFNET action report.

MEKONG-HYCOS STRENGTHENING INTEGRATED HYDROLOGICAL MANAGEMENT IN THE MEKONG RIVER BASIN CURRENT STATUS OF IMPLEMENTATION

LIKO SOLANGKOUN

Mekong River Commission Secretariat, Vientiane, Lao PDR

OBJECTIVES

The Mekong River is one of the least developed major international river basins, covering parts of the south-east Asian countries of China, Myanmar, Laos, Thailand, Cambodia and Vietnam. The Basin is marked by under-utilization of its vast water resources potential, and by recurrent natural disasters of large magnitude causing widespread devastation.

The development goal of the project is to minimize the loss of lives and property by reducing flood vulnerability in the Mekong River Basin, through strengthening integrated water resources management in the context of trans-boundary river basin management.

The project will contribute to:

- the improvement of the forecasting system at National and Regional Level;
- the implementation of the Procedures for Data and Information Exchange and Sharing (PDIES) approved by the MRC Council in 2001;
- the upgrading of national data processing and archiving systems;
- the establishment of distributed regional databases and telecommunication networks;
- the provision and dissemination of hydrological information to the users in timely manner;
- the building of the necessary capacity in operation and maintenance of the system in the long run.

PROJECT DESCRIPTION

The Mekong-HYCOS project (the Mekong Hydrological Cycle Observing System Project) consists in establishing an efficient, reliable and accurate timely hydrometeorological data collection and transmission system at basin level, while also strengthening relevant national and regional capacities. This information will be shared between the MRC Member States: *Cambodia, Lao PDR, Thailand and Viet Nam*. The Mekong-HYCOS project will establish a basin wide hydrometeorological information system, which spatially covers mainstream and main tributaries of the Mekong river system. It is expected that under the Mekong-HYCOS project, more than 20 hydrometeorological stations will be upgraded (Figure 1). The Mekong-HYCOS system will be integrated into the existing MRC monitoring system, while improving the national hydrological networks and river monitoring/forecasting capacities.

THE WHYCOS CONCEPT

WHYCOS (World Hydrological Cycle Observing System) is a WMO programme with the ultimate objective to promote and facilitate the collection, exchange, dissemination and use of water related information, using modern information technologies.

Figure 1. Field visit by Mekong-HYCOS Team, Kompong Cham station, Cambodia

The WHYCOS missions are:

- to strengthen the technical and institutional capacities of National Hydrological Services;
- to collect and transmit, in real or near real time, hydrometeorological data and information of a consistent quality;
- thereby improving water resources assessment and management and promoting regional and international cooperation in data collection, sharing and research.

WHYCOS is being developed in the form of regional components referred to as HYCOS, each of which meets the priorities expressed by the NHSs and end-users of the participating countries (Figure 2).

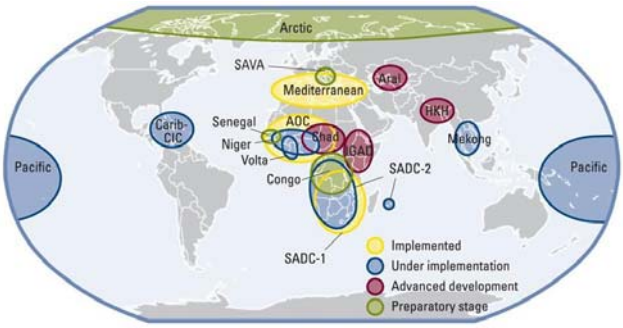


Figure 2. WHYCOS

The existing MRC 'Guidelines for the management of MRC Hydrometeorological Network' and 'Procedures for Data and Information Exchange and Sharing (PDIES)' are in line with the WHYCOS Guidelines and the spirit of Resolution 25 of the XIII-th session (1999) of the WMO Congress 'Exchange of Hydrological Data and Product'.

TECHNICAL SPECIFICATIONS

Under the 1995 Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin, signed by the governments of the four riparian countries of Lao PDR, Thailand, Cambodia and Vietnam, the Mekong River Commission was established to promote and co-ordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well-being by implementing strategic programmes and activities and providing scientific information and policy advice.

The existing hydrological and hydro-meteorological networks in the region are insufficient, especially in the mountainous areas, and the technologies involved in the data collection, transmission and processing should be improved to the required levels of technical sophistication, operational efficiency and institutional support.

IMPLEMENTATION

The project is planned from 2007 to 2011 with 3 main steps:

- *Inception Phase* that will last approximately 12 months: project conception, tendering and ordering process for hydro-meteorological stations (equipment, telemetry system, civil work);
- *Construction and Installation Phase*. It is anticipated to last 6 months. Depending on the total number of stations and the start of rainy season, it could be split in 2 steps in 2008 and 2009;
- *Follow-up* of the system, during approx 3 years in order to assure proper maintenance and training to the local staff and therefore to make the project more sustainable.

To ensure the sustainability of the system implemented by Mekong-HYCOS project, MRC is working on the creation of the MRC Hydro-meteorological Network. This single network will improve the quality and sharing of information, and reduce the costs of maintenance (Figure 3).

Figure 3. Inspection team Nam Songkhran at Ban Tha Kok Daeng, Thailand

CURRENT STATUS OF THE PROJECT

Stations to be upgraded by Mekong-HYCOS as per May 2008

Measuring stations

After field visits in March-April 2007 and National Consultations with the countries, the technical elements of the project were presented during the Mekong-HYCOS Regional Workshop in July 2007. It was decided to define priorities for station upgrading.

An International Invitation for Bids for Supply of hydrometeorological equipment and services of equipment expert was published in August 2007. Eight bids from famous hydrometeorological equipment suppliers were received and evaluated. The contract has been

awarded to OTT Company.

Firm stations (Lot 1)

It was decided that the stations as shown in Table 1 will be upgraded as Priority 1 stations.

Optional stations (Lot 2)

In complement of these stations, for a better knowledge of the tributaries of the Mekong River, and according with the project budget, it is planned the possibility to add a maximum of 14 other stations as Priority 2 (Table 2).

Second optional stations list (Lot 3)

Other financial resources are currently mobilised to upgrade a measuring network along the main stem of the Mekong River (AHNIP project). These stations would be modernized at later stage in order to harmonize the whole of the MRC hydrologic network. A Modernising station is the first step in integrating the AHNIP Network with Mekong-HYCOS.

Data flow

The dataflow for the MRC Hydrometeorological network is based on 2 principles:

Data flow as proposed by Mekong-HYCOS

Data are sent from the station by GPRS (if available) to a FTP server and accessible for all authorized users;
Then, using HYDMET, data are downloaded by authorized users from the MRC FTP Server (Figure 4).

Data flow as AHNIP experience

- data are sent from the station by GPRS or SMS to the National Data Terminal;
- then, using HYDMET, data are downloaded into the database of HYDMET;
- then, data are sent to MRCS FTP Server and RFMMC FTP Server;
- then, using HYDMET, data are downloaded by authorized users from the MRC FTP Server (Figure 5).

Table 1. Stations to be equipped (Lot 1)

N°	Lot and Item	Station	River	Coordinates (WGS 84)		Country	Parameter	WL Sensor	Telemetry	Power supply
				Latitude	Longitude					
1	1 - 1	Chaktomuk	Bassac	11.563	104.935	Cambodia	WL	Bubble	GSM (Camshin)	Solar Panel
2	1 - 1	Voeun Sai	Sesan	13.968	106.885	Cambodia	WL/R	Bubble	GSM (Camshin)	Solar Panel
3	1 - 1	Lumphat	Sre Pok	13.501	106.971	Cambodia	WL/R	Bubble	GSM (Camshin)	Solar Panel
4	1 - 1	Siempang	Sekong	14.118	106.389	Cambodia	WL/R	Bubble	GSM (Camshin)	Solar Panel
5	1 - 1	Kompong Thom	Stung San	12.715	104.888	Cambodia	WL/R	Radar	GSM (Camshin)	Solar Panel
6	1 - 1	Battambang	Sangker	13.092	103.200	Cambodia	WL/R	Radar	GSM (Camshin)	Solar Panel
7	1 - 2	Phiengluang	Nam Ngum	19.568	103.071	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
8	1 - 2	Ban Mixai	Nam Khan	19.786	102.183	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
9	1 - 2	Muong Ngoy	Nam Ou	20.570	102.617	Lao PDR	WL/R	radar	GSM (ETL)	solar panel
10	1 - 2	Mahaxai	Se Bang Fai	17.419	105.196	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
11	1 - 2	Ban Veun Kehn	Se Kong	14.819	106.806	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
12	1 - 2	Vientiane	Mekong	17.931	102.616	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
13	1 - 3	Ban Mai Bua Daeng	Nam Kok	20.025	99.960	Thailand	WL/R	bubble	GSM (AIS)	solar panel
14	1 - 3	Ban Tha Kok Doeng	Nam Sonkhran	17.866	103.775	Thailand	WL/R	Radar	GSM (AIS)	solar panel
15	1 - 3	Wang Saphung	Nam Loei	17.300	101.776	Thailand	WL/R	shaft encoder	GSM (AIS)	solar panel
16	1 - 4	Kontum	Dak Bla	14.347	108.034	Vietnam	WL/R	Bubble	GSM (Mobifone)	solar panel
17	1 - 4	Duc Xuyen	Krong Kno	12.296	107.976	Vietnam	WL/R	Bubble	GSM (Mobifone)	solar panel
18	1 - 4	Ban Don	Se Re Pok	12.898	107.784	Vietnam	WL/R	shaft encoder	GSM (Mobifone)	solar panel
19	1 - 4	My Thuan	Mekong	10.275	105.926	Vietnam	WL/R	shaft encoder	GSM (Mobifone)	solar panel
20	1 - 4	Can Tho	Bassac	10.053	105.787	Vietnam	WL/R	shaft encoder	GSM (Mobifone)	solar panel
21	1 - 4	Vam Kenh	Mekong	10.274	106.737	Vietnam	WL	shaft encoder	GSM (Mobifone)	solar panel
22	1 - 4	Dinh An	Bassac	9.533	106.363	Vietnam	WL	radar	GSM (Mobifone)	solar panel
23	1 - 4	Cua Tieu	Mekong			Vietnam	WL	radar	GSM (Mobifone)	solar panel

WL: water level; R: rainfall

Table 2. Stations to be equipped as potential option (Lot 2)

N°	Lot and Item	Station	River	Coordinates (WGS 84)		Country	Parameter	WL Sensor	Telemetry	Power supply
				Latitude	Longitude					
1	2 - 1	Kompong Speu	Prek Thnot	11.456	104.496	Cambodia	WL/R	Radar	GSM (Camshin)	Solar Panel
2	2 - 1	Sisophon	Sisophon	13.584	102.979	Cambodia	WL/R	Bubble	GSM (Camshin)	Solar Panel
3	2 - 2	Sopnam	Se Bang Hieng	16.687	106.215	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
4	2 - 2	Ban Nape	Nam Phao	18.305	105.073	Lao PDR	WL/R	radar	GSM (ETL)	solar panel
5	2 - 2	Ban Keng Done	Se Bang Hieng	16.187	105.313	Lao PDR	WL/R	bubble	GSM (ETL)	solar panel
6	2 - 2	Se Bang Fai	Se Bang Fai	17.077	104.985	Lao PDR	WL/R	radar	GSM (ETL)	solar panel
7	2 - 3	Thoeng	Nam Mae Ing	19.689	100.187	Thailand	WL/R	Radar	GSM (AIS)	solar panel
8	2 - 3	Ban Had Paeng	Nam Songkhram	17.676	104.287	Thailand	WL/R	bubble	GSM (AIS)	solar panel
9	2 - 4	Giang Son	Krong Ana	12.510	108.183	Vietnam	WL/R	radar	GSM (Mobifone)	solar panel

WL: water level; R: rainfall

Table 3. Second optional stations list (Lot 3)

N°	Lot and Item	Station	River	Coordinates (WGS 84)		Country	Parameter	WL Sensor	Telemetry	Power supply
				Latitude	Longitude					
1	3 - 1	Stung Streng	Mekong	13.545	106.017	Cambodia	WL/R	Bubble	GSM (Camshin)	Solar Panel
2	3 - 1	Kratie	Mekong	12.240	105.987	Cambodia	WL/R	Bubble	GSM (Camshin)	Solar Panel
3	3 - 1	Prek Kdam	Ton le Sap	11.813	104.804	Cambodia	WL/R	Shaft encoder	GSM (Camshin)	Solar Panel
4	3 - 1	Kompong Luong	Ton le Sap	12.575	104.215	Cambodia	WL/R	Shaft encoder	GSM (Camshin)	Solar Panel
5	3 - 2	Luang Prabang	Mekong	19.892	102.137	Laos	WL/R	Bubble	GSM (ETL)	electricity
6	3 - 2	Pakse	Mekong	15.117	105.800	Laos	WL/R	Bubble	GSM (ETL)	Solar Panel
7	3 - 3	Chiang Saen	Mekong	20.273	100.083	Thailand	WL/R	Bubble	GSM (AIS)	electricity
8	3 - 3	Chiang Khan	Mekong	17.897	101.668	Thailand	WL/R	Bubble	GSM (AIS)	electricity
9	3 - 3	Nong Khai	Mekong	17.877	102.720	Thailand	WL/R	Shaft encoder	GSM (AIS)	electricity
10	3 - 3	Nakhon Phanom	Mekong	17.398	104.803	Thailand	WL/R	Bubble	GSM (AIS)	electricity
11	3 - 3	Mukdahan	Mekong	16.540	104.737	Thailand	WL/R	Bubble	GSM (AIS)	electricity
12	3 - 3	Khong Chiam	Mekong	15.318	105.500	Thailand	WL/R	Bubble	GSM (AIS)	electricity
13	3 - 4	Tan Chau	Mekong	10.803	105.243	Vietnam	WL/R	Shaft encoder	GSM (Mobifone)	electricity
14	3 - 4	Chau Doc	Bassac	10.707	105.133	Vietnam	WL/R	Shaft encoder	GSM (Mobifone)	electricity
15	3 - 4	Vam Nao	Vam Nao	10.575	105.357	Vietnam	WL/R	Shaft encoder	GSM (Mobifone)	electricity

WL: water level; R: rainfall

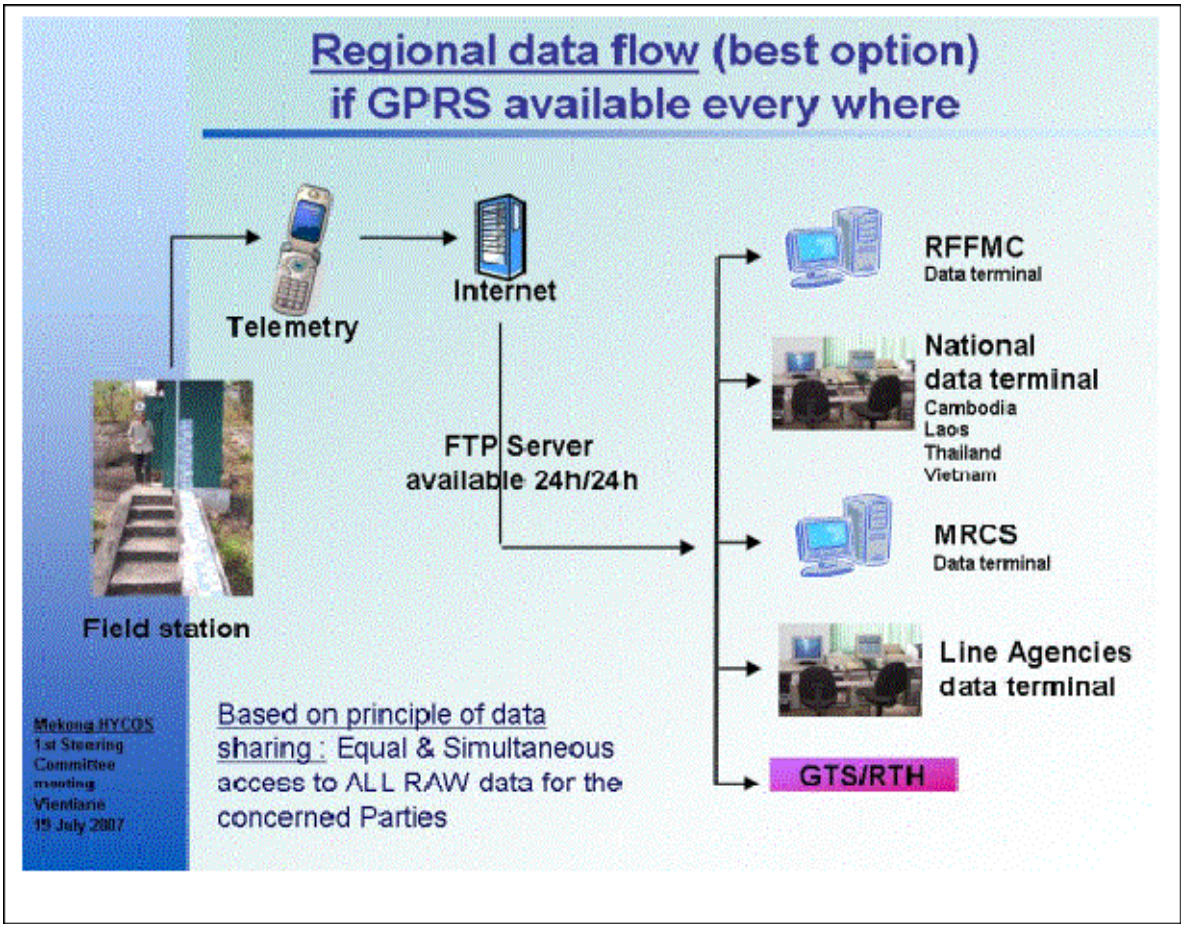


Figure 4. Data flow as proposed by Mekong-HYCOS

PROPOSED WORKPLAN FOR IMPLEMENTATION DURING THE END OF 2008

After signature of agreements with the four MRC member countries – one for 'Management of MRC Hydrometeorological Network' and one for 'construction of civil works', the second phase of the project (installation phase) is ready to start

Due to the number of stations proposed to be installed (more than 30 instead of 20-25) and due to the coming rainy season, the construction and installation phase is proposed to be managed in two steps: the 1st step in 2008 for installation of priority 1 stations easy to install and the 2nd step in 2009 for installation of other priority 1 stations and priority 2 stations. During this 2nd step, depending on availability of funds and agreements reached with countries, the AHNIP stations upgrading could be planned. The objective is to seek coherency of MRC Hydrometeorological Network based on actual MRCS reflections on 'Integration of MRC Hydrometeorological systems'.

During the installation phase, the sustainability of the MRC Hydrometeorological Network shall be sought by establishing and strengthening, at Regional and National levels, the technical capacities required to: (i) operate, maintain and expand a hydrometeorological network of automatic data, (ii) collect and share accurate, real-time hydrometeorological data, (iii) measure discharge in order to validate and update the H(Q) transformation curves essential for the management of trans-boundary water issues (iv) implement a Hydrological Information System with Intranet and Internet accessibility.

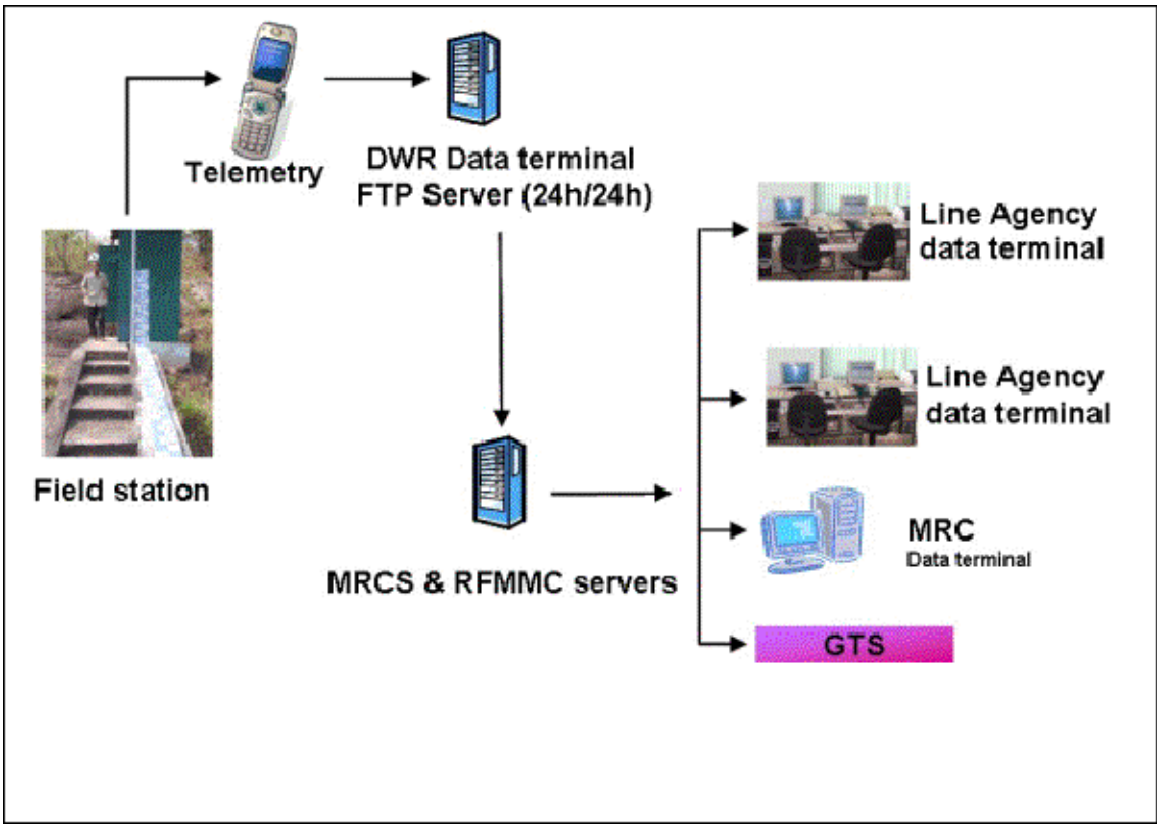


Figure 5. Data flow as AHNIP experience

First Step - construction of stations with a few civil works to do. Moreover, the stations should also be easy to install the equipment.

- *1st step in 2008,* it is planned to install a part of priority 1 stations:
  - Construction and installation of some stations with few civil work to be done:
    - *Cambodia (3):* Chaktomuk - Battambang - Khompong Thom;
    - *Lao PDR (3):* Ban Mixai - Ban Veunkenh Vientiane KM4;
    - *Thailand (1):* Ban Mai Bua Daeng;
    - *Viet Nam (4):* Can Tho - Din Anh - Cua Tieu - Vam Kenh;

    This list should be validated by countries.
  - *Equipment.* installation of hydrometric and telemetry equipment after civil work;
  - *Database.* Consistency between AHNIP and HYCOS will be sought: receiving stations with the same software: HYDMET developed by HydmetSoft of Viet Nam;
  - *Training.* Training in the field, Regional and National Trainings based on MRC accredited Technical Training Program (ATTP) and supply of Standard Operating Procedures (SOP).
- *2nd step end of 2008, early 2009* (during the dry season), it is planned to install other priority 1 stations with the following schedule:
  - Construction of Civil work by each line agency, between October 2008 and March 2009:
    - *Cambodia (3):* Voeun Sai, Lumphat, Siempang;
    - *Lao PDR (3):* Phiengluang, Muang Ngoy, Mahaxai;
    - *Thailand: (2):* Tha Kok Daeng, Wang Saphung;
    - *Viet Nam: (4)* Kontum, Duc Xuyen, Ban Don, My Thuan.

The construction of stations in priority 2 will be depended on the availability of fund)

* *Equipment:* installation of hydrometric and telemetry equipment on the field between January and March 2009;
* *Database:* evaluation of existing data management system in coherency with IKMP policy and link between real time database and historical database;
* *Training:* Training on the field. Sustainability of the project should be sought: technical support by Regional ongoing assistance could be initiated mainly with Cambodia and Lao PDR line agencies.

REFERENCES

Mekong River Commission Secretariat, 2007. The Mekong Hydrological Cycle Observing System-Mekong-HYCOS, Inception Report.

Mekong River Commission Secretariat, 2008. Establishment of a hydrological information system in the Mekong River Basin, The Mekong Hydrological Cycle Observing System Project Document, Final

World Meteorological Organisation (WMO), 2005. Hydrological Information systems for integrated water resources management, WHYCOS Guidelines – October 2005.

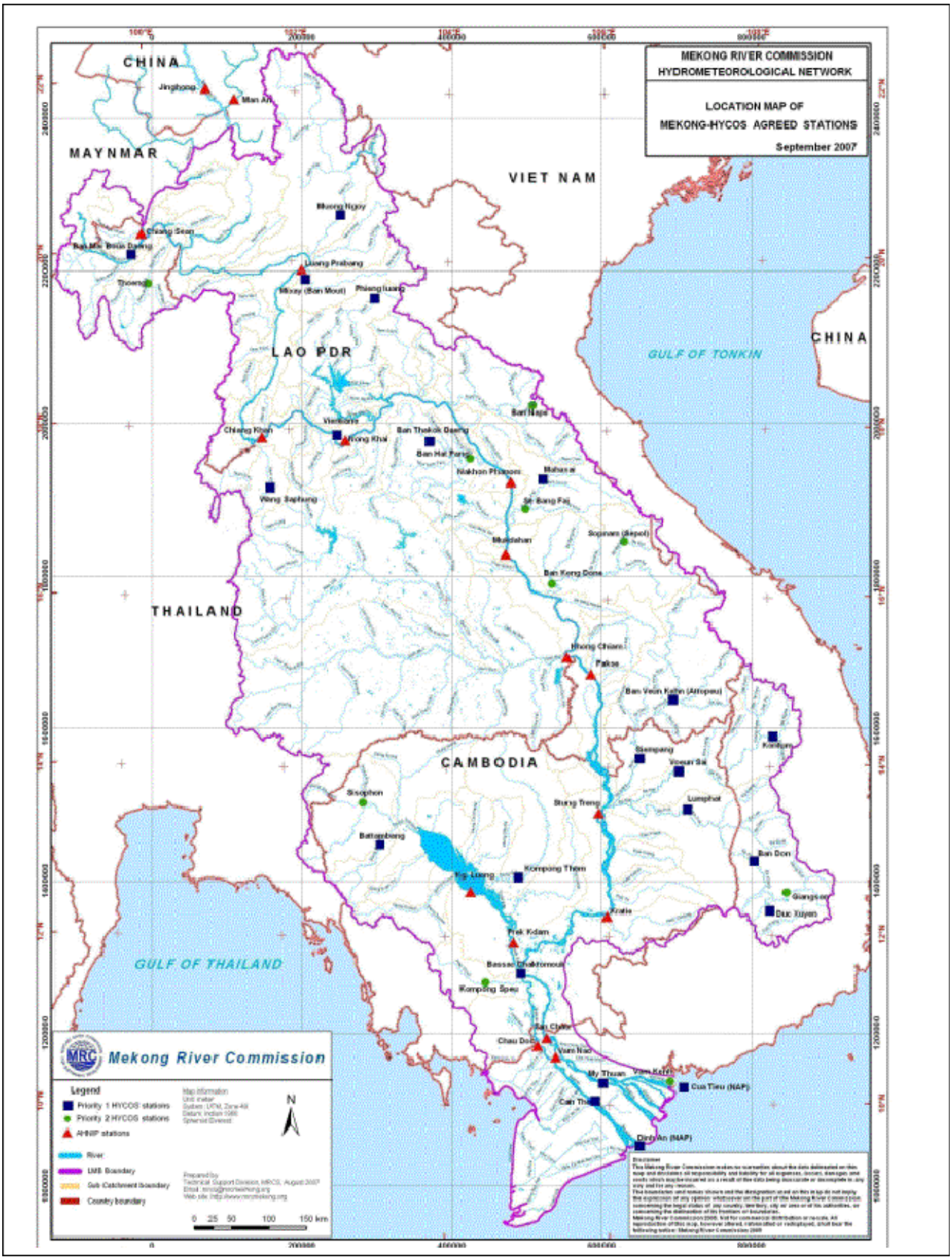
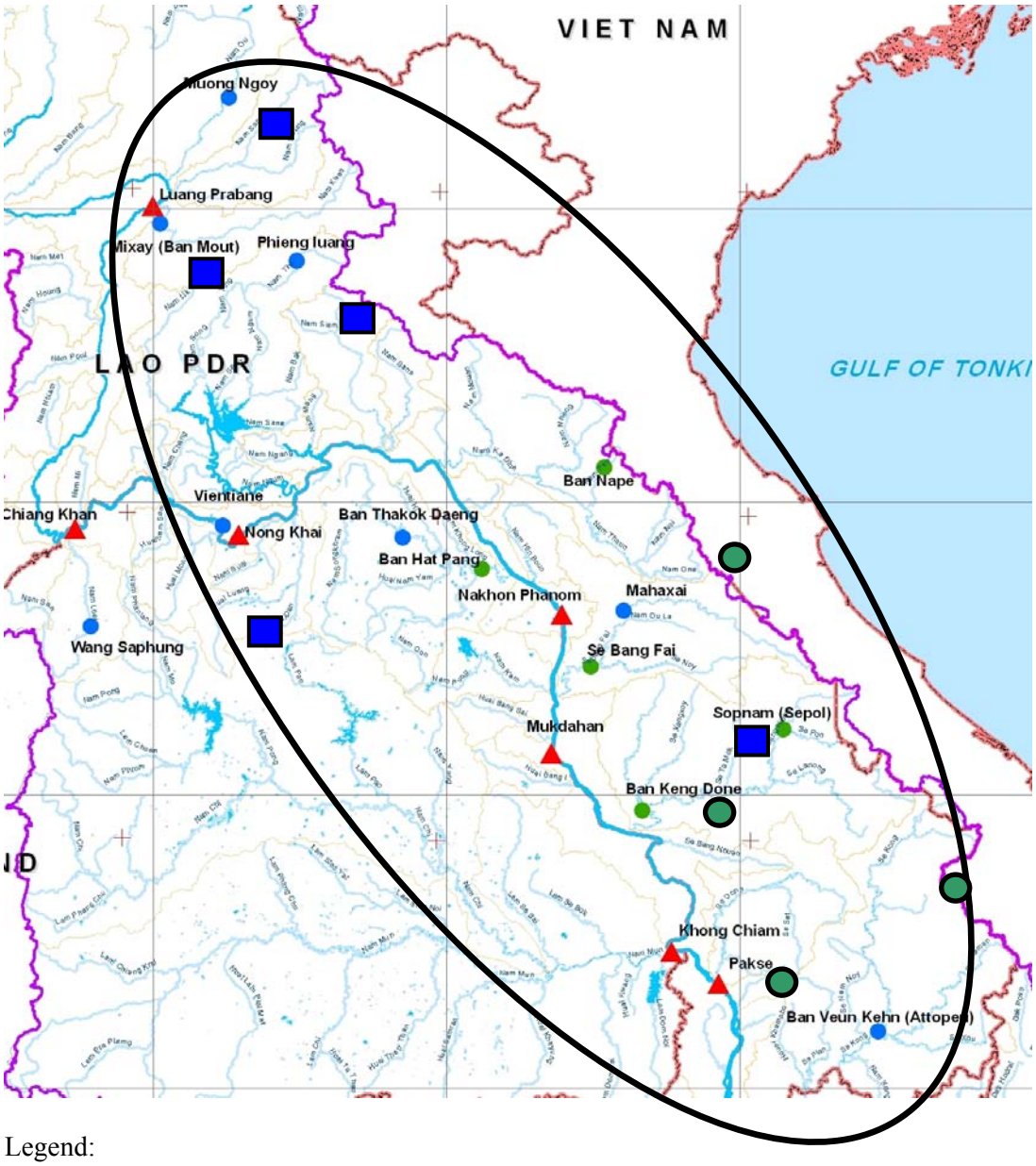


Figure 6. Location map of Mekong-HYCOS agreed stations

Legend:

- stations priority 1 in Cambodia
- stations priority 2 in Cambodia
- existing AHNIP stations

Figure 7. Location map stations in Cambodia



Legend:

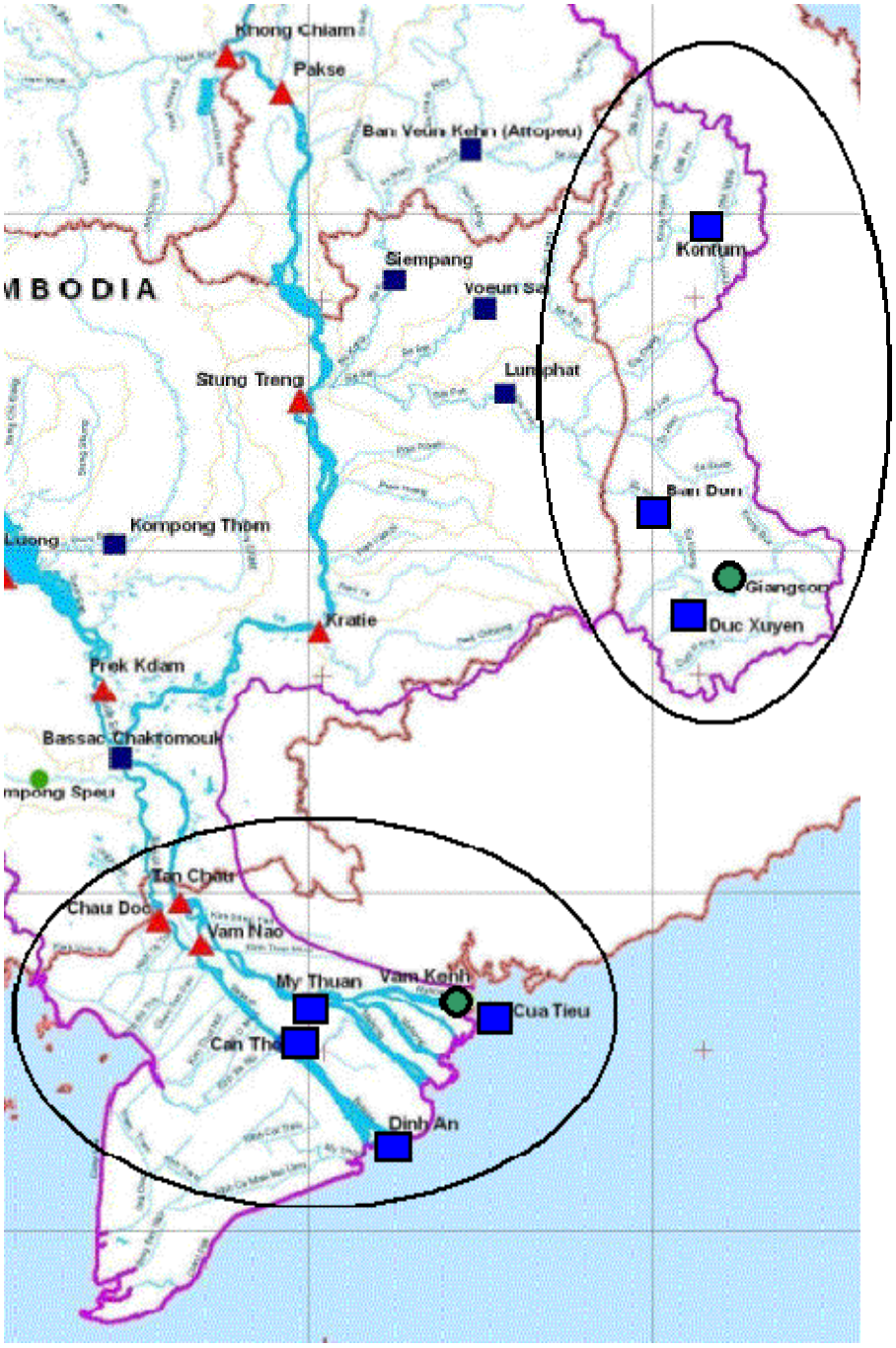
- stations priority 1 in Lao PDR
- stations priority 2 in Lao PDR
- existing AHNIP stations

Figure 8. Location map stations in Lao PDR

Legend:

- stations priority 1 in Thailand
- stations priority 2 in Thailand
- existing AHNIP stations

Figure 9. Location map stations in Thailand



Legend:

stations priority 1 in Vietnam

stations priority 2 in Vietnam
existing AHNIP stations

Figure 10. Location map stations in Viet Nam

OUTLINE OF AN APPROACH TO GENERATE FLOOD PROBABILITY INFORMATION AND ITS POSSIBLE USE IN LAND MANAGEMENT

GEORG KÄSLER

Technical Adviser, Land Management Component, Flood Management and Mitigation Programme, Mekong River Commission, Vientiane, Lao People's Democratic Republic

ABSTRACT

The article describes the approach used by the Land Management Component of MRC's Flood Management and Mitigation Programme (FMMP) to generate flood probability information for selected parts of the Mekong flood plains in Cambodia.

It first explains the concept of 'probability of exceedance', which is crucial for the correct interpretation of the information. Then presents the steps involved in processing the underlying data, the ways in which various flood related probability statistics are calculated and the software used to display the results. It concludes with a few remarks on the possible use of this information for land management and other purposes.

WHAT IS FLOOD PROBABILITY INFORMATION?

Flood probability information provides statements about the likelihood with which certain flood related events occur. More precisely, it states the probability of exceedance of these events.

'Probability of Exceedance' (POE) is a technical term used in science to describe the likelihood with which an event will surpass a given limit. An illustration is provided in Figure 1 which shows the POE of the annual maximum water level at three river stations along the Mekong: Kompong Cham, Phnom Penh Bassac and Neak Luong. At Phnom Penh Bassac, for example, the probability of exceedance is 0.7 for an annual maximum water level of 9.50 m**.** This means that there is a 70% probability that the annual maximum water level will be higher than 9.50 m. Or in other words: in the long term the annual maximum water level will exceed 9.50 m in seven out of ten years. It will only remain below 9.50 m in three out of ten years.

Besides the POE for annual maximum water levels, probabilities of exceedance can also be calculated for a variety of other flood related events. These may relate to time (e.g. the duration of flooding or the completion of draining) or to location (e.g. the maximum depth of flooding at a certain place). The Land Management Component of MRC's Flood Management and Mitigation Programme (FMMP) has calculated a set of such probability statistics for selected parts of the Mekong flood plains in Cambodia. It has then gone a step further by combining the results of these analyses with detailed topographic information thus creating maps showing the POE of different flood related events not only for certain spots like river stations but for whole areas like communes or districts.

An example of such a map is given in Figure 2. It shows for parts of Peam Ro district (a district in Cambodia downstream from Phnom Penh on the left bank of the Mekong) the times at which the draining of the annual floodwaters is completed at a probability of exceedance level of 10%. Such a low probability of exceedance level indicates that it is very unlikely that a given area will not yet be drained at the indicated point in time. At a level of 10% this may only happen in one out of ten years.

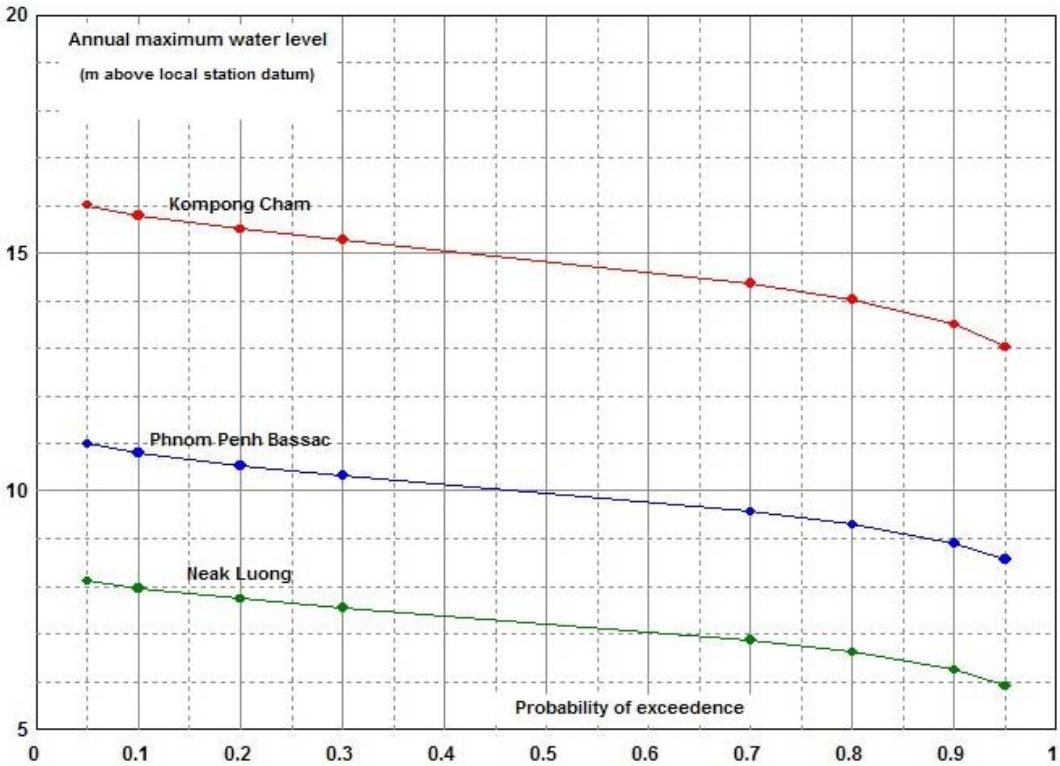


Figure 1. Probability of exceedance of the annual maximum water level at three river stations based on records from 1960 to 2006.

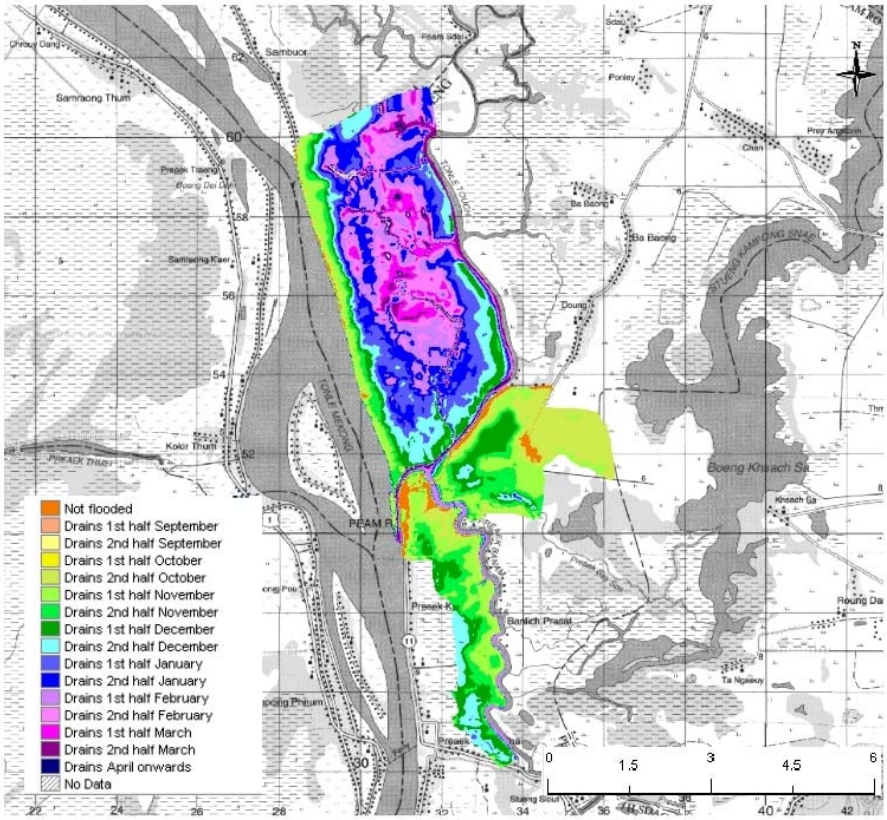


Figure 2. Completion of draining in Peam Ro district (Cambodia) at a probability of exceedance level of 10%.

HOW HAS THE FLOOD PROBABILITY INFORMATION BEEN GENERATED?

Figure 3 shows an outline of the steps used by the Land Management Component of FMMP in generating the information displayed in its flood probability maps. It indicates that in this approach three groups of data have been used as inputs:

- historical water level records of the main river covering the period of 1960 to 2006;
- recent observed water level records in the flood plains covering the period of 2003 to 2006;
- data from a topographic survey of features and overall ground levels in the flood plains specifically commissioned for this purpose in 2006.

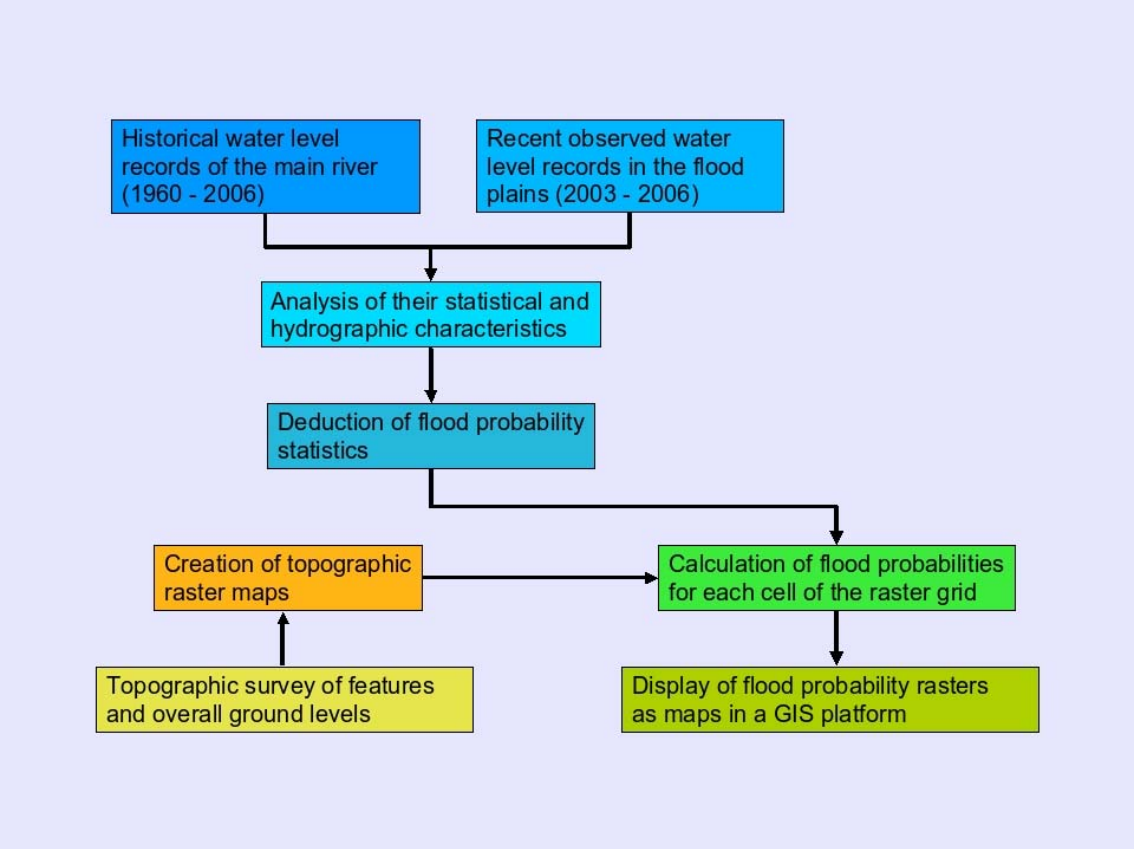


Figure 3. Outline of the approach used by the Land Management Component of FMMP to generate flood probability information and corresponding maps.

In a first step, the two sets of water level records have been analysed with regard to their statistical and hydrographic characteristics, with the results then serving to calculate a series of flood probability statistics. The statistical description of the seasonal floods of the main river is derived from historical water level records, which are available in form of daily readings starting in 1960. These data have been used to derive statistical descriptions of the floods using standard hydrological methods.

In contrast to the well-established system of hydrographic stations at the main river, there are almost no records of water levels on the flood plains, the only exception being data collected since 2003 in connection with a project supported by the USAID Office of Foreign Disaster Assistance (OFDA). The aim of this project is to provide communities on the Cambodian flood plains with early warning information on approaching floods. As part of this undertaking a number of flood marks have been installed by the Department of Hydrology and River Works (DHRW) in the villages participating in the project (Figure 4). During the flood season village

volunteers take daily readings from these flood marks and transmit them to the DHRW. Their records have been proven to be complete and very accurate.

Figure 4. Examples of village flood marks used to record water levels on the flood plains.

The key step then was to relate these data about the flooding on the plains to the behaviour of the Mekong main stem. The aim was to use the correlation between the two sets of data to 'extrapolate' the limited records from the flood plains – only four flood seasons have been recorded so far – by employing the longer term statistical information from the main river. An empirical approach has been taken to determine the relationship between the levels in the river and on the plains, supported by consideration of the controls on the flow of floodwater across the plains.

In the areas selected for these calculations, the relationship between the main river and the water on the flood plains typically looks as shown in Figure 5, although with slight variations between the different sub-areas: the river starts diverting into the flood plains once it has reached point A (in this case about 5.7 m above mean sea level). The water then fills up the plains relatively fast (A → B). At the peak of the flood season (between points B and C) the levels of the main river and the flood plains are connected and fluctuate together. When draining sets in, the two disconnect at point B, from whence draining continues relatively evenly towards point D. The inflow and outflow of the floodwaters take place to a large degree through different channels, which explains the Y-shaped form of the graph.

Once these relationships were established for selected sub-areas of the districts, the process of estimating flood levels and the timing of flood events could be started. The results were subsequently validated by verifying that the statistics were consistent with the observed water levels from the village flood marks, although this validation was limited by the fact that floods in recent years have not been extreme – neither particularly high nor low.

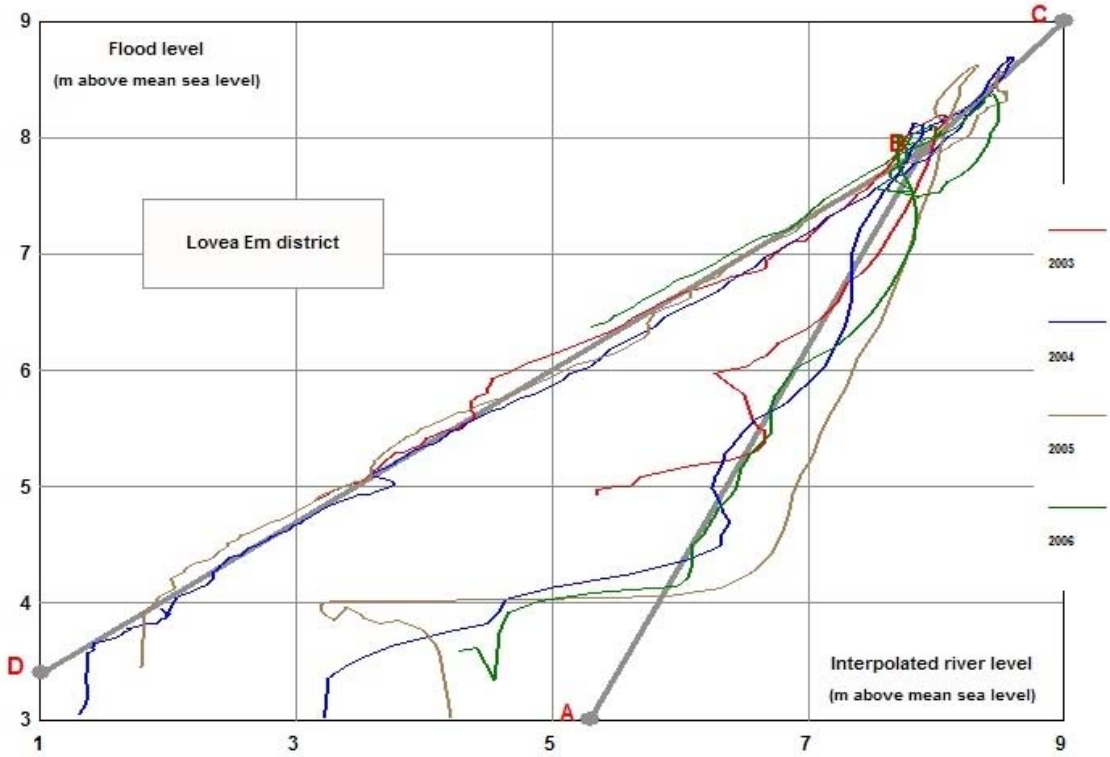


Figure 5. Example of the relationship between the river level and the flood level on the plains (main river data: interpolated records from the stations in Phnom Penh and Neak Luong; village level data: records from flood marks in Lovea Em district)

A second process then consisted in creating detailed topographic raster maps. The data for these maps came from a survey of features and overall ground levels in the flood plains specifically commissioned for this purpose in 2006. The need for such a specific survey arose from the fact that none of the available data sets (DTMs, aerial photography, etc.) were detailed enough for the envisaged purpose of providing information which could be used for planning exercises at district level and below.

The topographic data have been collected using traditional ground based surveying techniques. The Component had also considered other options like the evaluation of aerial photography and a LIDAR[1] survey. All these methods do not differ much in terms of costs per square kilometre, however the ground based survey turned out to have several advantages in comparison to the airborne methods:

- small linear features like ditches and embankments influence the flow of water in the flood plains. The ground-based survey was able to accurately capture the location and profile of these features by taking more measurements in their vicinity than in open areas with a more uniform slope. The airborne methods may have missed them while providing unnecessary amounts of data in flat areas;
- the more relevant parts of the flood plains (settlements, gardens, agricultural fields) are unevenly distributed and irregularly shaped. On the ground the surveyors could adjust the areas they surveyed accordingly and focus on these parts. The airborne methods would have provided a rectangular block of data thus including also a lot of irrelevant areas;
- from an administrative and logistical point of view it was much easier to organise the ground-based survey. For airborne surveys special permissions have to be acquired, in case of a LIDAR survey not only from national but also from foreign authorities. On the

1 LIDAR = **Li**ght **D**etection **a**nd **R**anging

flood plains the time slots during which the seasonal water has drained completely while the agricultural areas are not hidden under a canopy of crops are very few and short. The timing of any airborne survey has to be scheduled precisely to find such a slot. Even then the survey may still be impeded by unfavourable weather conditions. In contrast to this, during a ground-based survey the surveyors can adjust their work areas in a flexible manner, surveying flooded areas when the water recedes and cultivated areas when the crops have been harvested.

A challenge for any topographic survey in the Mekong flood plains is its relative lack of benchmarks. This is felt even more when the focus of the mapping exercise is on vertical rather than horizontal accuracy. In order to determine the levels of the village flood marks the surveyors commissioned by the Land Management component had to level traverses in the form of closed loops from a benchmark at the Japanese Bridge in Phnom Penh and a second one in Neak Luong some 55 km downstream on the left bank of the Mekong. In addition to this, horizontal control points were fixed for each of the surveyed areas using differential GPS.

The processing of the survey data was then standard procedure: They were first geo-referenced using the positions and heights of the control points and then referenced to a standard height datum (Ha Tien 1960)[2]. The adjusted data were subsequently used to create a Triangulated Irregular Network (TIN) which was edited where necessary to correctly define features. The edited TIN finally formed the basis for the creation of topographic raster maps with a pixel size of 5 x 5 m. This resolution was found to be adequate to define small linear features like ditches and embankments while maintaining reasonable file sizes. See Figure 6 for an example of such a map.

The next step then was to combine the earlier created information on the flood probability statistics with the topographic raster maps to calculate flood probability statistics for each cell of the raster grid. It would of course be a very tedious task to calculate these values manually for each individual cell. The Component has therefore developed a software programme called 'MapStats' that can execute this task. At its core is a Fortran Programme DLL for the actual calculations while the user is provided with a graphical interface where choices can be made regarding the properties to be mapped. Figure 7 shows the overall structure of this process.

The options provided by the programme for selection are as follows:

- *Area (district).* So far data are available for three districts in Cambodia: Lovea Em, Peam Ro, Leuk Dek. During its upcoming second phase the Component plans to assist national authorities in Cambodia, Laos and Vietnam to extend the covered areas;
- *Type of statistic.* The following statistics can be mapped;
    - Maximum depth of flooding;
    - Probability of flooding;
    - Completion of draining;
    - Duration of flooding;
- *Probability of exceedance.* Users can choose from the following levels: 1%, 5%, 10%, 20%, 30%, 50%, 70%, 80%, 90% and 95%. When 'Probability of flooding' is selected in the previous step these options are of course not available because in this case all probabilities will be in one output file;
- *Classified results.* The results of the 'Probability of flooding' statistic are always classified by the programme according to the levels listed above. When 'Completion of draining' is selected there is an option to classify the results replacing day numbers with class numbers representing monthly or half-monthly increments. Similar options may in future versions of the programme be included for 'Maximum depth of flooding' (e.g. 0.5 metre increments) and 'Duration of flooding' (e.g. 10 day increments);

[2] Vertical positions in the lower Mekong basin are still referenced to the Ha Tien 1960 datum (mean sea level), although this datum has in Vietnam been replaced by the Hon Dau 1992 datum. The vertical difference between Ha Tien 1960 and WGS84 is about 10 metres in the lower Mekong basin, but this is not properly calibrated.

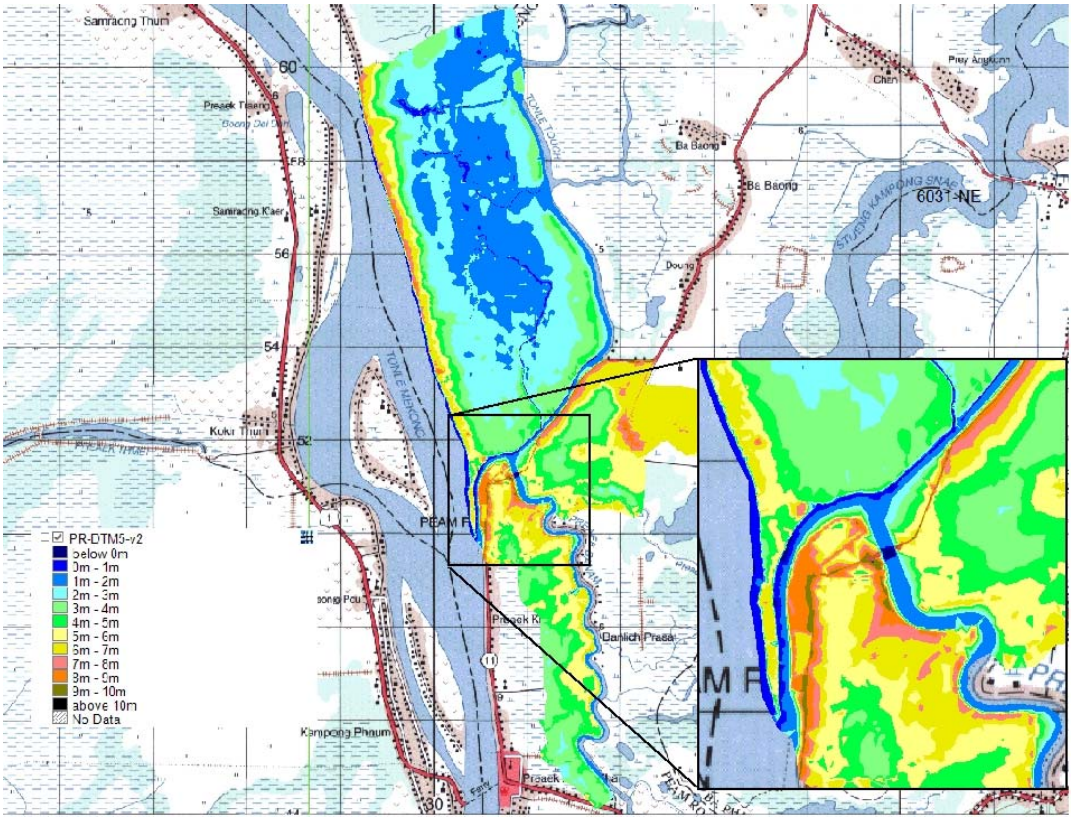


Figure 6. Example of a map based on a topographic raster file with a pixel size of 5 x 5 m (Peam Ro, Cambodia).

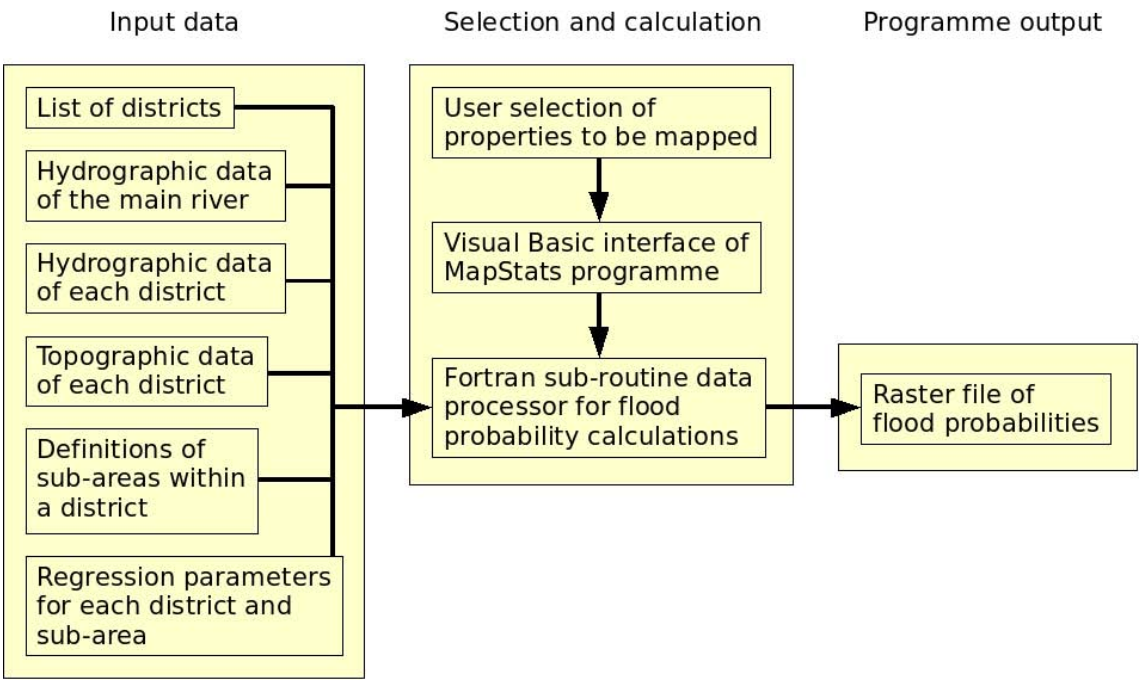


Figure 7. The flood probability calculation process of the MapStats programme.

- *File name.* The programme provides a recommended name for the output raster file but users can replace this by one of their own choice. They can also select whether the file

extension should be 'txt' to be compatible with ArcGIS or 'asc' for a programme like MapWindow GIS.

The resulting output raster files can then be displayed as maps in any GIS platform (e.g. ArcGIS, MapWindow GIS, Quantum GIS). As most of the potential users of this information can not be expected to have a license of ArcGIS, the Component has looked for a suitable low-cost (preferably free of charge) alternative and found it in form of 'MapWindow GIS' which is an open source application and set of programmable mapping components developed and maintained by a group of voluntary developers at Idaho State University. It is included in the Component's installer CD but can also be downloaded from http://www.mapwindow.org/ .

WHAT CAN THIS FLOOD PROBABILITY INFORMATION BE USED FOR?

From what has been explained so far it should have become apparent that this approach cannot be used as a forecasting tool. The flood probability information generated in this way does not predict when a flood will come or which level it will reach in a certain year. It is rather meant to be a planning tool in support of longer-term decisions.

It could in this respect be useful for a range of subjects related to land management in its wider sense, be they in the fields of land use planning, agriculture, forestry, fisheries or nature conservation. It may also assist in considering flood probabilities for infrastructure projects like roads, buildings (housing, schools, health stations, etc.), water supplies, rural sanitation and flood controls. And of course it can provide useful information in flood preparation exercises like the determination of escape routes or the selection of safe areas.

THE LOWER MEKONG BASIN FLOOD MAPPING SERVICE: DEVELOPMENT AND DELIVERY OF NEAR-REAL-TIME FLOOD MAP PRODUCTS

A.M. DEAN[1], O.T. TSUI[2], A. SYED[2] AND T. BOIVIN[2]

[1]*PT Hatfield Indonesia, Bogor, Indonesia*
[2]*Hatfield Consultants, West Vancouver, Canada*

ABSTRACT

The *Lower Mekong Basin Flood Mapping Service* (LMB-FMS) involved the delivery of Near-Real-Time radar flood products to the Mekong River Commission (MRC), according to defined product specifications and a pre-determined acquisition schedule. The LMB-FMS was implemented for the MRC by Hatfield Consultants (Hatfield, Canada) with support from the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) and the Canadian Space Agency (CSA).

Since 1999, the RADARSAT-1 satellite data has been used by the MRC to map the extent of the annual floods, and complement data from river gauges and flood models. RADARSAT-1 is particularly useful for flood mapping because of its ability to see through clouds and sensitivity to changes in surface properties related to flooding. In 2007, the successful implementation of the LMB-FMS was a step forward from previous mapping projects. The advantages of the LMB-FMS compared to previous flood mapping products included:

- flood map products were delivered to MRC-RFMMC in Near-Real-Time every 5 to 7 days during the flood season (July to December 2007);
- flood map products specifications were carefully defined by MRC-RFMMC and Hatfield, and rigorously followed for the delivery of products in a variety of formats on each acquisition date;
- flood map products were made available by MRC to users of the MRC River Monitoring Portal (http://ffw.mrcmekong.org/) within 24 hours of acquisition;
- flood map products included flood extent and flood area change maps and data for the Lower Mekong Basin and individual Hydrological Stations to complement gauge data.

Between June and December 2007, flood map products were delivered on 20 individual dates, with a maximum of 42 individual flood map products per date. Based on the experience gained in the first year of delivery of the LMB-FMS, evaluation of the service has been conducted, and a set of recommendations for service improvement and enhancement defined.

INTRODUCTION

Background

Since 1999, RADARSAT-1 satellite data has been used by the Mekong River Commission (MRC) to map the extent of the annual floods, and supplement and complement data from river gauges and flood models. RADARSAT-1 carries an active radar instrument (see NRCan, 2008; Rees, 1999) which is particularly useful for flood mapping because of its ability to see through clouds or image at night, and its sensitivity to changes in land surface properties related to

flooding (Disasters Charter, 2008; Meina *et al*. 2000; Hatfield Consultants, 2003).

RADARSAT-1 data has provided a unique contribution to understanding the hydrological regime of the Mekong River and Tonle Sap floodplain in Cambodia and Vietnam (Fujii, *et al.* 2003). Other river basins, such as Songkram River in Thailand, have also been studied using RADARSAT-1 data. The key information that can be derived from RADARSAT-1 data is the extent of flooded area, which in addition to supporting scientific investigations can be combined with other geographic data for numerous applications. For example, information on flood extent in the Mekong region derived from RADARSAT-1 has supported a range of initiatives including fisheries assessments (Hatfield Consultants 2000), environmental management (Hatfield Consultants 2000), and community flood vulnerability (Hatfield Consultants 2008, MRC, 2006).

In the Mekong region, frequent and timely delivery of flood information has the potential to support flood disaster management activities, specifically *preparedness* and *response* activities conducted by governments, MRC, and civil society organizations. With advances in data processing capabilities, RADARSAT-1 data can be delivered in so-called "Near-Real-Time", which means that information can be provided to end-users only a few hours after acquisition by the satellite. Strictly speaking, flood extent information derived from RADARSAT1 is flood "now-casting", rather than flood forecasting conducted using hydrological models. However, an advantage of RADARSAT-1 is that the extent and pattern of flooding observed is much more detailed compared to models, which are limited by poor elevation data.

Lower Mekong Basin Flood Mapping Service

The *Lower Mekong Basin Flood Mapping Service* (LMB-FMS) involved the delivery of Near-Real-Time flood products to the Mekong River Commission (MRC) Regional Flood Management and Mitigation Centre (RFMMC), according to defined product specifications and a pre-determined acquisition schedule.

Flood map products derived from RADARSAT-1 were delivered to MRC on a weekly basis between June and December 2007; MRC made these map products available to the users through their River Monitoring Portal (http://ffw.mrcmekong.org/) within 24 hours of acquisition. The product specification was defined by MRC and Hatfield Consultants (Canada), and included *flood extent* and *flood area change* maps and data for the part of the Lower Mekong Basin and individual hydrological stations to complement gauge data. The implementation of the LMB-FMS in 2007 was undertaken as a proof-of-concept or feasibility study. The aims were to:

- implement the LMB-FMS according to service and product specifications;
- evaluate the quality of the LMB-FMS from a technical and operational perspective, including product quality and service reliability;
- provide recommendations for service improvement from a technical, operational, and institutional perspective.

STUDY AREA AND DATA

The area of focus for the LMB-FMS was the floodplain of the Mekong River and Tonle Sap River / Great Lake in Cambodia and Mekong Delta in Vietnam (Figure 1). Sub-basins of the Mekong River in Thailand and Lao PDR were also of interest.

The ScanSAR mode of RADARSAT-1 was used for this application, as it provides relatively high resolution imagery (50 m pixels) across a 300 km swath. The RADARSAT-1 ScanSAR acquisition schedule for the LMB-FMS in 2007 was semi-monthly from June to July, and approximately weekly from August to November. The nominal revisit period for the

RADARSAT-1 satellite to cover the same area in the same beam mode is 24 days. In order to obtain weekly observations, images from ascending and descending orbits and different beam modes (i.e., ScanSAR Narrow A [SNA] and ScanSAR Narrow B [SNB]) were required. The geographical extents of the ascending and descending orbits and ScanSAR swaths are different, meaning that the coverage of products is different. The geographical extents of flood/change maps are shown in Figure 1.

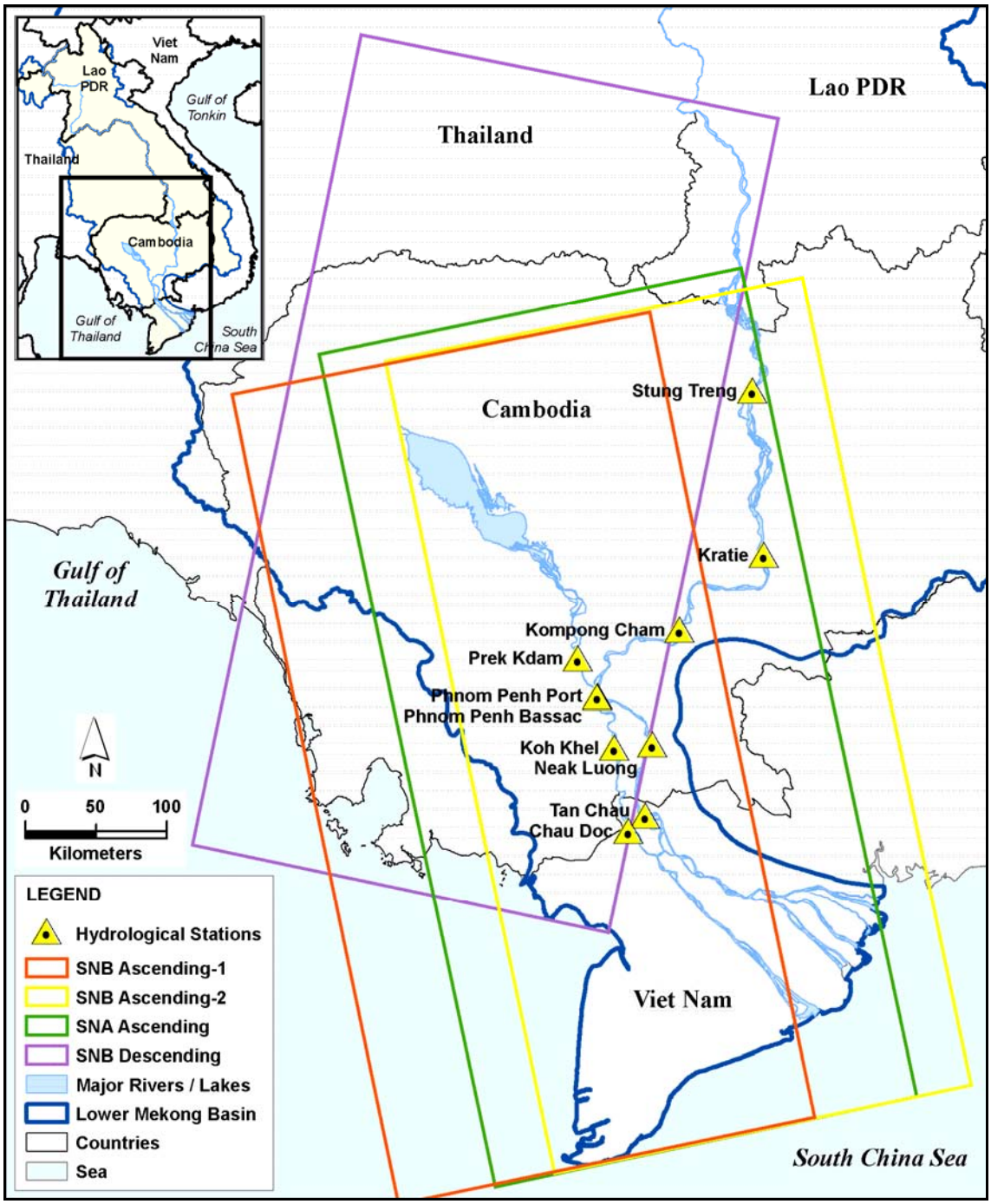


Figure 1. Study area and coverage of the flood product delivered, 2007.

RADARSAT-1 imagery was provided by the Canadian Space Agency (CSA) to support the LMB-FMS feasibility study and a Memorandum of Understanding between MRC, CSA and Natural Resources Canada.

METHODS

Product specification

The specifications of products delivered for the 2007 LMB-FMS are defined in Table 1. Under the LMB-FMS, products were generated in Near-Real-Time using semi-automated data processing methods. These methods can be considered as a set of defined sub-tasks, as follows:

- data download from secure server;
- data pre-processing, including calibration and speckle (noise) reduction;
- geometric correction of imagery, and co-registration;
- analysis to determine flood extent and flood change;
- map and metadata generation.

PCI Geomatica image processing software was used to process RADARSAT-1 data to produce flood product data; ESRI ArcView GIS software was used to produce flood maps.

Table 1. Product specification for Lower Mekong Flood Mapping Service, 2007.

Product #	Description	Classes	Format
1	Radar Image: Geometrically corrected Calibrated and speckle filtered	n/a	GeoTIFF
2	Open water flooded area: Based on change detection from a dry season image.	1. Open water 2. Others	GeoTIFF ESRI Shapefile
3	Change in flooded area: Based on change in open water since previous image.	1. No change – non-water 2. No change – open water 3. Flood expansion 4. Flood recession	GeoTIFF ESRI Shapefile
4	Flood map: Flood Map for area of LMB covered by image. Flood maps centred on individual flood stations (50 x 50 and 100 x 100 km area)	n/a	Web display: Gif Downloadable: Png
5	Change in flooded area map: Change in Flooded area map for area of LMB covered by image. Change in Flooded area map centred on individual flood stations (50 x 50 and 100 x 100 km area)	n/a	Web display: Gif Downloadable: Png

Data processing

Under the LMB-FMS, products were generated in Near-Real-Time using semi-automated data processing methods. These methods can be considered as a set of defined sub-tasks, as follows:

- data download from secure server;
- data pre-processing, including calibration and speckle (noise) reduction;
- geometric correction of imagery, and co-registration;
- analysis to determine flood extent and flood change; and
- map and metadata generation.

PCI Geomatica image processing software was used to process RADARSAT-1 data to

produce flood product data; ESRI ArcView GIS software was used to produce flood maps.

RESULTS

The LMB-FMS was successfully implemented, and the product specifications were met. RFMMC enabled access to LMB-FMS products by end-users through use of the MRC River Monitoring Portal. The LMB-FMS products were delivered on the majority of the planned dates. A description of acquisition success, product quality control, and product delivery is provided below.

Image acquisition success

It was anticipated that some planned acquisitions of RADARSAT-1 might be unsuccessful for the following reasons:

- *superseded by a higher priority acquisition.* The LMB-FMS was operated in 2007 as a feasibility study, and the imagery provided by CSA was non-commercial; therefore a planned LMB-FMS acquisition could be superseded by another acquisition from a commercial customer;
- *technical problems with the satellite system.* Some of the planned data could not be acquired due to satellite malfunction;
- *other error.* One incident of processing error occurred related to uplinking acquisition plan to the satellite.

The LMB-FMS products were delivered on 20 individual dates. In order to fill the gaps of cancelled acquisitions, acquisitions were re-planned for replacement images (where possible) and the weekly acquisition schedule was also extended into December 2007. Table 2 summarizes the overall status of the LMB-FMS product delivery.

Table 2. Summary of LMB-FMS image acquisition status, 2007.

Status	Number	Dates
Planned acquisitions	24	
Failed	5	Aug 13, Sep 11, Oct 5, Oct 24 and Nov 17
Data quality issues	2	Jun 26 and Jul 6
Successful replacements	3	Dec 4, 11 and 16
Total successful acquisitions	20	

Flood extent and flood change products

The weekly acquisition of radar imagery over the Lower Mekong Basin from July to December, 2007 provided an unprecedented amount of satellite data information on the pattern of flooding. A total of 1,680 map products were delivered to MRC under the LMB-FMS in 2007. Figure 2 provides an example of a flood extent map (Product 4) produced on October 17, 2007, centred on the Chau Doc Hydrological Station; this 50x50 km image covers an area north from the border of Cambodia and Viet Nam to Phnom Penh. Figure 3 provides an example of a flood change map (Product 5) for Chau Doc hydrological station, which reveals the flood dynamics in terms of flood expansion and flood recession between the October 10th and October 17th flood extent. In Figure 3, the course of the Mekong, Tonle Sap and Bassac Rivers, as well as other permanent water bodies, are coloured black; the huge extent of the area flooded on both October 10th and 17th is shown in a light blue colour; the greater extent or expansion of the October 17th flood situation is shown by the red colour. Those areas that were flooded on the October 10th image, but not on the October 17th image (representing flood recession) are shown in green.

There are several areas in the lower Mekong basin where the October 17th flood extent (red colour) has exceeded the October 10th flood extent. Examples include the western fringe of the Tonle Sap or Great Lake, in the floodplain south of Phnom Penh, and in the delta area. In 2007, October appeared to be the month of peak flooding in the lower Mekong floodplain and the delta area, which was no exception from the usual pattern of flooding in this region.

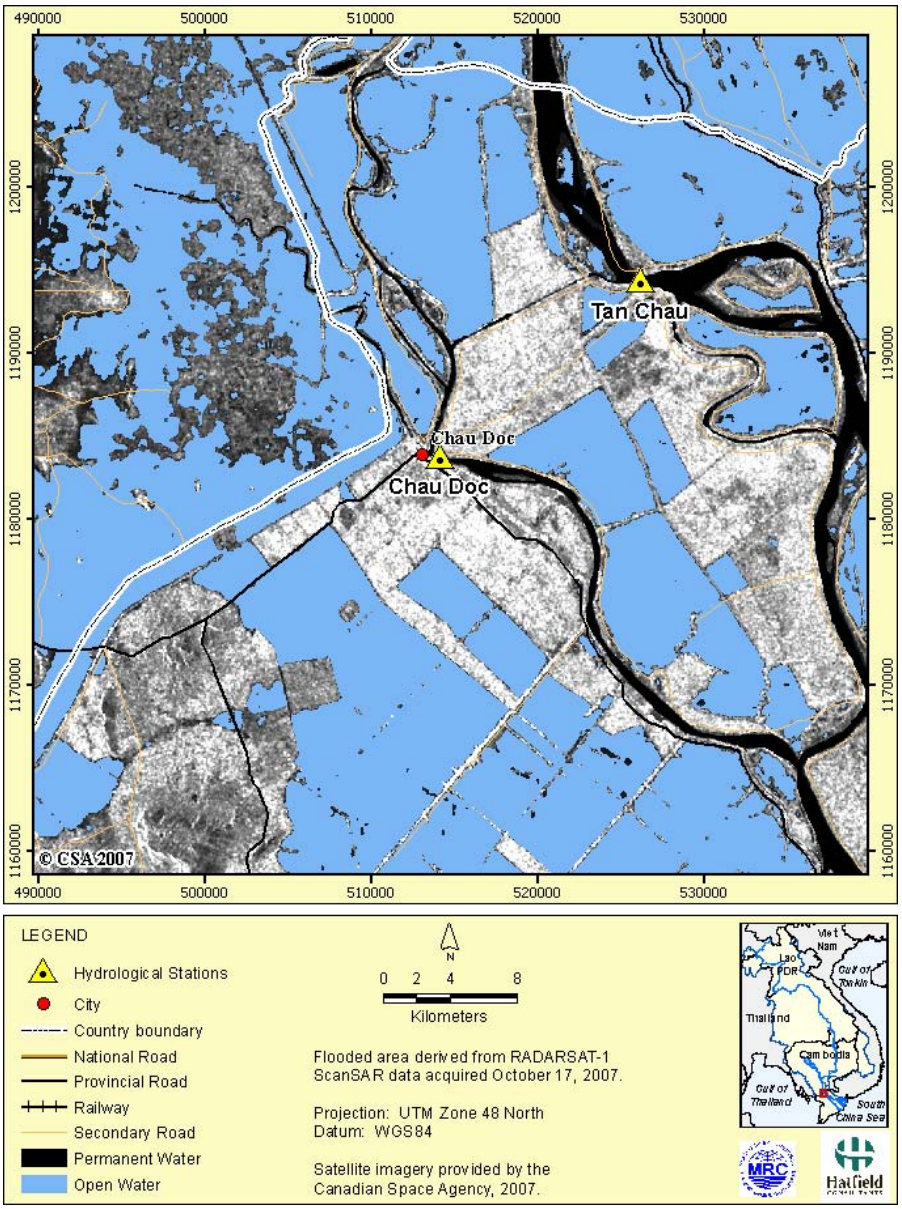


Figure 2. Flood Extent product for the Chau Doc hydrological Station in Viet Nam, October 17, 2007

A flood change map centred on Chau Doc gauge station can be compared with actual river gauge measurements from the MRC River Monitoring Portal (http://ffw.mrcmekong.org/). The flood gauge information (Figure 4 for the hydrograph of Chau Doc gauge station on October 24th) confirms the interpretation of the RADARSAT–1 imagery, and the accuracy of flood change product. On September 28th, a belt of monsoon rain was active in the southern part of the lower Mekong basin, and the river gauges at Chau Doc, Tan Chau in Vietnam and Koh Khel in Cambodia recorded water levels that crossed/reached the flood alarm level. During the

month of October, much of the accumulating flood water typically drains toward the rice growing areas to the east and west of the mainstream of the Mekong and Bassac Rivers. At the Chau Doc and Tan Chau gauges, water levels reached very close to the flood level mark of 3.5 m and 4.2 m, respectively. The observed overall trend suggests that 2007 may be considered as a "normal" flood year in the LMB. Examples of a flood map integrated into the MRCs River Monitoring Portal can be observed at the MRC River Monitoring Portal.

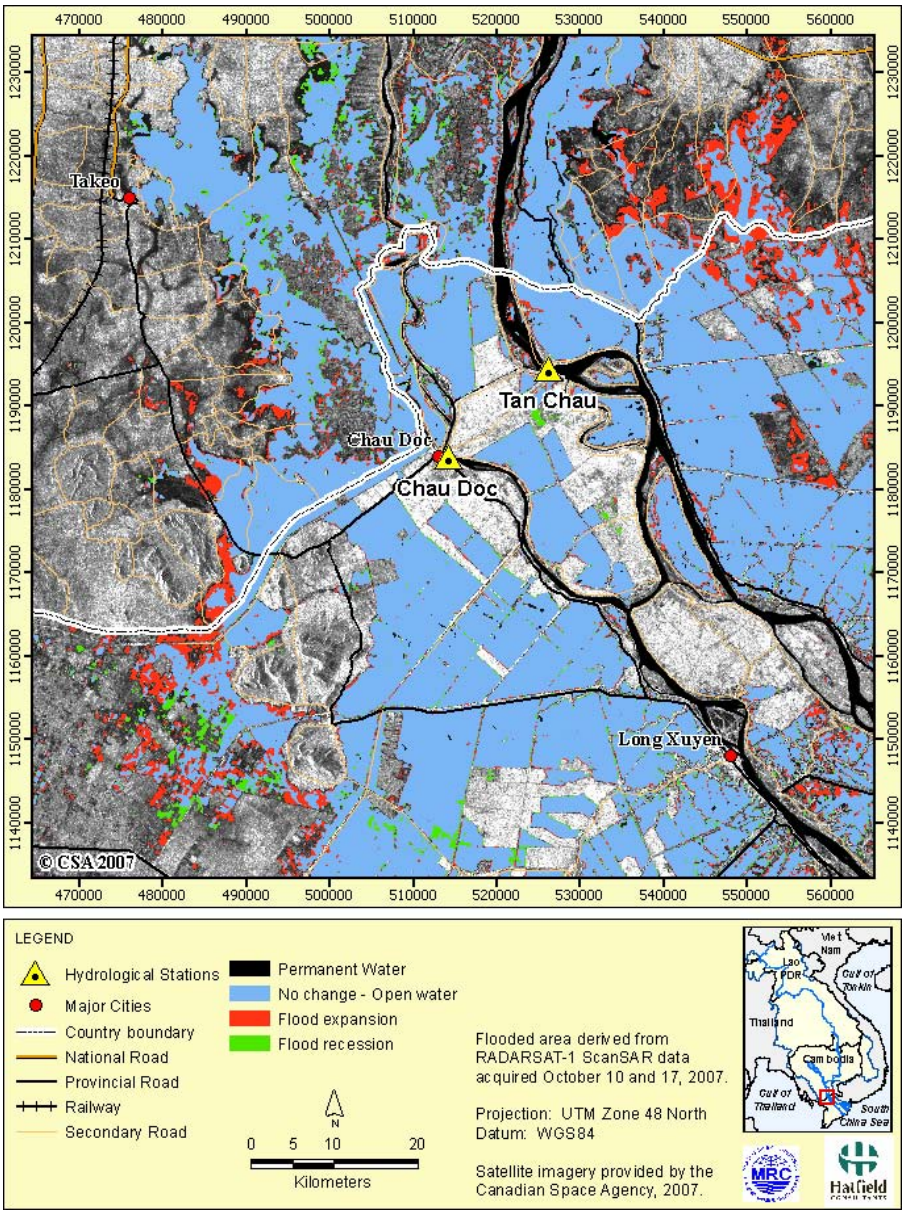


Figure 3. Flood expansion and flood recession around the Chau Doc hydrological station in Viet Nam between October 10 and 17, 2007

Product delivery

The final LMB-FMS products were made available to MRC via dedicated FTP site (ftp://MRCFlood:kj85vw2@hatfieldgroup.net/) hosted by Hatfield Consultants. Delivery was made within 24 hours of image acquisition, depending upon receipt of the imagery by Hatfield Consultants from CSA. Delivery notification was made by email, which was sent to a list of people provided by MRC.

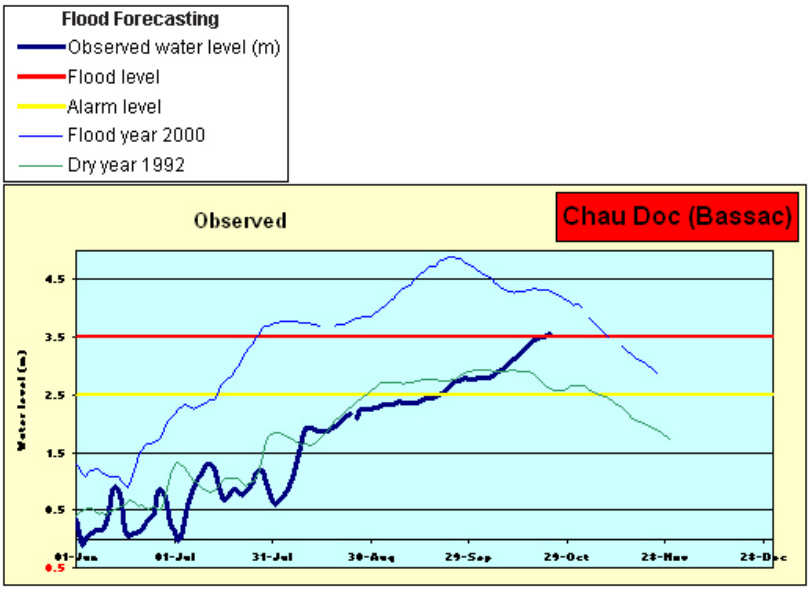


Figure 4. Hydrograph of the Chau Doc gauge station on October 24, 2007 (Source: http://ffw.mrcmekong.org/)

CONCLUSIONS

The operational implementation of the LMB-FMS in 2007 provided the opportunity to evaluate the feasibility of providing a reliable flood mapping service to the MRC-RFMMC, and to identify potential service improvements. The products included RADARSAT-1 images, flood extent maps, and flood change maps as GIS/image data and graphics.

Hatfield performed an evaluation of the LMB-FMS, which is presented in Table 3. Overall, the LMB-FMS demonstrated that it is feasible to provide an operational service delivering weekly flood map products to the MRC in Near-Real-Time. There were several challenges related to service performance because of cancellation of planned satellite data acquisitions; however these cancellations were beyond the control of Hatfield. Attempts were made to replace cancelled acquisitions as close as possible to the original date; however, given that the LMB-FMS was already operating close to the maximum possible image delivery frequency, replacements were often not possible. Hatfield Consultants extended the overall period of image acquisition to ensure the MRC were provided with a sufficient number of products.

Recommendations

Based on the experience gained through the LMB-FMS in 2007, the following initiatives are recommended to improve future service performance:

- *Increase the frequency of product delivery.* This requires the integration of data from multiple sensors into the LMB-FMS. Product delivery could be increased to 2-5 days, and improved reliability could be offered through redundancy of data options;
- *Information Delivery / Web Application.* The MRC River Monitoring Portal requires redesign to enhance functionality and usability. The key areas of improvement are:
    - provide access to archived flood extent and flood model outputs in GIS data formats so that local users and other stakeholders can perform further analysis as required;
    - create a data-flow pipeline for automatic importing and exporting of LMB-FMS products into the river monitoring portal, and out to MRC stakeholders;

  - integrate LMB-FMS data, and other river monitoring data, with the MRC Information System Portal (MRC-IS) and other MRC information products.
- *Integration with Hydrological Modelling.* The LMB-FFS provides now-casting information, and there are likely benefits from integration of the information provided by the LMB-FMS and hydrological modelling activities conducted by MRC and external consultants;
- *Integration with Emergency Response Systems.* The weekly flood extent information was integrated with information on the location and elevation of important infrastructure (e.g. health centres, safe sites). Automatic detection of infrastructure at risk could be identified, and a pilot web, email, or text message alerting system could be developed;
- *End-user Communication.* Awareness raising could be conducted with government agencies and non-governmental organizations (NGOs) to help disseminate the flood information generated. This could be completed using several information channels:
  - Mekong Flood Forum, through a poster and oral presentation;
  - Meetings with relevant government agencies and NGOs;
  - River Monitoring Portal email alert list.
- *Improved Products.* Products could be improved through knowledge of the vegetation or land cover.

Table 3. Evaluation Summary for the LMB-FMS, 2007.

Theme	Evaluation	
	Positive	Negative (Improvement Required)
Reliability	LMB-FMS Products are consistent through a reduction in human intervention in data analysis.	LMB-FMS success rate for acquisition and product delivery was 70%, which should be improved.
Temporal Latency	Successful delivery of radar-based flood mapping products in 'Near-Real Time' (less than 24 hours).	
Acquisition Frequency	Successful delivery of products every 5 to 7 days.	Due to cancelled acquisitions, the frequency of product delivery was reduced; 2 weeks could separate consecutive products, instead of 5-7 days. Some hydrological stations had reduced frequency of observation because of satellite orbit and swath.
Scale / resolution	Products have 50 m resolution, which appears to be suitable to capture the flood dynamics.	
Extent / Coverage		Some hydrological stations were only covered on a semi-monthly or monthly basis due to the swath of satellite.
Flood extent product	Product thematic information provides the required classes for flood extent and flood changes.	Flood depth information is desirable. Flooding in dense vegetation may not be detected in radar image. Products are dependent on the status / quality of the baseline dry-season image.
Delivery System	Web-based delivery is the appropriate method	MRC River Monitoring Portal was not specifically designed to accommodate the LMB-FMS products and does not provided intuitive access to products or data.
Integration with other MRC services	LMB-FMS products integrated into River Monitoring Portal.	Little integration of Flood Extent and Change Products with MRC hydrological model development or other MRC information systems.

ACKNOWLEDGEMENTS

The LMB-FMS was implemented for the MRC-RFMMC by Hatfield Consultants with financial support from RFMMC and RADARSAT-1 data provided by the CSA.

REFERENCES

Disasters Charter. Accessed from: http://www.disasterscharter.org/disasters/

Fujii, H., H. Garsdal, P. Ward, M. Ishii, K. Morishita, and T. Boivin. 2003. Hydrological roles of the Cambodian Floodplain of the Mekong River. Intl. J. River Basin Management, Vol. 1, No. 3 (2003), pp. 1-14.

Hatfield Consultants. 2000. Using RADARSAT for improving fisheries management and food security in the Mekong River watershed, Southeast Asia. Final Technical Report and GIS prepared for the Canadian Space Agency, Saint-Hubert, Quebec, Canada. Hatfield Consultants, West Vancouver, BC, Canada.

Hatfield Consultants 2001. Inundation Mapping in the Lower Mekong Basin. Final Report and GIS database prepared for Land Resources Inventory for Agricultural Development (LRIAD) Project, the Mekong River Commission. Hatfield Consultants, West Vancouver, BC, Canada.

Hatfield Consultants. 2003. Flood Area and Volume Analysis. Final Report and GIS database prepared for Consultancy Services for the Consolidation of Hydro-Meteorological Data and Multi-Functional Hydrologic Roles of Tonle Sap Lake and Its Vicinities (Basinwide) Project, the Mekong River Commission. Hatfield Consultants, West Vancouver, BC, Canada.

Hatfield Consultants. 2007. Development of a Flood Vulnerability GIS Application: a Tool for Community Self-Reliance and Flood Risk Reduction. Final Report and CD-ROM for ADB-TA 4574-CAM. Asian Disaster Preparedness Centre, Bangkok, Thailand; Asian Development Bank.

Mekong River Commission. 2006. Annual Flood Report. MRC, Vientiane, Lao PDR.

Meina, R.G., T.D. Keenana, and J.F. Elliott. 2000. Flood estimation using radar and raingauge data. Journal of Hydrology. Vol. 239, 1-4, Pages 4-18 .

Rees, W.G. 1999. The Remote Sensing Data Book Cambridge University Press.

WORKSHOP DISCUSSION REVIEW

DETERMINING THE COSTS AND BENEFITS OF FLOOD FORECASTING AND EARLY WARNING

P.T ADAMSON

Consultant to Mekong River Commission (MRC), Marlborough, UK

ABSTRACT

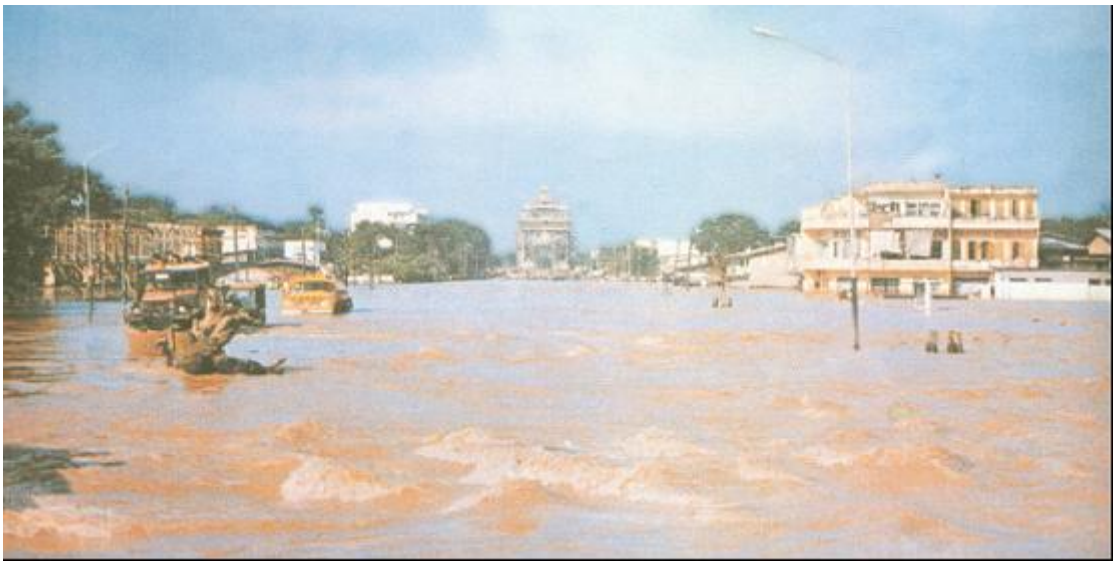
Objectives
A flood forecasting, warning and response system comprises an important element of integrated water resources management. Although the social and economic benefits of flood forecasts are virtually self-evident it is often difficult to obtain a complete estimate of the costs of flood damage, which may be classified as follows:

- *primary damages* due to the fact of inundation by floodwater, including that to property, infrastructure and crops;
- *secondary damage* due the loss of production, lost business and services, impacts upon health and communications. Secondary damage can often far exceed the value of the direct damages;
- *intangible damage* such as that to the environment, social well being and loss of life, which are extremely difficult to assess in financial terms.

The objective of the workshop is to provide a matrix of the damages that should be assessed and review the methodologies that are being applied in various parts of the world to obtain consistent estimates of the socio economic damage that arises from floods and their practicality in the Mekong context. These objectives will be supported by examples of post flood damage assessment, the effectiveness of flood forecasting and the lessons learnt. The key theme will be that a total flood warning system must integrate flood forecasting, the assessment of the likely impacts, the prompt and effective dissemination of warnings and any associated information, the response of the relevant agencies and the public within the threatened communities and post event review and improvement. These components must operate together for the process to be completely effective.

Expected outputs
The major output will be a short report document which draws together the above issues and which will form the basis for the discussions at the workshop. The principal theme will be the identification of the major constraints to the assessment of costs and benefits to flood forecasting in the Mekong regions and how best to overcome them.

Key issues
The key issue is the problem of adapting the type of cost benefit analysis for flood forecasting that is applied in the US and Europe, largely based upon insurance information, to the Mekong region. This theme will be illustrated with an analysis of the costs and benefits of improving the flood protection works for Vientiane and how forecasting the inundation of the city comparable to 1966 might be implemented.



INTRODUCTION

The cost benefit analysis of flood management and mitigation activities, including the value of flood forecasting, requires that the damage resulting from floods can be reliably estimated, a subject that has received intense attention in recent years. Though much has been written and many complex procedures developed the consensus is that the process is extremely difficult, particularly within urban areas. Although damage to property and that within the agricultural sector is the more straightforward to assess, that to services at a time when communities are least capable of absorbing the disruption of power, water, emergency services, health facilities and so on is far more difficult to measure. In particular intangibles such as impacts upon public health tend to loom large with regard to the impacts of floods in developing countries.

Here emphasis is placed upon trying to make sense of this complexity both in urban and rural areas since without the potential damage costs, the benefits of flood mitigation activities cannot be estimated. The challenges of estimating the value at risk from flooding in Vientiane and the value of flood warning is used as an example. The key points that are emphasised are as follows:

- for forecasting to be really cost effective, preparedness and mitigation measures need to be already in place and potentially operational at relatively short notice leading to a coordinated preparation to reduce the value at risk and the consequences of flooding;
- the value of a flood warning lies with the adaptive capacity of the socio-economy at risk, that is the extent to which it can rapidly modify itself to move to a less vulnerable state. Developing this capacity is an integral part of overall flood risk management;
- in effect three databases are required. One containing systematic information on the hydrological aspects of historical flood events and their risk of occurrence, a second on the associated flood damages and a third collating evidence of the socio-economic benefits of flood management and mitigation measures, including forecasting, that have been implemented.

Forecasting is one thing, knowing what to do is another. In many ways flood preparedness should be seen from an organisational perspective and the development of an increased resilience to the magnitude of the hazard that is predicted. The prediction should also be meaningful and expressed in a way that communities can understand. Communities should be made aware of their exposure and vulnerability and those that are critically exposed targeted for education in terms of what to do given a warning.

In summary, the direct tangible economic value of flood forecasting and warning is damage and loss reduction. The potential for achieving this depends upon three elements:

- the nature and magnitude of the forecast event;

- the accuracy of the forecast in relation to the actual event;
- the ability of the flood affected communities to respond.

OVERVIEW OF THE REGIONAL CONTEXT AND THE SOCIO – ECONOMIC IMPACTS OF FLOODS AND FLOODING

The context and impacts of regional floods was ably summarised in a United Nations University News Release dated June 2004. This provides an indication of the general scale of the hazard and the socio-economic consequences of floods. The major points are as follows:

- globally the greatest potential flood hazard lies in Asia where between 1987 and 1997 97% of all flood related deaths occurred;
- floods are responsible for a third of the overall economic loss resulting from natural hazards;
- one billion people, or one sixth of the global population, the majority of them the world's poorest inhabitants, are estimated to live in the path of the 100 year flood event, a number that could double in as little as two generations;
- world wide the flood related loss of life represents 15% of all deaths resulting from natural disasters (United Nations University, 2004), although (Berz, 2000) contends that they account for about a third of all natural catastrophes and more than half of the fatalities;
- the pressure to live and work in flood prone areas, which typically feature attractive rich soils, abundant water supply and ease of transport will increase as the global population spirals upwards;
- increasing sea levels as a result of global warming will intensify the problem in such areas as the Mekong Delta;
- recent studies have shown that the cost of constructing flood resistant buildings adds only 2 to 12% on average to their final cost;
- meanwhile, forecasting and warning systems commonly show a cost benefit ratio of 10 or 15 to 1;
- while economic losses due to natural disasters in developed countries destroy resources equivalent to 2% of GDP, in developing countries the proportion can be as high as 13 to 15%.

The scale of the social and economic benefits to be had from effective forecasting, management and mitigation are clear, indicated most emphatically by the potential cost benefit ratios of implementing forecasting and warning systems.

In recent years there has been a sharp increase in the economic and human losses attributed to flooding in the Lower Mekong Basin. This is caused not by deforestation, as is often incorrectly argued, but mainly by the simple fact that more people are living, working and generating more wealth in flood plains. Thus, many floods that previously would have been only minor events are now major disasters. Another factor that has had a significant influence on social perceptions of an increase in the incidence and severity of floods is that during the 1980's and early 1990's flood magnitudes were modest and the annual damage limited. This quiescent period was then followed by a sequence of extreme events from 1994 onwards which caused huge economic loss and damage. This picture is clearly evident from the time series of annual flood damages suffered by Lao PDR between 1965 and 2005 (Figure 1) and the split sample of annual flood damage in Cambodia during the intervals 1982 to 1991 and from 1992 to 2001 (Table 1).

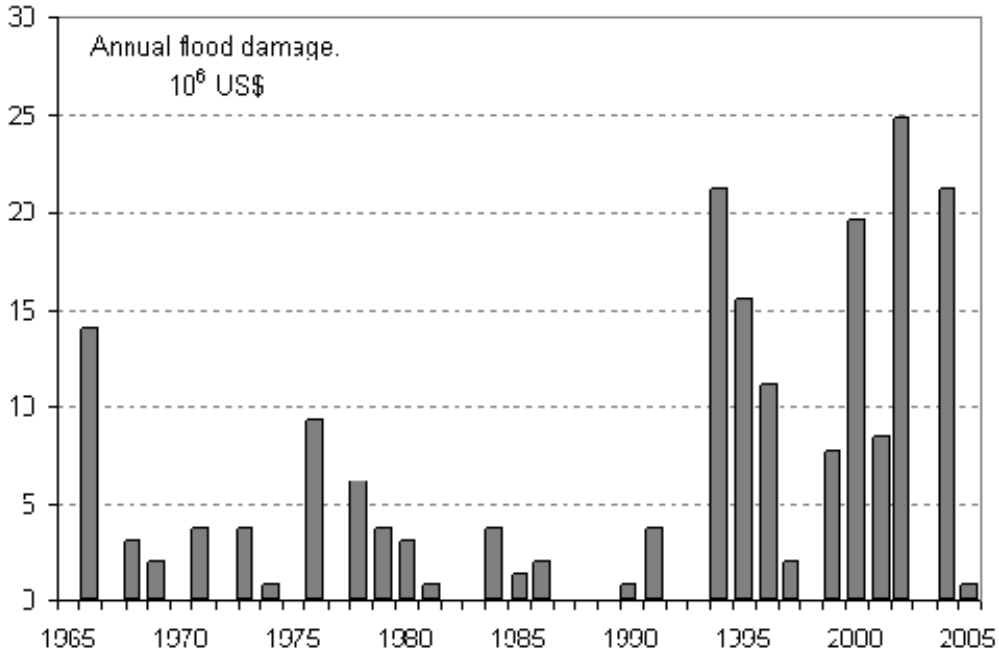


Figure 1. Lao PDR. Annual flood damage, 1965 – 2005. (total over period =180 10^6 US$ or 6% of the GDP in 2005 (2.9 10^9 US $)

Table 1. Cambodia - Flood related deaths and the number of people affected during the sub-periods 1982 to 1991 and 1992 to 2001 (IFR World Disaster Report, 2002).

Index	Sub period	
	1982 – 1991	1992 – 2001
Reported deaths	100	1,100
People affected	900,000	13,350,000

The question arises as to whether this apparent clustering of extreme events is part of the natural periodicity of the process and/or a tangible indication of the consequences of global warming. What ever the case the economic consequences of such events are significant at the national scale:

- the flood of 2000 in the Mekong river basin was the worst in terms of damages in over 70 years, even though from the perspective of hydro-meteorology, the event was not significantly different from other historical floods. More than eight million people in Laos, Cambodia and Vietnam were affected, plus two million in Thailand. The estimated socio-economic damage was:
  - Lao PDR - US$ 19.5 million, 398,760 people affected and 15 dead;
  - Cambodia - US$ 157 million, 3.5 million people affected and 347 dead;
  - Vietnam - US$ 285.7 million, 5 million people affected and 448 dead;

  These figures as a proportion of national GDP are surprisingly small for developing countries, all are less than 1% of the 2000 GDP figure. The major regional damages tend to be felt in the agricultural sector. In Lao PDR and Cambodia the figures as a proportion of GDP are probably influenced by the fact that although agriculture accounts for 52% and 31% of GDP respectively, it is very much of a subsistence nature with relatively low value added. In Vietnam the economy is much more diversified, with agriculture accounting for only 20% of GDP;
- even so the impact of the 2000 flood and that of 2001 impacted the agricultural sector in Viet Nam to a substantial extent. Of all the world's rice crop only 7% is traded internationally and after Thailand, Viet Nam is the second largest exporter. In late 2001, largely due to the consequences of the floods in the Red River and Mekong Deltas, Vietnamese rice exports were temporally frozen due to a lack of reserves for its own population. The export value of rice during the year consequently fell by 12%;

- in Cambodia the 2001 flood occurred when the national economy was still in the process of recovering from the effects of the 2000 flood disaster when 10% to 20 % of the rice crop was destroyed. As a result, the expansion of real gross domestic product slowed from the 5% growth rate achieved in 1999;
- in contrast to its impact on crops, extensive flooding tends to boost production in the large Cambodian fisheries industry, so moderate growth in fisheries value added is expected during flood years. Fisheries value added accounted for 10.5% of Cambodian GDP in 1999, making it the fourth largest sub-sector, behind crops, manufacturing, and wholesale and retail trade. Recorded value added for fisheries has been increasing rapidly over the last several years, growing by 45.0% since 1994 and by 16.0% in 1999 alone. Yet, Government statistics are believed to underreport the extent of activities in this subsector. Private estimates put the annual catch at 300,000 to 400,000 tons, as compared with official statistics of 100,000 tons or less.

These macro economic impacts of extreme floods indicate the damage that they can cause to national wealth and economic rates of growth and that any systematic program of national flood management, mitigation and forecasting at the appropriate scale would have far reaching and long term benefits. Obviously this fact is widely recognised.

COSTING POTENTIAL FLOOD DAMAGE

General

Within the Mekong Basin flood affected areas probably account for more than 80% of the GDP generated within the region and are generally the most densely populated. The inability to mitigate flood damage is a major factor that threatens sustained growth in the agricultural sector particularly. For example, in Cambodia rice is the most important crop, accounting for about 60% of 1999 crop value added. It is generally produced through low-input, low-output, rain-fed, single-crop subsistence farming which results in high crop losses not only from flooding but also as a result of drought and pest damage. In average years 95% of the area cultivated to rice is harvested. However, during extreme flood years the figure can fall to 80%.

The first part of flood damage evaluation is the determination of the inundated area, the depth of flooding and its duration. Flood damages are a function of all three, though two kinds of damage and loss can be separated out:

1. *primary flood damage.* This results from the *fact* of inundation and involves structural damage to buildings and service infrastructure such as roads, electricity supply (such as transformers), telecommunications and water supply, to name but a few. Primary damage also refers to crop and stock losses, commercial stock and inventory loss and damage and it is principally a function of flood depth;
2. *secondary flood damage.* This results from the duration of inundation and the period over which normal socio-economic activity is suspended and traffic, trade and services are disrupted. It also includes the time taken to clean up, repair the damage, replace stock and inventory such that normal levels of service, commercial and industrial activities are resumed. Such economic losses can be severe and in large rivers, where the duration of flooding can involve relatively long periods, secondary damage often becomes a very significant proportion of total damage.

Other factors such as flow velocity and turbulence can have a significant impact on flood damages. For example, the simple incidence of inundation does lead to some, but not necessarily major damage to roads. However, high velocity and turbulence can lead to major road damage and multiplies by orders of magnitude that to services such as electricity, water and telecoms. Similarly the damage to buildings and contents is multiplied many times if toxic or significant sediment loads are involved.

The final evaluation of flood damage cannot be set in monetary terms alone. There are many intangibles to which value cannot be added, for example loss of life, unique personal possessions and cultural heritage as well as the longer term consequences for human health.

It goes without saying that there is huge uncertainty in the estimation of potential flood damage because there are so many variables involved that can combine in any number of ways during the course of a particular event. For an urban landscape such as that of Vientiane therefore the calculation of the damage potentials has to be undertaken at the macro scale, given that the detailed information regarding building value, stock held and its vulnerability to flooding, number of employees, residential capital, fixed assets and so on have not been aggregated. But then, such information at the detail required for flood damage assessment is very rarely publicly available anywhere and is the confidential property of the insurance industry.

Assessing primary damage

The first step in the assessment of primary damage is to determine to potential depth of inundation given a flood event of a certain risk of occurrence on the basis of a land surface map as illustrated below, combined with some information upon the distribution of land use.

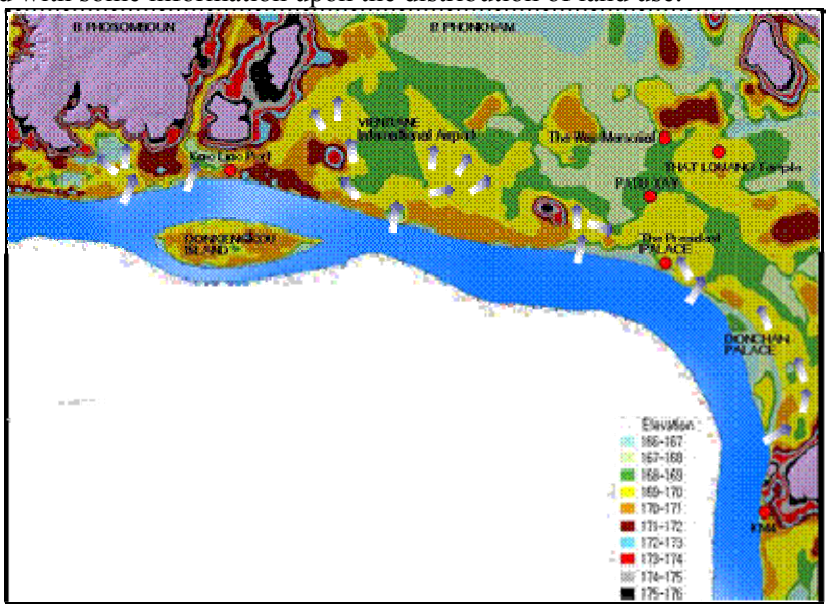


Figure 2. Vientiane. Urban landscape elevation (masl), landuse classification and its area (hectares) within each elevation zone

Table 2. Land use classification in Vientiane

Elevation (masl)	Land use classification.						
	Residence	Religion	Commercial	Public	Agriculture	Other	Total
< 167 below	200	-	37	16	68	271	592
167~168	190	-	13	38	102	573	916
168~169	225	0.1	47	58	171	415	915
169~170	498	0.3	199	92	181	314	1 284
170~171	109	-	36	25	48	48	266
171~172	215	-	9	43	59	66	392
172~173	66	-	6	8	32	7	119
173~174	113	1.6	11	16	35	5	181
174~175	109	0.1	6	22	34	5	179
> 175	143	1.0	2	37	33	2	219
TOTAL	1 865	3	365	356	762	1 705	5 057

This enables curves such as those illustrated below to be used, which relate flood depth to the degree of loss within each economic sector. So, for example, given a flood elevation, it is possible to compute the areas of the city inundated to a given depth and therefore the degree of loss to each sector in that elevation cell.

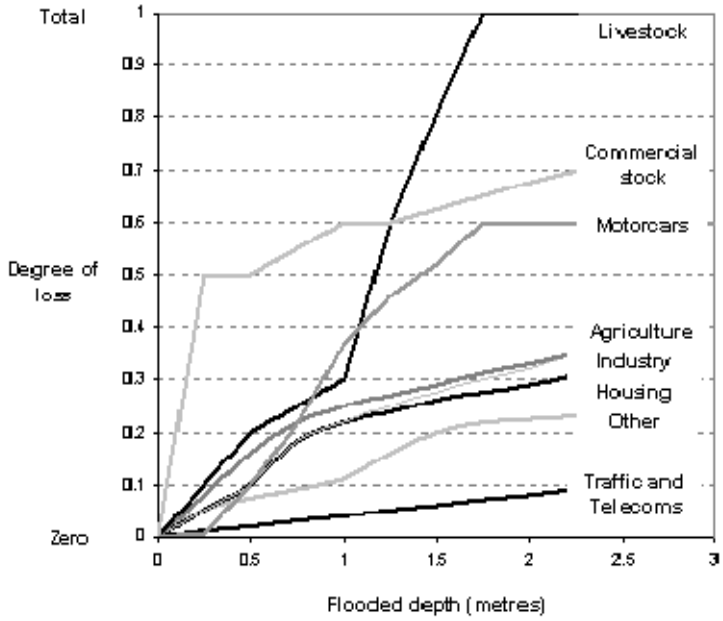


Figure 3. Depth damage functions. Degree of loss as a function of flooded depth for various components of the socio-economy (Messner and Meyer, 2005).

The actual value at risk in each land use sector may be assessed using the types of log normal distribution function show in Figure 4. The concept comes from flood damage studies undertaken in Germany based on insurance and monetary compensation for flood loss and damage. Consider building values in Vientiane. They will almost certainly be similarly log-normally distributed. Building uses range between private households, public infrastructure (schools, government offices, hospitals), the services sector (commercial buildings, shops, hotels and restaurants), industrial premises (factories, workshops), low value buildings for storage and heritage premises, such as temples and wats. In turn the fabric of these buildings will vary in value, structural integrity, their vulnerability to flood damage and the cost of repair. Each building will have a value that can be set out in units of US$/m^2. These values will vary between a few cents, for agricultural storage for example, to hundreds of dollars/m^2 for prime residences and public infrastructure and these values will be distributed in a similar statistical fashion to those illustrated in Figure 4. Log-normal distribution functions such as these were developed based on brief inquiries regarding building and inventory value. However, these were very variable. For example, car show rooms and adjacent new car parking areas might hold between 10 and 50 units. The unit area value of public buildings was a function of age. A significant factor with regard to public buildings and flood vulnerability in Vientiane is that most of the new ones are elevated, with the ground floor areas devoted to parking and low value storage areas.

Assessing secondary damage

Turning to a consideration of secondary economic damage, using Vientiane as the example, the approach is more straightforward. It is based on the fact that the GNP for the city, as reported by the Lao News Agency in late 2006, has reached US$ 970 million, which is the coarse equivalent of US$ 2.7 million/day. This provision of goods and services would not only be suspended during the period of flooding but a recovery period also needs to be taken into account. This would be expected to be several orders of magnitude longer than the inundation period itself, with a minimum four times longer than the period of inundation itself. In reality the recovery would be a slow process but one that is difficult to specify in terms of ongoing loss. It would depend on the type of damage, the duration of the inundation, whether significant issues of public health arose in the flooded areas, the degree of warning so that some mitigation measures could be implemented and so forth.

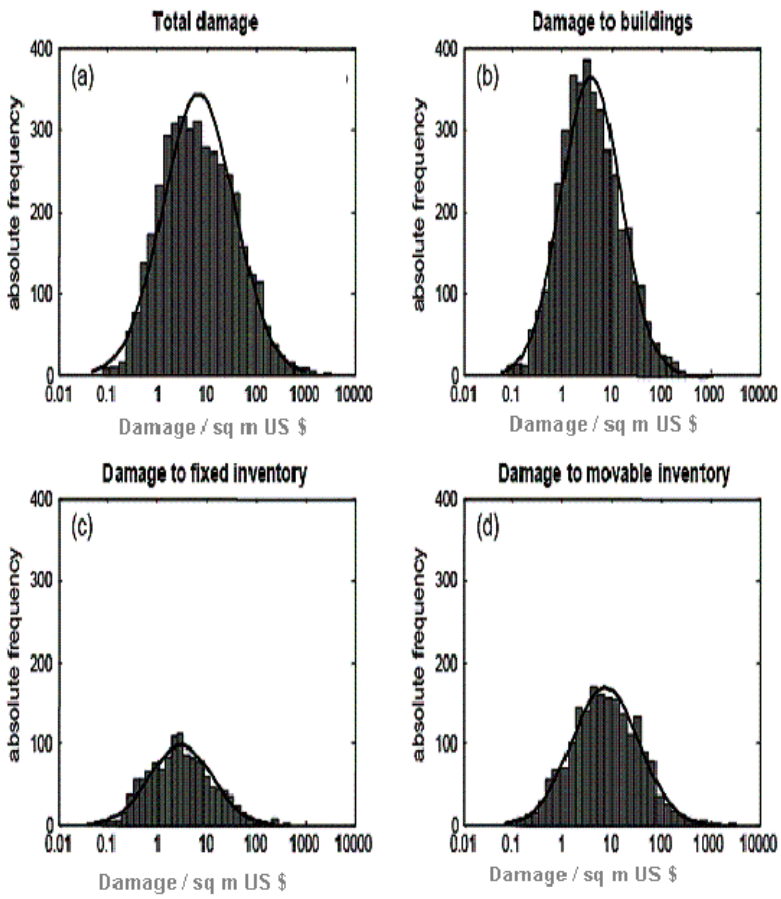


Figure 4. Histograms of log-normally distributed damage functions based on German insurance data (Merz et al., 2004)

The conditional value at risk from flooding – the case of Vientiane

The present degraded state of the flood protection bund along the Mekong at Vientiane is estimated only to provide protection against local breaching and overtopping for water levels that would be expected to occur once in twelve years. The conditional value at risk from this extremely low level of protection should be viewed firmly in the context of the present annual growth of the city in terms of capital infrastructure, inventory, property values, GDP and so on. Overall, the estimates of these annual growth rates are rarely less than 7% and often as high as 10%. Certainly capital expenditure on city infrastructure exposed to inundation is expanding rapidly such that the overall value at risk is compounding. This means that the potential capital annual loss from the flooding of the city is growing at a rate that could be as high as 10%, while at the same time the level of flood protection is falling as the condition of the present dyke and bank protection infrastructure deteriorates.

By combining a statistical model of the joint distribution of flood peak, volume and the duration of flows and water levels against critical values with the depth/damage and loss functions described above it is possible to set up a simulation experiment to estimate the value of the primary and secondary losses as a result of flood magnitude. Illustrative results are shown in Figure 5 for the case with the present level of flood protection for Vientiane and for that if the flood protection were to be improved to provide protection for floods up to the 100 year event (*the actual loss values in millions of US$ are not shown as they are confidential*). Non the less the cost – benefit ratio of upgrading the flood protection infrastructure for the city is of the order of 15, that is the total losses mitigated by the upgrade are 15 times greater than the investment cost, even at present land and infrastructure values. Obviously this benefit will accrue annually as the city develops.

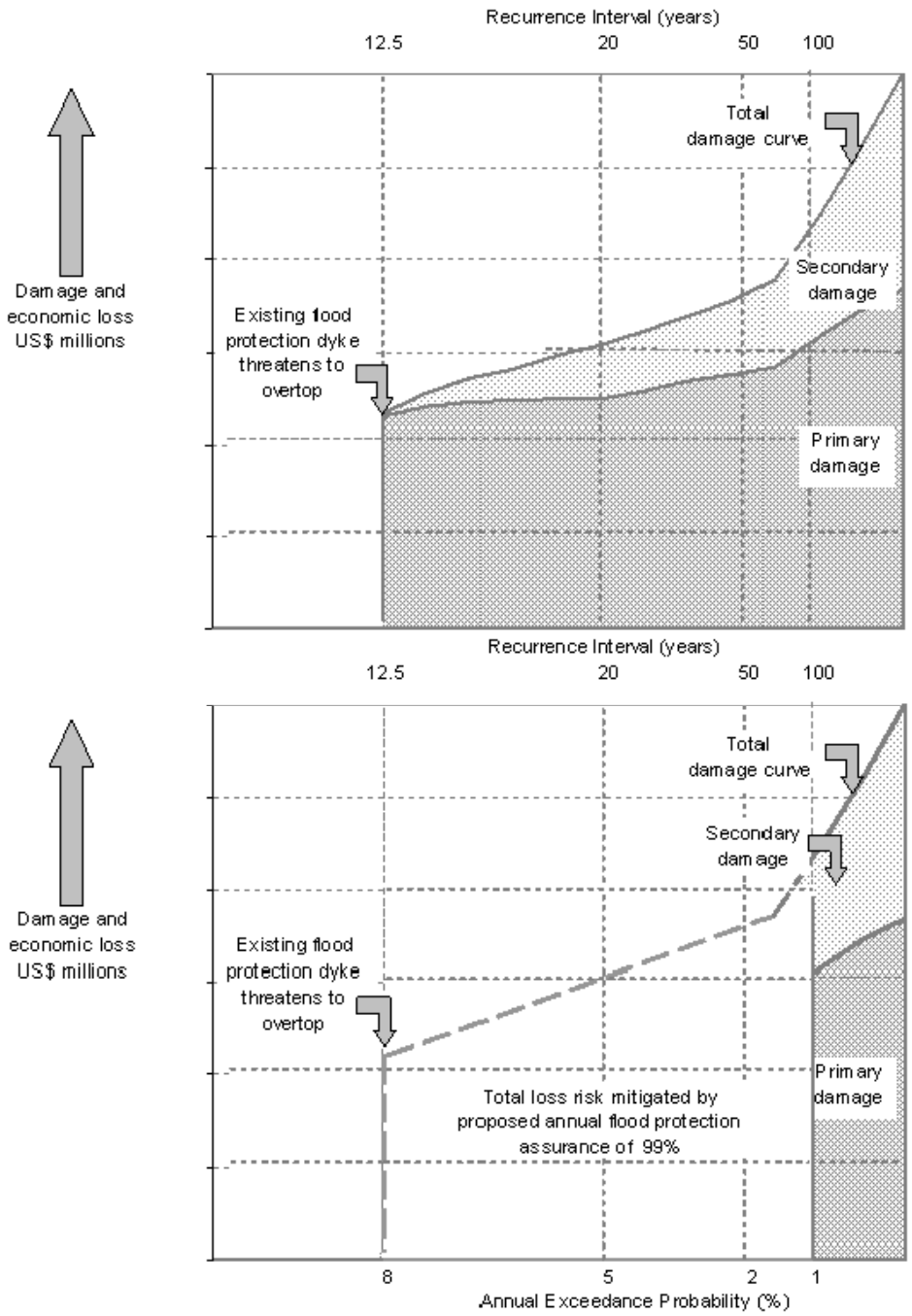


Figure 5. Vientiane - Flood inundation risk and estimated damage and loss without (top) and with (bottom) improvements to the flood protection infrastructure.

COSTING THE BENEFITS OF FLOOD FORECASTING

The case of urban areas such as Vientiane

The primary need for the provision of acceptable levels of flood defence for a city such as Vientiane is the need to upgrade the present flood defence infrastructure. However, flood forecasting still has a vital role to play in the reduction of primary and secondary damage. With sufficient lead time warning that there is a high probability that the city could be inundated stock and inventory could be moved to upper floors and higher parts of the city, stocks of fresh water and food could be laid in, rescue and medical services put on alert and so on. However, for forecasting to be really effective preparedness

and mitigation measures need to be already in place and potentially operational at relatively short notice leading to a coordinated preparation to reduce the value at risk.

This cycle of activities in flood management and mitigation is illustrated in Figure 6 and includes post flood impact assessment, response, recovery and reconstruction. It is essential to perceive the overall process as an integrated whole and not as independent activities. Plans need to be put in place and after the event lessons need to be learnt and acted upon accordingly.

The public need to be made aware of their exposure within each part of the urban area based upon the topography, land elevation and the forecast depth of flooding. Maps such as that indicated in Figure 2 make this a practicality. The public, commercial and residential sectors could then take measures to protect their property, stock and inventory thus significantly reducing the final damage.

There does though have to be a wide public perception that the forecast refers to a real threat and that their risk of significant loss is high unless they take the appropriate measures to protect their property. It is interesting to observe that in September 2002 when the threat of widespread urban flooding in Vientiane was considerable such were peak Mekong water levels, that there was little evidence of any such activity.

As far as costing the potential benefits of flood damage mitigation in urban areas is concerned the process is extremely difficult. Well designed statistical sample surveys to assess the economic value at risk need to be undertaken and these are not necessarily cheap. There is also the fact that in a rapidly developing urban landscape such as that in Vientiane, they are soon out of date. Indirect simulation methods such as that outlined above provide an alternative but their final accuracy is unknown. They are, however, very useful for the wider indicative assessment of costs and benefits and their sensitivity to the working assumptions is quite easy to evaluate.

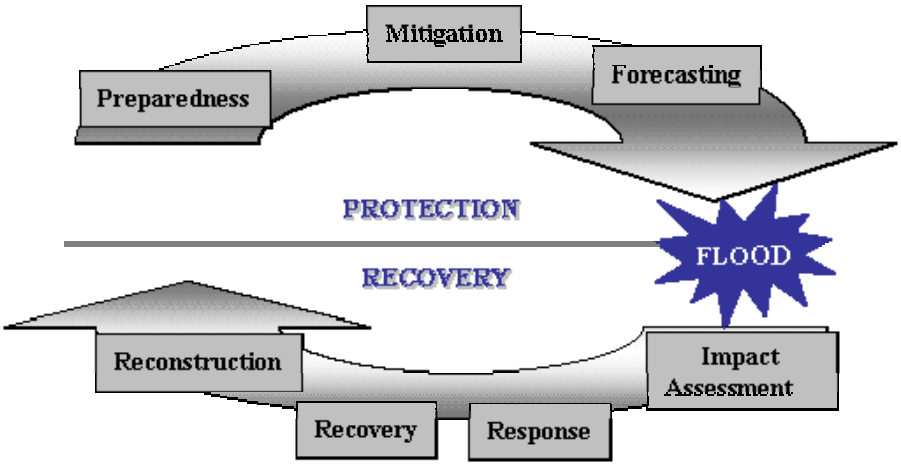


Figure 6. The lifecycle of activities in flood management and mitigation

These problems of costing damage are by no means confined to the developing world. The same issues arise in Europe, the USA and Australia where much emphasis has been placed upon building up flood damage data bases along the lines indicated in Figure 7. An important starting point for any flood damage database are the assets at risks and their value which can be estimated from field surveys or by simulation as above. What is needed is the market value of the assets at risk, including buildings, land and the contents of buildings. Other assets at risk include roads, telecoms, water utilities and electricity systems. These contribute to an assessment of the indirect affects of flooding, and it is not therefore the asset at risk that is important here but the value of that asset to maintaining the value of the system provided by the infrastructure.

In effect three databases are required containing systematic information on the hydrological aspects of historical flood events and their risk of occurrence, a second on the associated flood damages and a third collating evidence of the socio-economic benefits of flood management and mitigation measures that have been implemented.

There are obvious feedbacks. The benefits information will be linked to a reduction in damages, which will enable the cost benefit analysis of the steps taken to reduce the flood hazard and the exposure and vulnerability of the socio-economy to it. In turn the flood exposure and risk structure

will be favourably modified.

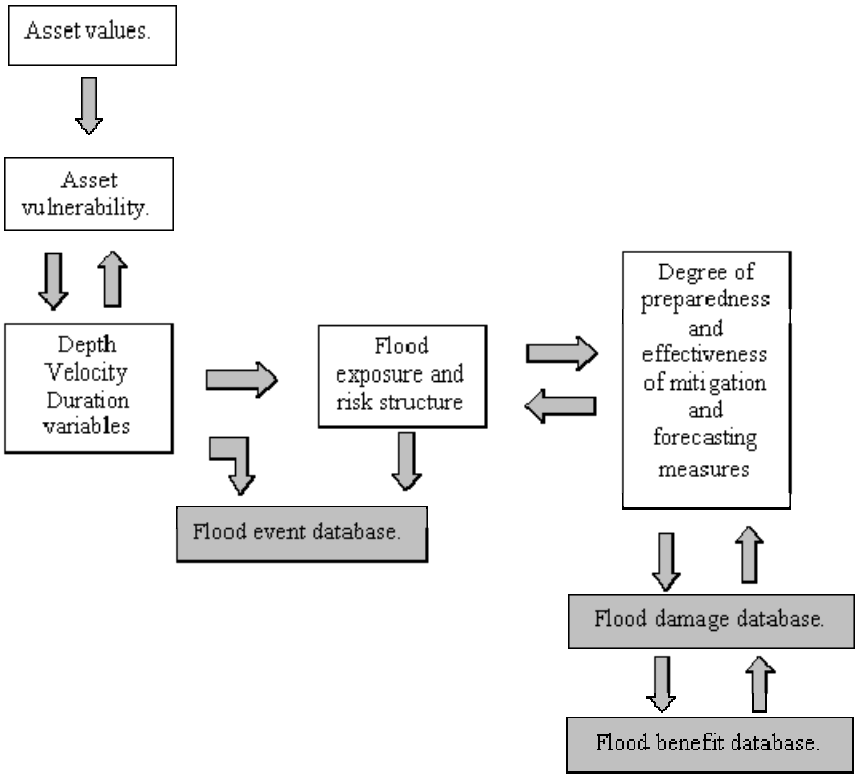


Figure 7. The construction of flood event, flood damage and flood benefit data bases.

In short, to be able to effectively determine the cost benefit structure of flood management and mitigation measures, including the value of flood forecasting, a dedicated database along the lines of that indicated in Figure 7 is required so that links and feedbacks can be evaluated in a systematic manner and the information assessed in a comprehensive context.

The case of rural areas and agricultural damage

A similar well structured approach to the cost benefit analysis of flood damage mitigation is required in rural areas where the major damages lie within the agricultural sector. Arguably crop and stock losses are more straightforward to evaluate since the net present market value is usually known with high accuracy and the area of damage and the degree of loss more easily assessable.

The principal variables that define the flood induced impacts and losses within the agricultural sector include:

- their frequency and seasonal distribution in relation to planting and crop maturity. More mature crops are more resilient to inundation and can be harvested and removed to drier areas. A common regional practise during flood inundation is to harvest as much of the crop as practical and remove it to road embankments for drying;
- the depth and duration of inundation, which are directly related to the degree of loss and the chances of crop recovery. Stock losses are arguably more a function of the depth of flooding and the availability of refuge areas;
- the degree of soil compaction and erosion. Fields which have recently been tilled and devoid of vegetation are more susceptible to erosion, for example;
- flow velocities, which are a major factor in damage to irrigation infrastructure and erosion.

The consequent flood damage costs include:

- the loss of output due to inundation;
- the cost of remedial work;

- the socio-economic losses caused by on farm prices rises as a result of crop and stock losses.

Rural areas, particularly those within river basins with steeper topography and higher rainfall, such as N Thailand, the larger part of Lao PDR and the Upper Se San and Sre Pok in Vietnam are particularly vulnerable to flash floods. These are characterised by extremely rapid increases in discharge and water level and are often combined with debris flows and landslides. They are extremely difficult to forecast and regionally are one of the major causes of flood fatalities.

IMPLEMENTING THE POTENTIAL BENEFITS OF FLOOD FORECASTING

Effectively implementing the potential benefits of flood forecasting relies, as has already been stressed, on the degree to which preparedness and mitigation measures are in place and the socio-economic ability to cope with the threat. Forecasting is one thing, knowing what to do is another. In many ways flood preparedness should be seen from an organisational perspective and the development of an increased resilience to the hazard. There would be a natural desire to protect as much stock and inventory by moving it to safety, either to upper floors or higher ground. But the practicality of doing so depends upon the forecast lead time and the nature of the stock. Large machinery, for example, would usually remain exposed while farm stock could be moved to higher ground and feed provided. Vehicles could also be moved out of harm's way.

In effect, the value of a flood warning lies with the adaptive capacity of the socio-economy at risk, that is the extent to which it can rapidly modify itself to move to a less vulnerable state. This capacity is an integral part of risk management. Regionally rural areas probably have a higher adaptive capacity and therefore can mitigate flood losses more effectively given an effective warning than urban areas. The most productive agricultural areas lie within flood plains anyway where flood inundation is a perennial risk that within certain limitations, the society has learnt to cope with.

Urban areas are a different matter. Here the value of a flood warning as much depends upon the individuals within the private sector as the public sector at large. Within the private sector there is very considerable scope for damage reduction in the face of a flood warning but it is difficult to regulate and requires that individual owners and operators are aware of the appropriate actions and carry them out. The threat of significant urban flooding is episodic and the threat is not perennial as in rural areas where a cooperative community response to warnings and imminent flooding is usual. Floods are a familiar hazard in many rural areas and lessons are continually being learnt and resilience improved to some degree. This is not the case generally speaking in the private sector within urban areas.

SUMMARY CONCLUSIONS

Estimating the costs and benefits of flood warning systems, whether based upon inexpensive and simple models using the routinely available hydrometric data or upon expensive dedicated systems specifically developed for the purpose is difficult, though there is a general consensus that the cost benefit ratio is of the order of ten to fifteen to one. Attaining such high cost/benefit ratios is, however, critically linked to the adaptive capacity of the socio-economy in question to rapidly respond to the warning and quickly reduce the exposure and vulnerability as far as is practicable. The degree to which this reduction can be achieved is in turn a function of the preparedness and mitigation measures that are already in place.

The value at risk from floods and flooding is extremely difficult to evaluate during the planning and pre-implementation phases of flood management, forecasting and mitigation projects. The damage and loss caused by floods is a complex function of their risk structure, the relationship between peak flows and water levels, flood volumes, the duration of critical water levels and the duration and depth of the consequent inundation. It is also a function of the value and vulnerability of the services, crops, livestock, infrastructure and inventory exposed. The example of estimating potential flood losses conditional upon Vientiane being flooded, as it was in 1966, is used here to illustrate the issues.

Systematically collating post flood event damage and the associated socio-economic impacts remains the most accurate way of developing the necessary insights into the potential benefits of

implementing flood management and mitigation strategies, including flood forecasting.

Three linked databases should be developed:

- the first would contain data and information on the hydrological aspects of historical flood events and their risk of occurrence, which should then be linked to;
- the second, which would hold the data on the consequent flood damage thereby enabling a direct link between the hydrological aspects of a flood event and the resultant impacts and losses;
- finally, a third database would contain the results of cost/benefit studies of the socio-economic value of implementing flood mitigation and management policies and interventions, including the gains to be had from flood forecasts.

This structured and systematic organisation of the relevant data would enable the accuracy of economic appraisals of flood management to be continuously improved. Considerable data already exists within the Mekong region at the national level which should be assembled into the types of databases described above and which should be held centrally under the management of the FMMP at the Regional Flood Centre.

REFERENCES

Berz, G. 2000. Flood disasters: lessons from the past - worries for the future, Proc. Instn Civ. Engrs. Water & Mar. Engn, Vol. 142, Mar. 3-8, p. 3 - 8.

IFR World Disaster Report, 2002.

Merz et al., 2004

Messner F and V. Meyer, 2005. ‘ Flood Damage, Vulnerability and Risk Perception’. UFZ Discussion Papers. 13/2005. Published by the Econometrics Department. University of Leipzig. Germany.

United Nations University, 2004.

THE ROLE OF FLOOD FORECASTING AND EARLY WARNING IN INTEGRATED FLOOD RISK MANAGEMENT

GUUS SUTMULLER

Royal Haskoning, Nijmegen, the Netherlands

ABSTRACT

Component 2 (FMMP-C2) of the Flood Mitigation and Management Program (FMMP) of the Mekong River Commission (MRC) aims at the development of guidelines for the preparation of flood risk management plans and for the evaluation of the impacts of flood risk management measures. A good knowledge of the flood hazards, potential damages and risks is fundamental for the development of a balanced mix of measures aiming at the reduction of the risks. The paper presents the concept of flood risk assessments and of the integrated approach for managing these risks, as applied in the FMMP-C2.

In the integrated flood risk management (IFRM) the flood forecasting and early warning aim at (i) the reduction of potential damages by decreasing vulnerability and (ii) at the reduction of the actual damages by disaster management. The evaluation of the impact of early warning on the reduction of flood damage is an important but difficult step in the IFRM planning process. Some ideas are presented for such evaluation in the Lower Mekong River Basin (LMB) flood prone areas.

INTRODUCTION

Component 2 (FMMP-C2) of the Flood Mitigation and Management Program (FMMP) of the Mekong River Commission (MRC) aims at the development of guidelines for the preparation of flood risk management plans and for the evaluation of the impacts of flood risk management measures. A good knowledge of the flood hazards, potential damages and risks is fundamental for the development of a balanced mix of measures aiming at the reduction of the risks. How to come to such balanced mix of measures requires, moreover, a proper evaluation of the impacts of the different measures on the flood risk.

INTEGRATED FLOOD RISK MANAGEMENT

Floods are a recurrent phenomenon in the Mekong basin that brings yearly damages, as well as benefits in terms of e.g. fish habitat and nutrients. The challenge for the Lower Mekong Countries is to reduce risk and damage, while sustaining the benefits, for now and for future generations. Component 2 of the Flood Management and Mitigation Programme (FMMP) defines Integrated Flood Risk Management (IFRM) as applying the most attractive mix of all possible measures, hard and soft, for the reduction of flood risk.

Flood risk management is an approach to identify, analyse, evaluate and control and manage the flood risks in a given system. A general scheme for flood risk management is presented in Figure 1 and distinguishes the following steps:

- definition of the system, the analysed hazards and the scale and scope of the analysis;
- a quantitative analysis where the probabilities and consequences are assessed and combined / displayed into a risk number, a graph or a flood risk map;

- risk evaluation: With the results of the former analyses the risk is evaluated. In this phase the decision is made whether the risk is acceptable or not;
- risk reduction and control: Dependent on the outcome of the risk evaluation measures can be taken to reduce the risk. Measures could concern structural and non-structural measures.

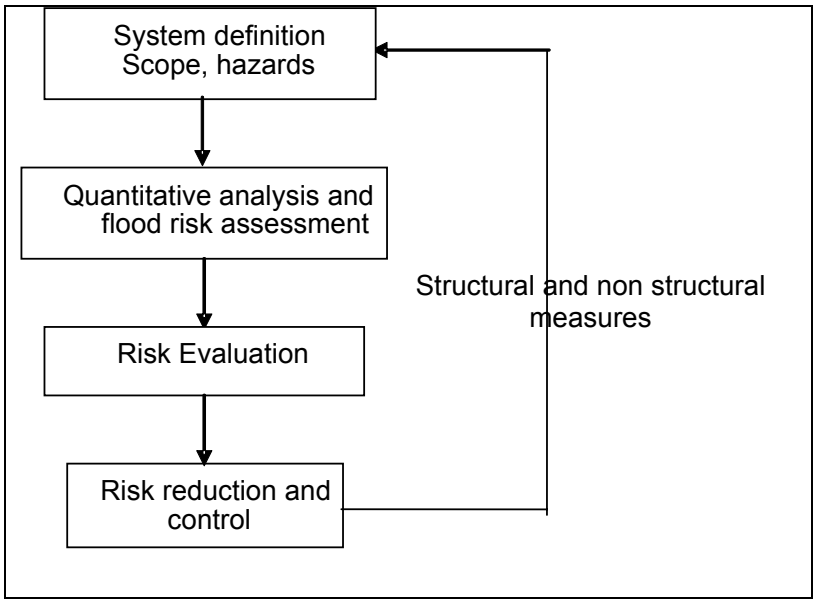


Figure 1. General scheme for integrated flood risk management

The scheme above is focused on minimization of flood risks to an acceptable level. In a broader application the approach could also be used to assess the overall hydrological performance of the system (e.g. minimization of drought, maximization of water quality and ecological quality). Then the approach will be focused on multiple objectives: not only to minimize the risk but also maximize the performance (e.g. drought minimization, water quality, or possibility of fishery).

Flood risk assessment

The flood risk is defined as the combination of the potential damage (vulnerability) in the flood prone system and the probability of flood hazards that would create that damage. Therefore, the two basic elements in a flood risk assessment are:

1. the assessment of the probable flood hazards, in terms of inundation depth, duration, timing, flow velocities, etc. and
2. the assessment of the potential damage that can be caused by these flood hazards.

A flood risk assessment can be illustrated as shown in Figure 2.

Expressed in mathematical terms, the flood damage risk is the product of the potential damage and the probability of the flood that creates that damage. Consequently, the risk can also be expressed as the ‘expected average annual flood damage’ and corresponds with the area below the damage probability curve as shown in the Figure 3.

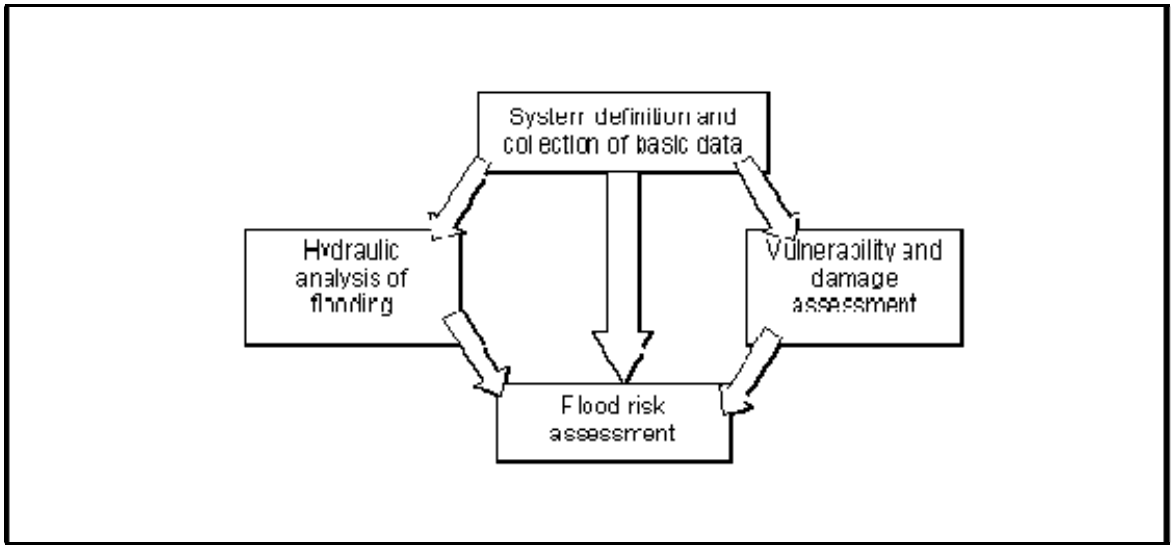


Figure 2. General scheme for flood risk assessment

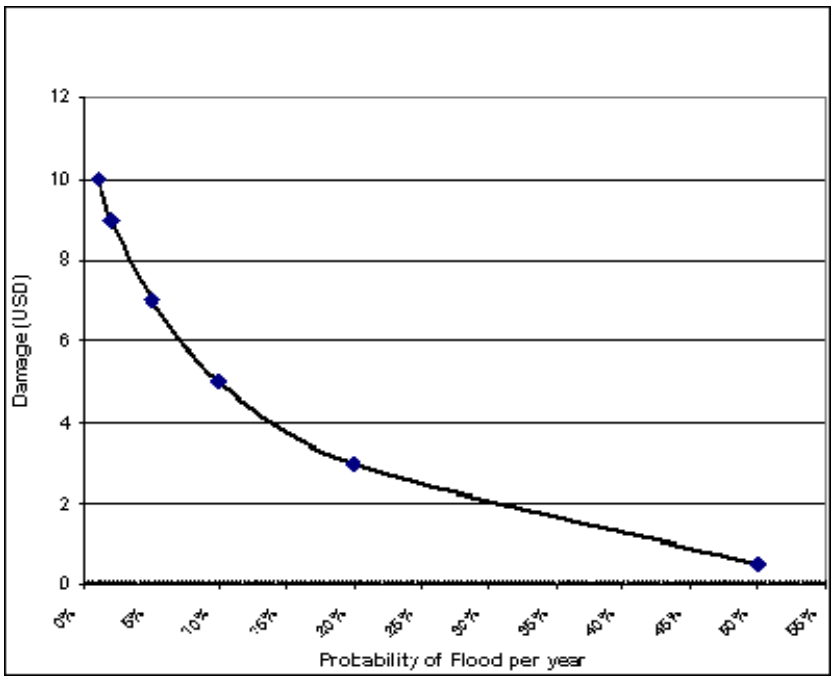


Figure 3. Example of a damage probability curve

Flood risk management measures

From the definition of flood damage risk it is derived that in principle flood damages can be reduced by:

1. risk reduction through:
   a. reduction of the probability of flooding;
   b. reduction of the vulnerability of the flood prone area and society;
2. damage reduction by proper disaster management.

In an integrated flood risk management approach these three types of measures are considered in connection with each other and aiming at an optimum mix of measures. The

relation of different types of measures with (the reduction of) respectively probability of flooding, flood vulnerability and the eventual damage is illustrated by Figure 4.

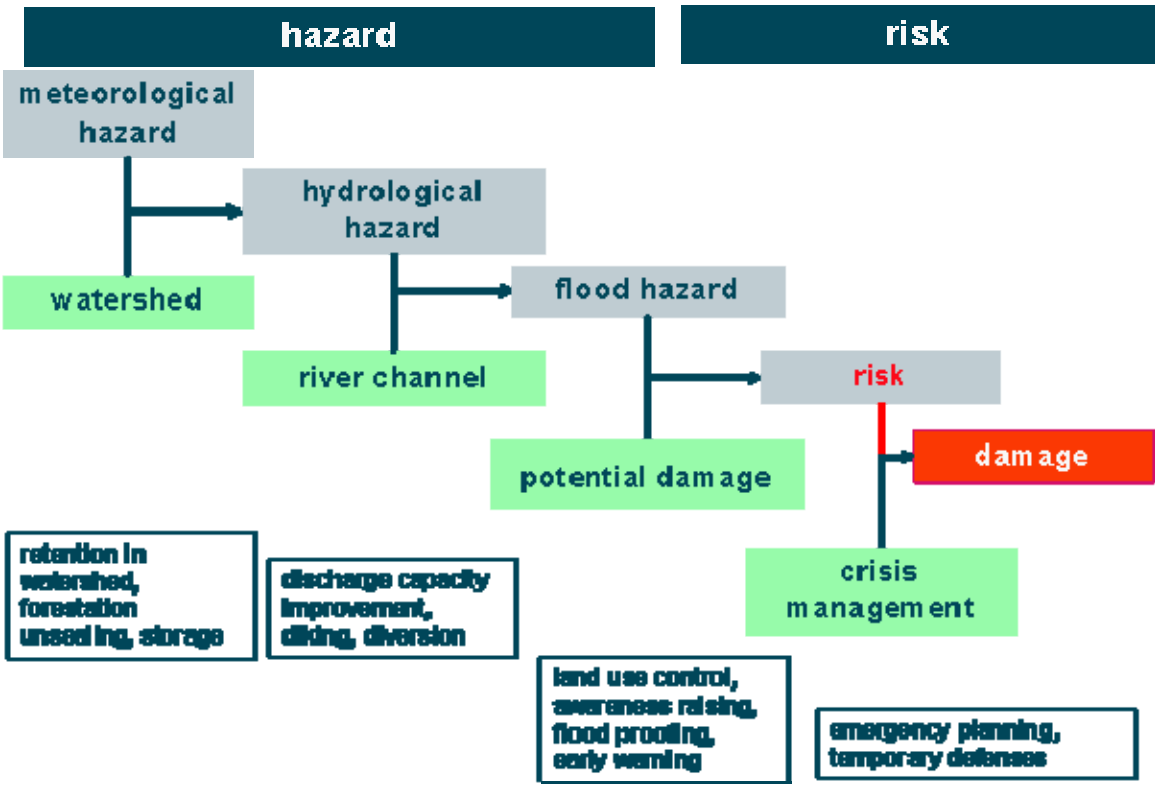


Figure 4. Flood risk management measures

As also reflected in the FMMP Components, most attention in flood risk management in the Lower Mekong River Basin is given these days to the so-called soft measures (forecasting, preparedness, emergency management, land management). These measures aim at the reduction of the vulnerability, rather than on the reduction of the probability of flooding. Structural measures generally aim at the reduction of the probability of flooding. Flood proofing can be seen as structural measures aiming at vulnerability reduction.

Structural measures in the Vietnamese part of the Delta consist mainly of flood protection dikes. In the northern part of the Vietnamese Delta the diking goes together with increased drainage capacity in order to prevent flood levels to overtop the dikes before the second crop is harvested. Residential areas are being made flood free by elevation. Diking schemes in the other riparian countries are mostly built for the purpose of the protection of settlements only.

Works specially built for flood retention are virtually absent in the Lower Mekong River Basin (LMB). Even though, the effective storage capacity of existing man made reservoirs in the Mekong basin is about 11 billion cubic metres (BCM). The use of (part of) this capacity for flood retention would require adjustments of the operation rules, which are now exclusively targeted on energy production.

Additional large scale hydropower development is planned on the Mekong mainstream in China, on the Mekong tributaries in Laos, the upper Se San and Sre Pok in Vietnam and on the Se San in Cambodia and Mekong mainstream at Stung Treng and Kratie. Combining information from various sources and assuming that 50% of the gross storage is effective, the active storage could grow to about 85 BCM in 2025. This corresponds with almost 20% of the average annual flow in the Mekong at the mouth. It implies that the potential to reduce the hydrological hazard at locations is substantial.

The Chinese dams (assumed active storage 28.5 BCM) could have a high potential to reduce flood peaks in the upper part of the LMB. The effect, however, rapidly reduces further downstream. Together with a high development of hydropower in the LMB (total active storage 47.6 BCM) still reductions of the annual flood peak in the order of decimetres can be achieved. In the delta the effect will be limited.

Earlier studies indicate that the hydropower development has at locations significant impact on the flood conditions and should be taken into consideration, particularly, when projects are developed in the upper reaches of the LMB.

It is anticipated that also in the Cambodian part of the Delta a combination of diking, diversion and colmatage/controlled flooding could provide attractive structural flood risk management options.

The impacts of flood risk management measures

The impacts of structural flood protection measures on the flood risk can relatively easy be assessed once a damage probability curve has been developed for a certain system. The benefit of flood protection is that part of the damage probability area that corresponds with floods with a higher probability than the protection level, as illustrated in Figure 5.

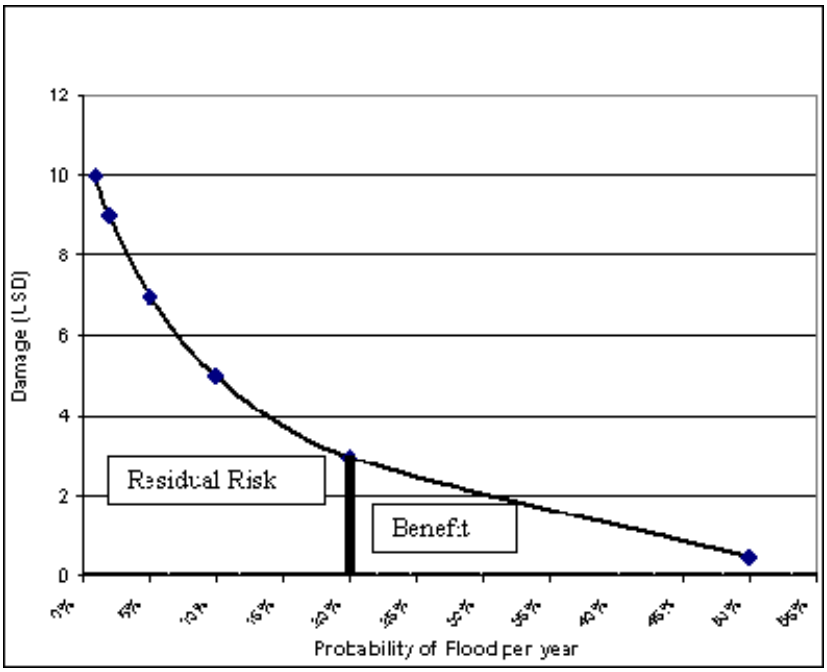


Figure 5. Impact of flood protection measure against floods with probability higher than 20% per year (5 year return period)

These benefits may appear relatively low in many flood prone areas in the LMB, simply because land use in these areas is attuned to the 'normal' flood regime. As a consequence damages are relatively low for floods with a high probability of occurrence. The benefits of flood protection in such areas are related to a more economically attractive land use, rather then to the reduction of the actual risks.

The impacts of measures that aim at the reduction of the vulnerability (or potential) damage can also be assessed with the help of the damage probability curve. In general the reduction will have the character as illustrated in Figure 6. It shows that reduction of vulnerability results in partial reduction of the flood risks for most floods.

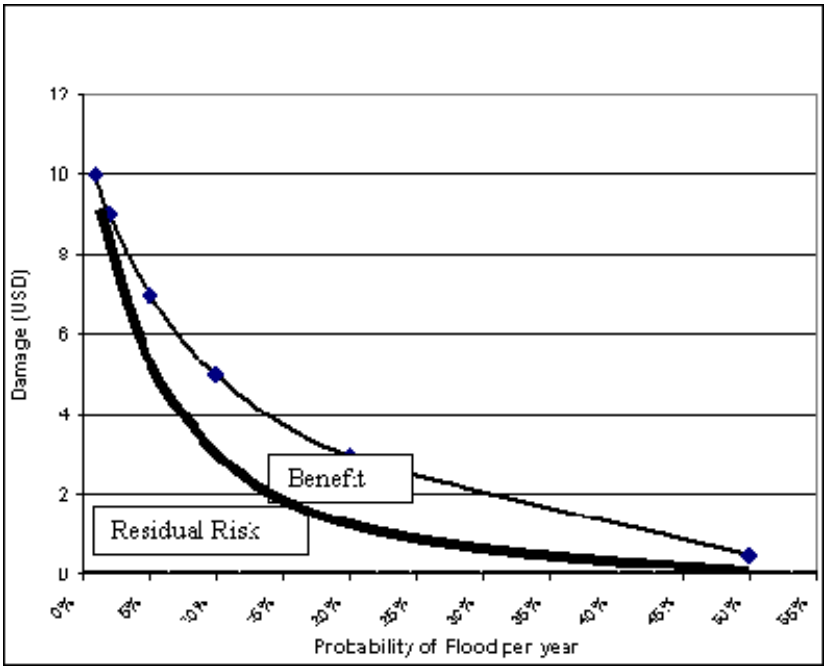


Figure 6. Impact of vulnerability reducing measures on flood risk

Impacts of flood forecasting and early warning

The assessment of damage reduction as a result of flood proofing and land use control can be evaluated with the help of the design criteria used for flood proofing or with the help of the so-called stage-damage curves for different land uses. The assessment of the impact of early warning on flood risks, though, is complicated by the effects of people's response to flood warning, evacuation behaviour, flood warning dissemination and other very site specific factors.

A timely and reliable early warning has the following potential risk reducing impacts:

1. the prevention of loss of live;
2. the reduction of direct damage to properties, by (re)moving them or protect them temporarily;
3. the reduction of the hazard by operational activities (closure of gates, clearance of channels or culverts, temporary defences).

It is evident that the reduction of loss of live and injury is the most important potential benefit of early warning. Even a warning system that provides less than 1 hour of warning for people living in the flood prone area will enable them to save their lives. The impact of early warning on mortality is closely related with the availability and quality of emergency and evacuation plans.

The economic benefits of such short notice will be very low though, because it provides very little possibility to reduce direct damages to properties or to carry out operational activities that aim at hazard reduction.

Despite the high importance of the prevention of loss of live, most of the methods that have been developed for the assessment of risk reduction refer to the direct damages to property only. These methods try to provide a relation between the total potential damages to properties (buildings, inventory, stocks, equipments) and the actual damage that would occur with and without early warning. Based on European data[1] it is found that the actual flood damage

[1] FLOODsite, Report No T09-06-01, Evaluating flood damages: guidance and recommendations on principles and methods, January 2007. Co-ordinator: HR Wallingford, UK

avoided is of the order of 30 - 40% only of the damages that potentially can be avoided by early warning. This is a result of the impact of people's response to early warnings.

The evaluation of the impacts of early warning on the reduction of direct tangible damages in the LMB requires reliable estimates (and thus data collection) regarding:

1. potential flood damage to properties in the flood prone areas;
2. potential flood damage that can be avoided by early warning;
3. response of people to early warning.

In the framework of the FMMP Component 2 a start is being made with the collection of relevant data with the help of socio-economic surveys in several focal flood prone areas in the LMB. It is anticipated that with the help of these data a first guestimate can be made of the relative impact of early warning on flood risk reduction in these areas. This information will then be used in the development of integrated flood risk management plans consisting of the most attractive mix of measures for flood risk reduction.

LONG LEAD CLIMATE FORECAST APPLICATION TO BENEFIT SOCIETY: EXPERIENCES OF 2007 BANGLADESH FLOODS

A.R.SUBBIAH AND S.H.M. FAKHRUDDIN

Asian Disaster Preparedness Centre (ADPC), Bangkok, Thailand

ABSTRACT

It has long been recognized that if society could have advance information on weather, the adverse effects associated with it could be minimized. Prevalence of traditional forecast practices in various parts of the world reflects the demand for long-range forecasts schemes to manage uncertainties associated with it. Recent advancements in long lead flood prediction under the Climate Forecast Applications in Bangladesh (CFAB) program promise huge benefits for society and developed strong interagency cooperation and networking to facilitate the development of flood forecasting schemes and their application at the various levels. During the last monsoon 2007, significant efforts were made to further refine the forecasting scheme and development of institutional networking and coordination mechanisms through series of training at national, district and local levels for interagency collaboration and capacity building at institutional and community level to facilitate generation, interpretation and communication of forecasts at the risk communities. The value of new generation CFAB long lead flood forecast products to reduce disaster risk at the community level has been demonstrated and proven a huge societal benefit and save life and property. This paper describes lessons learned on institutional and community aspects of CFAB in the context of 2007 floods experience.

INTRODUCTION

Bangladesh is deltaic country located at the lower part of the basins of three large alluvial rivers, the Ganges, the Brahmaputra and the Meghna. Total river basins area of these three rivers is of 1.7 million km^2 (River basins Map Figure 1). Numerous tributaries and distributaries of these rivers and extensive floodplains is the main physiographic feature of the country. In fact about four-fifths of the country is floodplain. As a result of flat topography of the floodplain, one-fifth to one-third of the country flooded by overflowing rivers during monsoon when rainfall is also very high. This annual phenomenon of rainfall and river flooding has played an active role in shaping the landscape, economy, society and culture of the country.

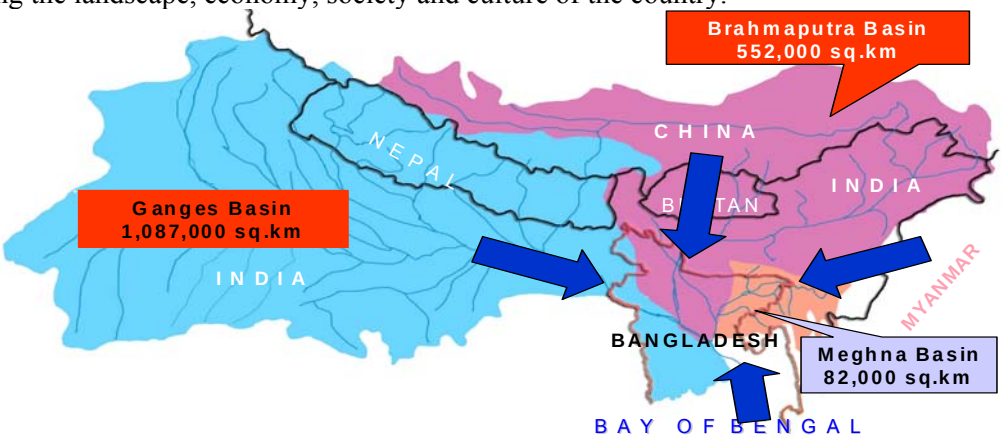


Figure 1. The Ganges, Brahmaputra and Meghna basins

The Climate Forecast Applications in Bangladesh (CFAB) program started from since 2001 is developing a series of forecasting schemes to increase lead-time of flood forecasting in Bangladesh. These schemes cover short (1-10 days), medium (20-25 days) and long term (1-6 months) time periods.

INSTITUTIONAL NETWORK FOR CFAB

A strong institutional networking and commitment has been developed to facilitate the development of flood forecasting schemes and their application. At international level, Climate Forecast Application Network (CFAN) of Georgia Institute of Technology (GATECH), established collaboration with the European Centre for Medium-range Weather Forecasts (ECMWF) for accessing its forecast products. At national level a steering committee formed consisting of Disaster Management Bureau (DMB), Department of Agriculture Extension (DAE), Flood Forecasting and Warning Centre (FFWC), Bangladesh Meteorological Department (BMD), Centre for Environmental and Geographic Information System (CEGIS), Institute of Water Modelling (IWM), Asian Disaster Preparedness Centre (ADPC), and CARE-Bangladesh to evaluate the forecast products, interpret, translate, disseminate at community level and other decision making process. The institutional partnership to connect all stakeholders with communities at risk shown in Figure 2.

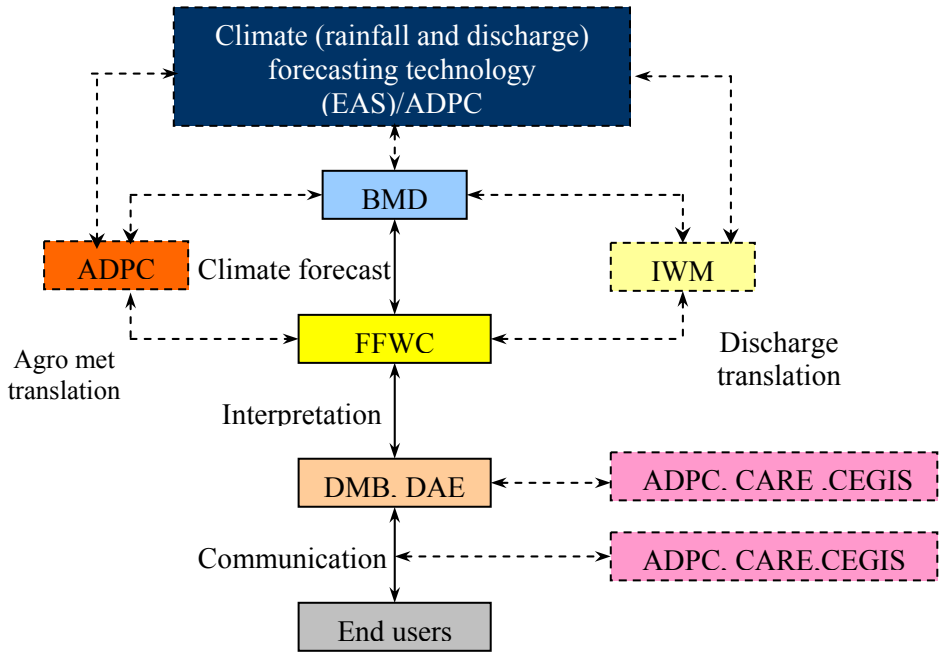


Figure 2. Institutional collaboration for sustainable end-to-end generation and application of flood forecasts

It is envisaged that in near future all the dotted lines agencies will back stop and the core government agencies of Bangladesh will take the lead to developing forecast information products, interpret and disseminate information at the nationwide.

At the local level the Upazilla (i.e. sub-district) level disaster management committee chaired by the Upazilla chairman discussed regularly and validate the information and usefulness of long lead forecast information products. A close consideration of social factors, design of climate forecast products to suit users' needs, communication of the forecast products, sector system models (crop climate models), decision behaviour, institutional constraints and

social settings in which the decisions are made were taken care of to institutionalised the system. At the same time a continuous dialogue mechanism between climate information producers, intermediary research organizations, and policy-makers and end-users has been established.

DECISION SUPPORT SYSTEM OF FFWC

Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB) is responsible for flood forecasting and its dissemination within Bangladesh. Flood forecasting models of FFWC developed on MIKE 11, one-dimensional modelling software used for the simulation of water levels and discharges in the rivers. For real-time flood forecasting, FFWC uses Flood Watch, a decision support system developed in ArcView GIS, which integrates database, modelling system, model outputs and dissemination of forecasts. Flood Watch and MIKE 11 modelling system have been used for the flood forecasting using CFAN data to produce 1-10 days forecasts. CFAN generated 1-10-day discharge predictions at Bahadurabad on the Brahmaputra River and Hardinge-Bridge on the Ganges River. The prediction generated 51 sets of ensemble forecasts for a particular day at each of the discharge prediction points (Figure 3). The coloured lines represent the 51 ensemble members. The bold black line indicates the observed values of discharge measured at Bahadurabad.

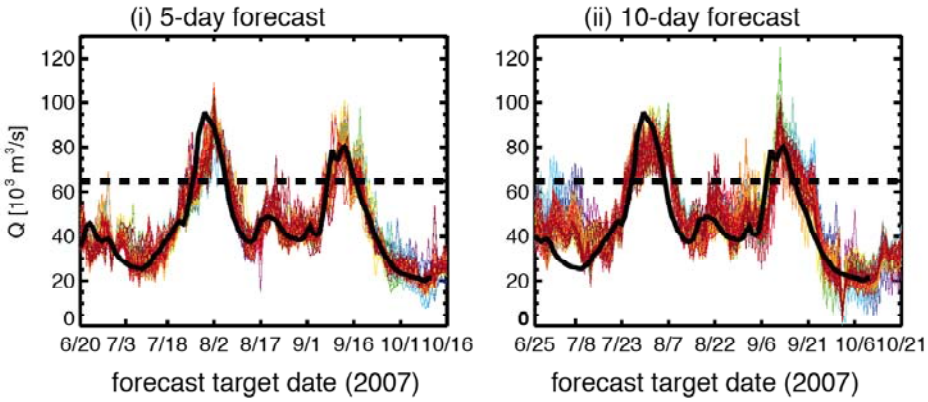


Figure 3. 1-10 days CFAN discharge forecasts at Brahmaputra River

Using 51 sets of data for simulation and further processing/ analyses of the results is not practical from operational viewpoint of a flood forecasting system and hence it was decided to carry out selective simulations and prepare forecast bulletin that would be easily understandable and usable to the end-user. Hence, CFAN was requested for further processing of ensemble forecasts and provide forecasts for 97.5% & 2.5% quantiles (upper and lower limits of 95% confidence limits), 16% and 84% quantiles (for -1 Stdv and +1 Stdv) and Ensemble Mean.

The updated FFWC model was taken for customisation for real-time flood forecasting utilizing CFAN predictions. The customized FFWC model used for the flood forecasting of extended lead-time using climate forecast application data has been named CFAB-FFS (CFAB Flood Forecasting Study) model. Under this program five pilot areas have been selected for the application and capacity building of community. Five pilot areas are Uria, Gaibandha, Kaijuri, Sirajganj, Gazirtek, Faridpur, Bekra Atgram, Tangail and Rajpur, Lalmonirhat. The forecast stations selected for the CFAB-FFS modelled river network and pilot areas presented in figure 4

FORECASTS PRODUCT APPLICATION METHODS

A method to bridge the gap between producers and users of forecasts has been developed

through the generation of user-friendly forecast products that provides an aggregated risk analysis to aid a user community in making absolute decisions. For an example, the crop is in 80% maturity stage and nearing physiological maturity during early July. It requires additional 10 days to reach complete maturity that falls after mid July. Consider that the decision to be taken during early July is whether to harvest the crop before its complete maturity or wait until middle of July to ensure good quality. The forecast indicates higher chance of above average flow during mid July that may cause inundation of paddy fields so that harvest would be affected substantially. Inundation during harvesting stage may lead to complete loss of produce and entire cost of investment. Figure 5 shows the decision outcomes tree for risk paradigm.

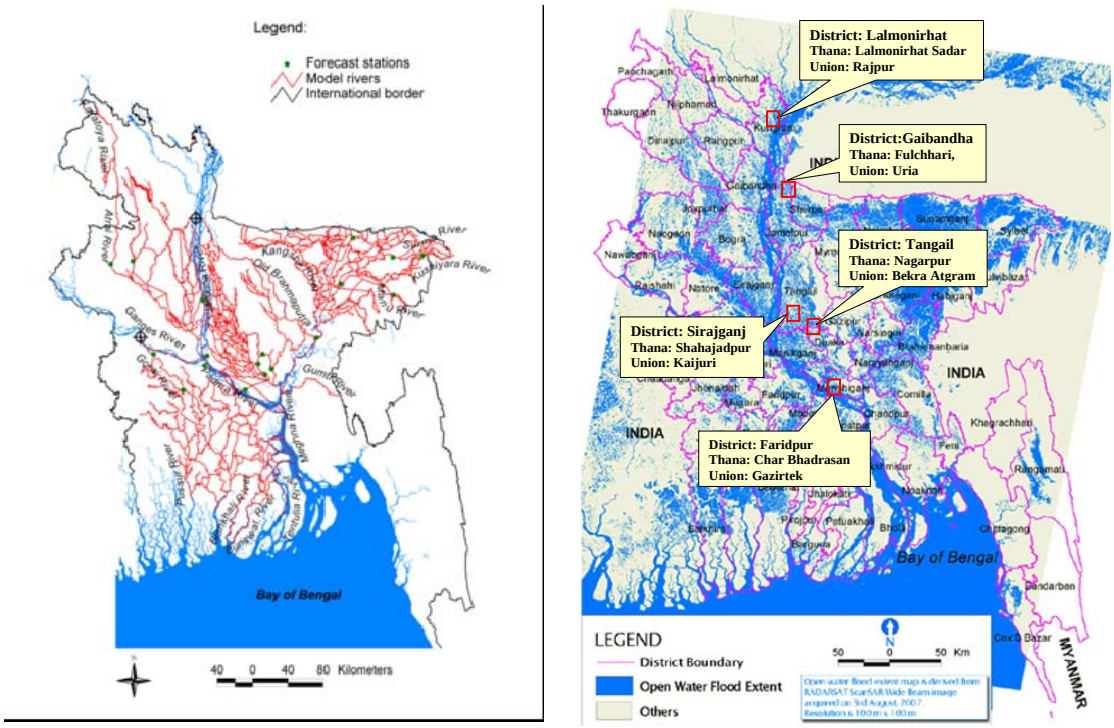


Figure 4. Model rivers and forecast stations (left) and five pilot areas for CFAB

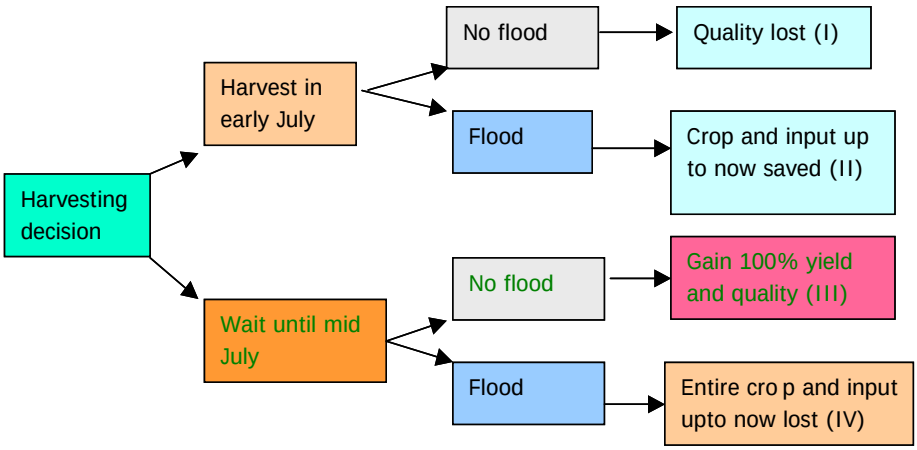


Figure 5. Decision outcome tree for risk reduction paradigm.

On the other hands a detailed assessment was made at each community regarding the forecast lead time requirement, users needs, impacts and management plan for crop, livestock and fisheries sector to customise the forecasts products. Table 1 shows the Disasters, impacts

and management plan matrix for crop, livestock and fisheries sector of one pilot area.

Table 1. Disasters, impacts and management plan matrix for crop, livestock and fisheries sector (e.g. Uria, Gaibandha district of Bangladesh)

Disasters	Crop	Stages	Season/ month	Impacts	Time of flood forecast	Alternative management plans
Early flood	T.Aman	Seedling and Vegetative stage	Kharif II Jun – Jul	Damage seedlings Damage early planted T.Aman Delay planting Soil erosion	Early June	Delayed seedling raising, gapfilling, skipping early fertilizer application
	T.Aus	Harvesting	Kharif I Jun – Jul	Damage to the matured crop	Early June	Advance harvest
	Jute	Near maturity	June-July	Yield loss Poor quality	May end	Early harvest
	S.Vegetables	Harvesting	June-July	Damage yield loss Poor quality	Mar - Apr	Pot culture (homestead) Use resistant variety
High flood	T.Aman	Tillering	Kharif - II July-Aug	Total crop damage	Early June	Late varieties Direct seeding Late planting
Late flood	T.Aman	Booting	Kharif II Aug-Sep	Yield loss and crop damage	Early July	Use of late varieties Direct seeding Early winter vegetables Mustard or pulses
Flood (early, high and late)	Cattle	-	Jun-Sep	Crisis of food and shelter. Diseases like cholera, worm infestation	Early June	Food storage, flood shelter, vaccination de-warming
Flood	Nursery table fish Brood fish	-	June to Aug	Inundation of fish farms Damage to the pond embankments Infestation of diseases Loss of standing crops	Apr - May	Pre-flood harvesting, Net fencing/bana, Fingerlings stocked in flood free pond, High stock density

FLOOD FORECASTING AND WARNING DISSEMINATION

The warning information was disseminated through FFWC's traditional dissemination process (Fax, Telephone, e-mail). In the five pilot areas the over all process of flood forecast dissemination is divided intro three part. First, the requirements of the flood forecast dissemination was analysed though consultation with FFWC and community. Secondly, message production system from regional to community was established. Finally, the flood forecast dissemination and monitoring instruments were established.

The information was sent via SMS, flag network and physical contact. Capacity building and community understanding was made through flood pillar, bulletin board, leaflets and regular training to the community people, flag operators, upazilla disaster committee member and schoolchildren.

RESPONSE OF NATIONAL INSTITUTIONS FOR 2007 FLOOD FORECASTS

The FFWC incorporated the CFAB forecasts to produce water level forecasts for many locations along Brahmaputra and Ganges rivers well in advance. National level disaster emergency response group consisting of International Non-Governmental Organization (INGO), Ministry of Food and Disaster Management and international organisations prepared emergency response plans, logistics for preparedness and relief in advance. National level NGO network and INGOs prepared localised warning messages and disseminated to their counterparts at local level.

National level service organisations like DAE prepared rehabilitation plans in advance. Figure 6 shows the daily response after getting the long lead flood forecasting from the national level.

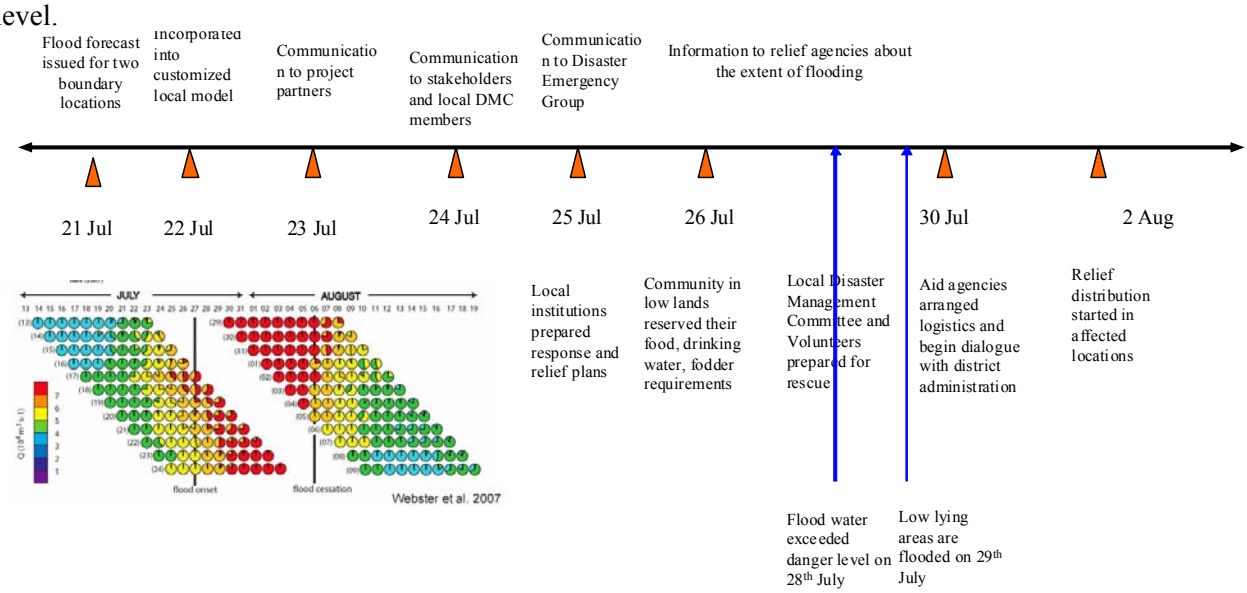


Figure 6. Users response during the 2007 flood. Forecast issued on 21st July showing greater chance of exceeding danger level in Brahmaputra from 28th July 2007

RESPONSE OF LOCAL INSTITUTIONS FOR 2007 FLOOD FORECASTS

Based on the forecast information, district level service organisations in partnership with NGOs communicated 1-10 days forecast in 5 days advance to their respective communities. Local NGOs and implementing partners prepared evacuation and response plans to protect lives and livelihoods. District level relief and emergency organisations plan to mobilise resources for relief and recovery activities. Local NGOs, Government organisations and Community Based Organization (CBO) mobilise mechanised and manual boats to rescue people and livestock from the 'char' areas. Local NGOs and Department of agriculture extension prepared work plan for relief and rehabilitation activities

COMMUNITY LEVEL DECISION RESPONSES FOR 2007 FLOOD FORECASTS (LOWLANDS)

Upon receiving the information, local people planned to store dry food and safe drinking water for about 15 days knowing that relief will start only 7 days after initial flooding.

Secured cattle, poultry birds, homestead vegetables, protected fishery by putting nets in advance, secured cooking stove, small vessels, firewood and animal dry fodder

Planed to evacuate and identified high grounds with adequate sanitation and communication and planed for alternative livelihood options immediately after flooding (e.g. Small scale fishing, boat making, etc).

COMMUNITY LEVEL DECISION RESPONSES FOR 2007 FLOOD FORECASTS (HIGH LANDS)

Community living at the high land abandoned T.Aman transplanting temporarily anticipating floods, secured additional seedlings for double planting of rice after the floods. They also protected homestead vegetables by creating adequate drainage facilities, reserved seeds of flood tolerant crops, planned for growing seedlings in high lands, planed for alternative off-farm employment during floods. Farmer early harvested their of B.Aman rice and jute anticipating floods and leaving livestock in high land shelters.

KEY LESSONS FROM 2007 FLOOD FORECAST APPLICATION

The 1-10 days forecast performed significantly well in 2007. Bangladesh faced two times flooding in 2007 which gives impacted the community and national economy at the same it gave a good opportunity to test and build confidence on the model developed under CFAB. No other country in the world would able to developed this kind of forecasting techniques. Some key lessons learned during the 2007 flood are summarized below:

- conflicting community perception and misinterpretation of forecast information reduces the local response actions in appropriate time. Future targets would be related to capacity building at community level;
- community level risk maps are the better tools to incorporate flood information and prepare localized impact outlooks;
- preparedness plans by local institutions are driven by response from local DMC members and require capacity building initiatives for DMC members;
- the relief activities are slow due to sequence of lengthy procedures with district administration;
- response to forecasts in low lying areas and ‘char’ regions are related to saving lives and small household assets (dry food, drinking water, fire wood, animal fodder, barrowing credit from micro-financing institutions);
- response to flood forecasts in high lands are mostly related to preparedness activities like reserving seedlings for double planting, protecting fisheries, early harvesting, abandoning early planting, protecting livestock and preserving fodder;
- local institutions during 2007 in pilot unions are well informed and prepared for floods in advance;
- local level infrastructure facilities (high lands, flood shelters, sanitation etc.,) are not sufficient to carry out preparedness and response actions.

CONCLUSION

The usage of increased understanding of probabilistic long lead flood forecasting is extremely valuable for the society and the environment in Bangladesh. In order to receive value-added benefits from the flood information, requirements of different users need to be looked very carefully and to be met judiciously. More over, accuracy and lead- time of forecast is very important for a country like Bangladesh, which is a lower riparian country of three major river systems and drains huge run-off from a large river basins.

The community based CFAN flood forecast system has generated greater interest of people living in the pilot unions and other region as well. The flood forecast should be more specific so that the forecast will match with real condition more accurately. People have realized the benefit of the forecast and start to believe in the system. More training and awareness of the Union Disaster Management Committee (UDMC) is required to institutionalise the system.

ECONOMIC VALUATION OF FLOOD DAMAGE FOR DECISION MAKERS IN THE NETHERLANDS AND THE LOWER MEKONG RIVER BASIN

JURJEN WAGEMAKER, JAKOLIEN LEENDERS AND JAN HUIZINGA

HKV consultants, Lelystad, the Netherlands

ABSTRACT

Economic activities in flood-prone areas are increasing around the world. At the same time we face changing weather conditions and a rising sea level as a result of climatic change. If no measures are carried out both probability and impact of floods will increase severely. In the Netherlands flood hazard and flood damage are combined in a risk-approach using a cost-benefit analysis for proposed measures. In this approach, risk is defined as the product of probability of flooding and impact of flooding. Could this approach also be applied in the Lower Mekong River Basin (LMB)? As far is the flood impact is concerned one can imagine that flood damage for instance in Chiang Rai in Thailand has other characteristics than a given polder in the Netherlands. One can also imagine that decision makers in the Lower Mekong would make different choices on how to valuate flood damage than decision makers in the Netherlands. This paper presents some considerations on how the Dutch damage assessment tool 'Hoogwater Informatie Systeem - Schade- en Slachtoffermodule' (HIS-SSM) and its underlying economic valuation model may be adjusted to serve the preferences of decision makers in the LMB. It first discusses various economic valuation techniques that are available to determine flood damage and the role of the decision maker. Next the backgrounds on risk-approach and cost-benefit analyses in the Netherlands are described and the opportunities and limitations to use such approach in the LMB are discussed. Finally reference is made to a pilot-project that recently started where the applicability of the Dutch approach is tested. The pilot project forms the link between the available economic valuation techniques for flood damage assessment and ex-ante evaluation of measures in 2T Kok River Basin. Its results are expected by the end of 2008.

ECONOMIC VALUATION TECHNIQUES

Economies need to consequently make choices on what to do with the limited resources available. Flood management can be costly and therefore governments and financiers (e.g. though Official Development Assistance) carefully consider how much they are willing to invest in it. But whose costs and benefits are we interested in? Let's take the example of the flood damage resulting from Katrina in New Orleans. It would depend on whom you are talking to what is included in flood damage. If we were to ask a former inhabitant of the ninth ward about what damage he suffers, he might answer that not only his house but also his entire life has been ruined. He is confronted with tremendous human suffering; the damage done to his personal life is enormous. Would the city of New Orleans be asked the same question they might answer that the social and economic disruption of the city is gigantic, public life has come to a standstill, industries are down, unemployment is rising, investors are pulling away (Kok et al., 2007). At yet another level the government of the United States of America sympathizes for lives lost and damage done and invests in the flood protection measures and projects to revitalize the city of New Orleans. Macro-economically however not much has changed, investors find new opportunities, industries move to other locations and total export numbers are hardly impacted (Herman, 2006). The estimates of flood damage in New Orleans vary

between US$ 30 billion up to US$ 650 billion, the latter being the sum of all claims (of inhabitants, companies and local government) in the court of law against Federal Government (Kok et al., 2007). Apparently different people have different views on how to value flood damage.

When flood damage assessment actually lays the basis for decision-making (e.g. ex-ante decisions such as flood management strategies or ex-post decisions such as insurance payments) the decision maker must carefully consider what damage to include in the decision. Is the decision maker interested in the macro-economic effects, the losses in production or in the human suffering accompanied with a flood? The next question is how to value this damage. If we would define economic valuation as the assignment of money values to non-marketed assets, goods and services (Pearce and Özdemiroglu, 2002), the decision maker has several options to choose from to estimate the economic value of flood damage (based on Ruijgrok et al., 2004):

- *damage cost avoided.* The economic value of flood damage is estimated by the cost of measures to prevent flooding;
- *averting behaviour method.* The economic value of flood damage is estimated by the cost to avoid actual damage and unwanted effects;
- *replacement costs.* The economic value of flood damage is estimated by the costs to repair or compensate for flood damage;
- *productivity costs.* The economic value of flood damage is estimated by the costs of the loss of production of commercially marketed goods;
- *conditional valuation method.* The economic value of flood damage is estimated by creating a hypothetical market in which people are enabled to price flood damage.

In ex-ante decision-making, replacement costs and productivity costs are widely accepted to value flood damage. For instance in the Netherlands replacement costs are used for the evaluation of physical damage to buildings, inventories, terrain and infrastructure and accounts for the flood damage to be fully repaired or replaced. Productivity costs are used for business interruption inside and outside the flooded area. By using these techniques in decision-making, the decision maker actually accounts for the costs to rebuild all damaged goods exactly as they were plus incurred losses of production in- and outside the flooded area. Replacement and productivity costs are also used in Germany and the UK. (Meyer and Messner, 2005). Recently HKVCONSULTANTS applied the same valuation methods on behalf of the Joint Research Centre of the European Union where the damage functions and country specific maximum damage per damage category were harmonized for all EU-27 countries on the basis of replacement costs and productivity costs, relating them to the Gross National Products of the various member states (Huizinga, 2007). The application of replacement costs and productivity costs and its institutional position in the Netherlands is subject of the next section. Other economic valuation methods can also be exercised for instance for the valuation of intangible goods such as human suffering. For instance contingent valuation can be used to assess what people are willing to pay to avert flood risk (Messner et al., 2007). Whether such methods may have added value for use in the LMB is discussed later on.

RISK-APPROACH AND COST-BENEFIT ANALYSES IN THE NETHERLANDS

The HIS-SSM and the Standard Method are used in the Netherlands to determine flood risk and the costs and benefits of flood management measures. In the risk-approach not only probability of a flood is considered but also the possible impact of a flood. To determine the actual risk, the Dutch Ministry of Transport, Public Works and Water management is carrying out a the project VNK[1] to outline the safety of the Netherlands documenting probability, consequences and risk

[1] VNK is the Dutch abbreviation for Netherlands Safety Map. The first phase of the project (VNK1)

of flooding of dike rings in the Netherlands. Much research is done to obtain insight in the strength of structures, weak areas of the dike ring and how to deal with uncertainty (Ministerie van Verkeer en Waterstaat, 2008). The potential consequences are being mapped using the national Dutch damage and casualties assessment model HIS-SSM and its associated 'Standard Method[2]'(Kok and van der Doef, 2007). The 'Standard Method' is explained in Textbox 1. Besides the assessment of actual risk, flood damage assessment is also used in cost-benefit-analyses of flood management measures. Since January 1st 2007 all infrastructural measures of national importance in the Netherlands are required to perform a cost-benefit analysis using a format called 'OEI'. OEI stands for 'Overview Effects Infrastructure' and encompasses the assessment of the positive and negative effects of a proposed measure on safety, economy and quality of life. The effects are expressed in monetary terms, i.e. in Euros. OEI is also obligatory for flood management measures comprising an assessment of a proposed measure on the change in risk (Ministerie van Verkeer en Waterstaat, 2007). In other words, for all structural flood defence projects the impact on probability, on flood damage and consequently on risk are determined. Suppose a flood management measure reduces probability of flooding, the change in risk can be illustrated as in Figure 1.

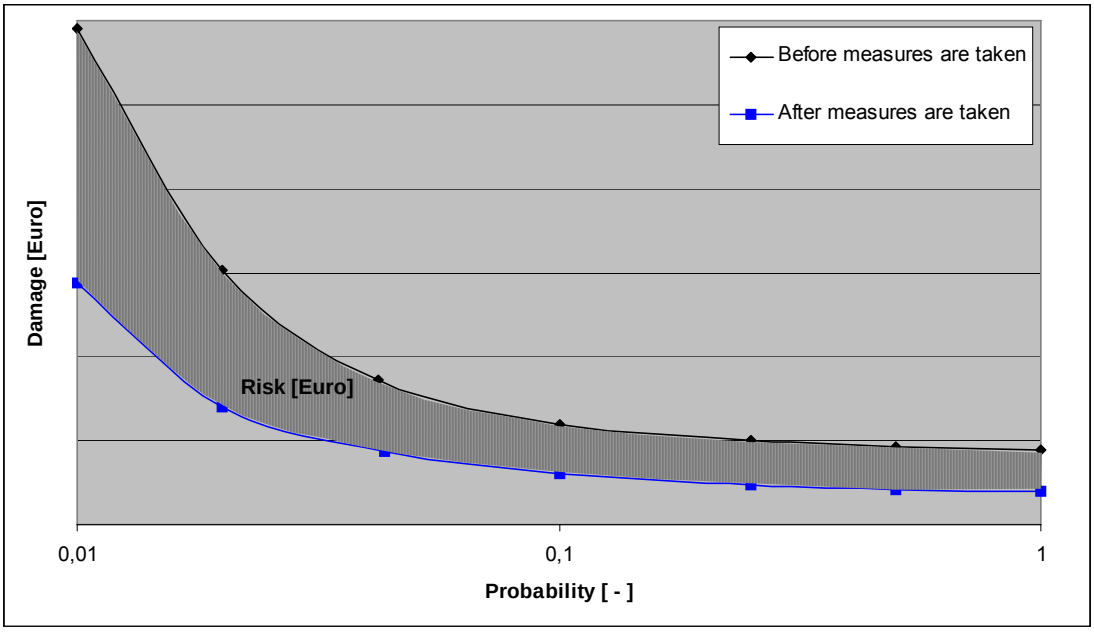


Figure. 1. Probability, damage and risk

In Figure 1 the horizontal axis represents probability, the vertical axis contains the damage and the surface of the shaded represents the change in risk. This change in risk represents the benefit of the proposed measure. The flood damage assessment is done using the national Dutch damage and casualties assessment model HIS-SSM and its 'Standard Method' (Textbox 1).

Although national decision-making in the Netherlands is not dependent on the outcome of the cost-benefit analysis in OEI alone, it is increasingly used to determine added value. Critics disqualify the approach because the outcome is approximate. It is widely accepted however that such cost-benefit evaluation provides a better grasp on the benefits of a new measure and that it can be used to stimulate economic efficient public investments. Besides use on national level, HIS-SSM is also used on regional level to evaluate the effectiveness of regional measures

started in 2001. Results of the second phase (VNK2) are expected in 2010.

[2] The Standard Method was developed in the late 1990's by HKV consultants and TNO, under supervision of the Dutch Ministry of Transport, Public Works and Watermanagement (Rijkswaterstaat). It has been continuously updated since.

against flooding. This includes the improvement of secondary and tertiary dikes within a dike ring area and safety within individual compartments.

HIS-SSM and the 'Standard Method'

HIS-SSM is the Dutch flood damage assessment model. It uses repair- en reconstruction costs, business interruption and an estimate of indirect effects to determine flood damage. The approach to valuate flood damage is captured in the so-called 'Standard Method'. De standard method comprises about 20 land-use types (damage categories). Many of these damage categories are differentiated according to damage type:

- direct damage within the flooded area: due to physical damage to buildings, inventories, terrain and infrastructure. The economic value of the flood damage is estimated by rebuilding/ replacement costs.
- direct damage caused by business interruption within the flooded area: economic damage caused by production loss. The economic value of flood damage is estimated by the productivity costs;
- indirect damage outside the flooding area: economic damage outside the flooded area because transportation routes through the flooded area are cut off or production stops due to lack of supplies from industry within the flooded area. Estimated by the productivity costs.

In the standard method a standard dataset is included covering the Netherlands. The economical damage S (expressed in Euro's) is calculated by:

$$S = \sum_{i=1}^{n} \alpha_i n_i S_i$$

where α_i is the 'damage factor' for category i , n_i the number of units (e.g. houses) in category i and S_i the maximum damage per unity in category i. Each category (i) represents a land use type. The damage-factor α_i represents the effect of hydraulic conditions and is affected by the maximum water depth, rise in water level, flow velocity, a material factor and for built-up areas the type of buildings (Kok et al., 2005). Not included in the method are type of floodwater (salt/fresh), duration of the flooding and seasonal land-cover variations in agricultural regions. The Standard Method has been developed for application in the whole of the Netherlands. This makes the Standard Method easy to apply, transparent and fast. Results are comparable and reproducible due to the fact that related software contains even a standard dataset covering the whole country (Kok et al., 2005).

Textbox 1. Backgrounds 'Standard Method' and HIS-SSM (Kok et al., 2005.

OPPORTUNITIES AND LIMITATIONS FOR THE USE OF HIS-SSM AND ITS ECONOMIC VALUATION IN THE LOWER MEKONG BASIN

At this moment a damage assessment tool comparable to HIS-SSM does not exist for the LMB. There are some case studies though on damage assessment in Vietnam (Das Gupta et al., 2004) and Bangladesh (Nabiul Islam, 2005, 2006). Some general flood assessments studies were exercised based on field surveys (Mekong River Commission, 2006, 2007) however, a general tool to obtain insight in spatial variability of damage resulting from different types of floods and among different sectors in society does not exist, yet. The question is, could such as tool, such as HIS-SSM, be adjusted and made applicable for use in the LMB? At least some essential adaptations with respect to the type of floods and the impact of these floods on society will be necessary. This section discusses the impact of floods on society in the LMB and presents some opportunities and limitations to use such an approach in the LMB.

Impact of floods

The impact of floods in the LMB is twofold; on one hand flooding in the LMB is a source of livelihood and essential for soil fertility and urbanization and on the other it can have a devastating effect on human lives, causing damage to infrastructure, human settlements, essential services and casualties. These devastating effects might even hamper economic development and force the society to remain on agricultural production (Mekong River Commission, 2006. (Messner, 2007) explains that there are social impacts to be considered such as the disruption caused by the flood to the life of the individual household and to the community as a whole and the effects of floods upon the health of the affected people. The impact a flood has on society depends amongst other on the vulnerability of a society or some groups of society. Hereby vulnerability is defined the degree to which some people, or classes of people, are more susceptible to, or suffer from a greater degree of harm from, some hazards than do other people or from other hazards (Messner et al., 2007). But which characteristic(s) of a household and or society determine whether people are vulnerable? One example is a marginal access to income. In a case study on the effect of tidal and flash floods in urban Bangladesh Nabiul Islam (2006) found that people with low-income (living in low-cost houses) were more vulnerable than others, as the percentage of the assets that people lost was the highest in this group. Vulnerability may have a profound influence on the impact of flooding so perhaps we should also account for it? Another consideration is resilience that is closely related to vulnerability, but looks at it from a different angle. Resilience is the ability to cope with disturbances and to persist without huge irreversible changes (de Bruijn, 2005). In general, vulnerable people will be less resilient. Whereas vulnerability demands for measures on reduction of flood risk in order to prevent floods, resilience aims at measures that prepare people on floods where preparedness includes all precautionary activities that enable society to respond rapidly and effectively to floods. In the LMB local authorities are increasingly implementing behavioural and informational measures as part of their flood mitigation strategy, but much work remains to be done (Weichselgartner, 2005).

The effects on human society and individuals can be enormous. In the Netherlands these effects are not accounted for in the flood damage assessment. The question is whether this does right to the human suffering that is accompanied with floods. Perhaps providing such considerations to the decision maker would accommodate economic valuation of floods in the LMB. The difficulty is how to valuate such effects, is there a way to express them in monetary terms.

Economic valuation of the impact of floods

The economic valuation of the direct tangible effects is already being done in the LMB using replacement valuation. However this is not always straightforward and sometimes it is difficult to obtain a clear idea of the financial damage caused: At village level, the communities do not have the tools for making this estimate. At district or provincial levels, only large objects and key infrastructure are subject to an accurate estimate when there are plans for rehabilitation or reconstruction through a tendering process (Mekong River Commission, 2006). Besides the tangible effects, how to valuated the intangibles mentioned in the previous paragraph? When looking at the options sketched in the previous section the replacement and productivity cost methodologies provide insight in the costs to reconstruct society and in the loss of production due to the flood, but cannot be used for the costing of wider social effects. However contingent or conjoint analysis may be of assistance. E.g. a survey that assesses how much respondents are willing to pay for a reduced risk of flooding would provide information on how people value flood damage. In conjoint analysis the question of payment is avoided, but insight is given in the preference of people for measures on flood risk reduction (Messner et al., 2007). Considering that yearly millions of dollars are spent in the aid industry in the LMB countries to relieve human suffering. In 2006 the gross disbursement of ODA for the Lower Mekong

Countries was US$ 3.6 billion (Organisation for Economic Co-operation and Development, 2008). Apparently, as a collective we highly value the well-being of the people in the LMB. Is there a possibility to use the valuation techniques based on what people and organizations are willing to pay to relieve human suffering elsewhere, to valuate flood damage?

The answer to this question lies with the decision maker. We already observed that there are various points of view that can be taken while assessing flood damage and the challenge now is how to present this information to the decision maker. Most flexible would be perhaps, to offer the above considerations to the various decision makers before the flood damage assessment is being done. Why not design a flood damage assessment model offering the flexibility to apply different economic valuation methods of flood damage. In such damage model decision makers may for instance:

- include or exclude wider social impact of floods with a chosen appropriate economic valuation for such effects. E.g. include an evaluation of the costs of human suffering and account for different levels of vulnerability;
- include or exclude the economic potential of a certain area. The return period of flooding and spatial planning are correlated. The decision maker could manipulate the flood damage assessment by altering land-use data and better understand the possible impact of flood management measures;
- include or exclude the possibility to include flood warning as a measure to determine its benefits. Although not much research has been done in this area (Messner et al., 2007) it could be helpful to include a damage reduction factor on flood damage (Penning-Rowsell et al., 2005). The damage reduction follows from early warning of a flood and the resulting use of prevention related measures (e.g. sandbags) and damage mitigation measures (e.g. moving valuables to the second floor);
- include or exclude the possibility to relate flood damage to the Gross National Product (GNP) of a given country. This would help to gain insight in the severity of flood damage.

With such flexibility, more stakeholders in flood management could apply their own standards and preferences. Investors in flood management, whether they are governments or banks, would be presented an overview of the various approaches to flood damage and gain better insight in the possible benefits of their public investment.

PILOT PROJECT IN 2T KOK RIVER BASIN

HKV$_{\text{CONSULTANTS}}$, ITC and the Dutch Ministry of Transport, Public Works and Water management have joined hands to determine whether HIS-SSM and its 'Standard Method' indeed has added value for the Lower Mekong River Basin. The project is called 'DACA' (Damage and Casualties Assessment). Objective of the project is to develop a damage assessment model for the 2T Kok River Basin in Thailand by adapting HIS-SSM to serve the preferences of local, regional and/ or national decision-makers. In order to do so the interface will be adapted and the database replaced (land-use and economic characteristics). The tool will be tested for three flood scenarios. The results can be used for ex-ante examination of flood risk and to evaluate the change in expected damage if measures were taken. The proposed project consists of three components:

- development of DACA: On the basis of HIS-SSM, the interface of DACA will be adjusted to serve the preferences of local, regional and/ or national decision-makers in the 2T Kok River Basin. The interface can be expanded to alter land-use (spatial planning) and to choose economic valuation method. Next the underlying land-use characteristics are gathered and imported in the damage model and damage functions and maximum damage values will be drawn up using various economic valuation techniques. Result is a

full functioning DACA for 2T Kok River Basin;

- demonstration of DACA for different flood scenarios: Aim is to determine three normative flood scenarios and assess the resulting flood damage using DACA. E.g. it would be interesting to determine the damage for an historic flood, a normative flash flood and a normative backwater flood scenario;
- dissemination of results: Whether the implementation of DACA is successful depends on the people using it. Therefore a 5-day workshop is scheduled in which possible users of DACA are invited to run and test the damage model. Besides an actual training on how to use the assessment model we will jointly develop normative flood scenarios, run DACA and test its results and conclusively investigate the possibilities of using DACA in other regions in the Lower Mekong Basin. The results will be incorporated in the final report on DACA and where necessary in the damage model itself. If the application is considered a success a final seminar will be organised in which it will be demonstrated to a larger audience.

This pilot forms the practical link between economic valuation techniques for flood damage assessment and ex-ante evaluation of measures by different decision makers. The political and economic relevance is that by using DACA decision-makers (governments, financiers or others) are enabled to evaluate themselves what risks are taken and whether they consider a measure viable on the basis of their own values and priorities. The results are expected end of 2008.

REFERENCES

Das Gupta, A., M.S. Babel and P. Ngoc, 2004. *Flood damage assessment in the Mekong Delta, Vietnam*. Proceedings of 2nd conference of Asian Pacific Association of Hydrology and Water Resources, Singapore

De Bruijn, K.M., 2005. *Resilience and flood risk management – A systems approach applied to lowland rivers*. PhD-thesis, Delft University of Technology, the Netherlands.

Herman, C., 2006. *Katrina's Economic Impact: One year later. The National Economy has rebounded but Economists tell ABC News the Gulf Region still struggles*; ABC News 25 august 2006 http://abcnews.go.com/Business/HurricaneKatrina/Story?id=2348619&page=3

Huizinga, H.J., 2007. *Flood damage functions for EU member states*. HKV Lijn in water, Lelystad, the Netherlands.

Intergovernmental Panel on Climate Change (IPCC), 2007. *Climate Change 2007 – Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change.*

Kok, M., Huizinga, H.J., Vrouwenvelder, A.C.W.M., Braak, W.E.W., van den, 2005. *Standaard methode 2005, Schade en Slachtoffers als gevolg van overstromingen*. HKV Lijn in water. , Lelystad, the Netherlands.

Kok M., E. Vermeij – van den Braak, W. Kanning, B. Kolen, B. Thonus, A. Adams –Tonk, 2007. *Twee jaar na Katrina. De catastrofale overstroming van New Orleans*. HKV Lijn in water, the Netherlands.

Kok M., M. van der Doef, 2007. *Uitgangspunten voor overstromingsscenario's in VNK2.* Ministerie van Verkeer en Waterstaat, Waterdienst.

Meyer V., Messner F., 2005. *National Flood Damage Evaluation Methods. A Review of Applied Methods in England, the Netherlands, the Czech Republic and Germany, UFZ-Diskussionspapiere 21/2005*. FloodSite Project Report.

Messner F., Penning-Rowsell E., Green C., Meyer V., Tunstall S. & Veen A. v/d, 2007. *Evaluating flood damages: Guidance and recommendations on principles and methods* FloodSite Project Report T09-06-01.

Ministerie van Verkeer en Waterstaat, RIZA 2007. *Werkwijzer OEI bij SNIP*. Sterk Consulting, HKV Lijn in Water en RebelGroup. RIZA Rapport 2007.010.

Ministerie van Verkeer en Waterstaat, 2008. *Netherlands Safety Map*. www.verkeerenwaterstaat.nl.

Mekong River Commission, 2006. *Annual Flood Report 2005.* Mekong River Commission, Vientiane, Lao PDR, 82 pp ISSN 1728 3248.

Mekong River Commission, 2007. *Annual Mekong Flood Report 2006* Mekong River Commission, Vientiane, 76 pp.

Nabiul Islam, K.M., 2005. *Flood Loss Potentials in Non-agricultural Sectors – Assessments Methods and Standard Loss Database for Bangladesh*. Forkan Ahmad. MA. Palok Publishers, Dhaka, Bangladesh

Nabiul Islam, K.M., 2006. *Impact of flood in urban Bangladesh – Micro and Macro level Analysis.* AH Development Publishing House and Community Development Library. Dhaka, Bangladesh.

Organisation for Economic Co-operation and Development (OECD), 2008. *International Development Statistics (IDS) online - Databases on aid and other resource flows.* http://www.oecd.org/dataoecd/50/17/5037721.htm

Pearce D., E. Özdemiroglu, 2002. *Economic Valuation with Stated Preference Techniques*. Summary Guide. Department for Transport, Local Government and the Regions: London.

Penning-Rowsell E., C. Johnson, S. Tunstall, S. Tapsell, J. Morris, J. Chatterton, C. Green, 2005. *The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques*. Flood Hazard Research Centre.

Ruijgrok, E.C.M, R. Brouwer, H. Verbruggen, 2004. *Waardering van Natuur, Water en Bodem in Maatschappelijke Kosten Baten Analyses. Een handreiking ter aanvulling op de leidraad OEI.* Ministerie van Landbouw, Natuur en Voedselkwaliteit, in samenwerking met de ministeries van Verkeer en Waterstaat, Economische Zaken, Financiën en VROM.

Weichselgartner, J., 2005. From the Field: Flood Disaster Mitigation in the Mekong Delta. Proceedings for the 7th European Sociological Association Conference, 'Rethinking Inequalities', Torun, Poland, 9-12 September 2005. Disaster & Social Crisis Research Network.

AUGUST 2002 AND 2005 FLOODS IN DANUBE RIVER

KIM SEANVIRAK

Mekong Institute, Khon Kae, Thailand

ABSTRACT

Flood impacts are tremendously shocking for human being in the 21st century. Learning from the lessons learned of recent floods is essential for minimising the impacts and managing risks of the floods for every member state within Greater Mekong Sub-region (GMS). This paper will review the lessons that can be learned from two 100-year floods, August 2002 and 2005 in the Danube River in Europe where its status and characteristics are quite the same as for the Mekong River.

DANUBE RIVER

Why Danube River?

The Danube River Basin is Europe's second largest river basin, with 2,780 km length and a total area of 801,463 km² (Figure 1). It is the world's most international river basin as it includes the territories of 19 countries, stretches from the West to the East and finally flows into the Black Sea. The ecosystems of the Danube River Basin are highly valuable in environmental, economic, historical and social terms.

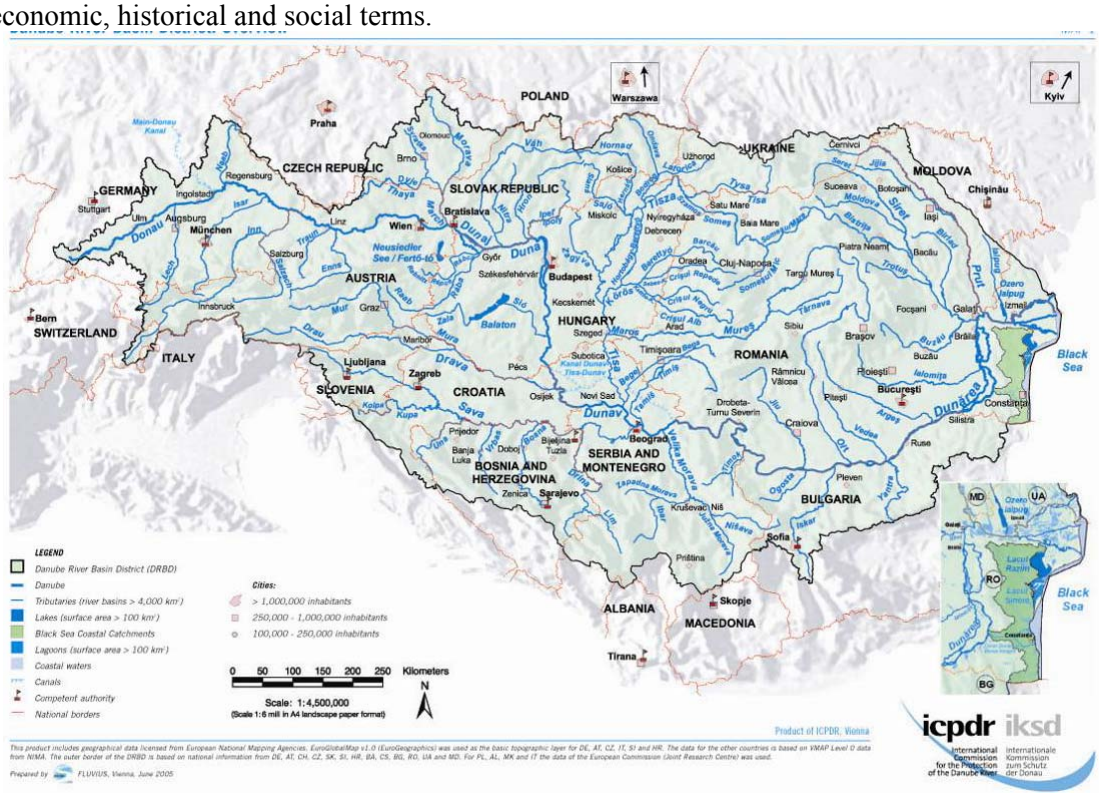


Figure 1. Danube River Basin (International Commission for the Protection of the Danube River (ICPDR))

The Danube River Basin is home to 81 million people with a wide range of cultures, languages and historical backgrounds.

Based on its gradients the Danube River Basin is divided into three sub-regions: the upper basin, the middle basin, and the lower basin (including the Danube Delta)[1]. Description of hydraulic characteristics of the Danube River is as follows. The *Upper Danube* has a rapid current of between 8 - 9 km/hour, due to the pronounced gradient of the river bed. Depths vary from 1 to 8 metres. In *Middle Danube*, it looks more like a flatbed river, with around half the speed of the Upper Danube. There the river slows down abruptly and loses its transporting capacity, leading to the deposition of enormous quantities of gravel and sand on the riverbed. The *Lower Danube* beyond the Iron Gates flows across a wide plain; the river becomes shallower and broader, with several major islands, and the current slows down considerably.

Flood phenomenon

A flood is a phenomena which occurs by two main reasons: (i) *Natural phenomenon:* natural abundance of water in response to storm rainfall, snowmelt, rainfall combines with snowmelt and (ii) *Human activities:* human interventions into the processes of nature, such as alterations in the drainage patterns due to urbanisation, agricultural practices and deforestation, development of land in the floodplain area, have considerably changed the situation in entire river basins. At the same time, exposure to risk and vulnerability in flood-prone areas has been growing constantly.

As most of mega-cities in European countries are located along rivers or coastal areas, and Danube River is a symbolic, as recent decades, navigation plays a very importation role in the trade development of the world and Europe partly, because of its effectiveness and cheapest in economic terms, therefore floods which are natural hazards that regularly occur, but become disasters when they interact with the society, especially in those highly urbanized areas (Figures 2 and 3).

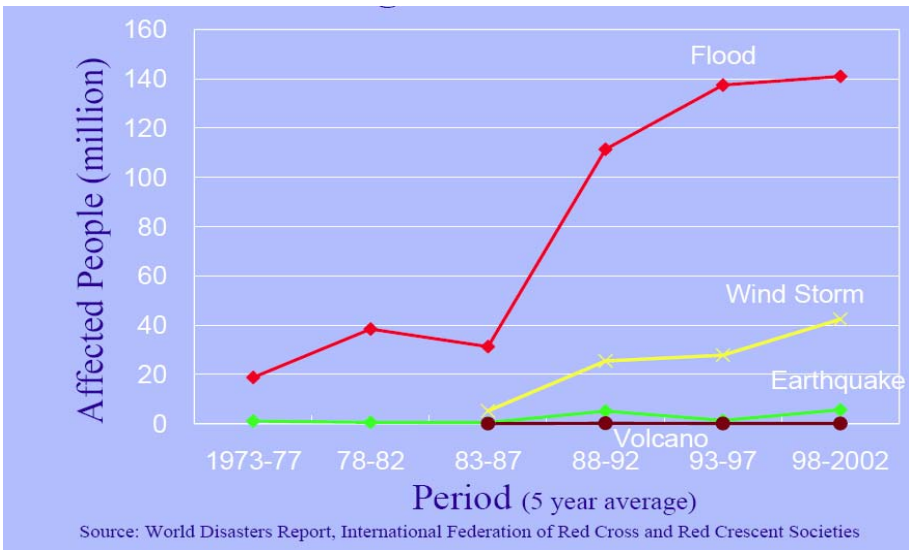


Figure 2. Icreasing natural disasters (Høst-Madsen et al.)

General information on August 2002 and 2005 floods

Spring in Europe is referred to as the rainy season, regular floods occur these period widely in European countries and the 100-year floods of August 2002 and 2005 derived from the Alps

[1] Website of International Commission for the Protection of the Danube River: *River Basin (ICPDR)* (http://www.icpdr.org/icpdr-pages/river_basin.htm accessed Jan 16, 2008)

with a wide-spread torrential week-long rainfall with precipitation amounts of 100 - 160 mm[2], in some parts even more combined with well saturated soils and snowmelt lead, to a rare flood with a return period of 100 years and more. This rare hydrological event not only caused a national catastrophe with damaged properties of historical and modern cities (Figure 4), industries, agriculture, environment, social located on its shore which cost of billions of Euros, but also endangered more than millions of people, and even killed some hundreds.

Figure 3. August 2002, Parliament of Hungary, Budapest (www.flickr.com)

Figure 4. August 2002, International City in Austria, Wien (www.flickr.com)

As floods are dangerous, life-threatening, destructive, and certainly amongst the most frequent and costly natural disasters especially 100-year floods of August 2002 and 2005 in terms of human hardship as well as economic loss, therefore, from these valuable lessons, a great effort has to be made to protect people against negative impacts of floods and enhanced capacity to exploit its beyond benefits, because floods are hazardous, but also a very important ecological factor for river ecosystems and species.

In order to achieve this objective, various regulations in land use planning (flood maps), constructive measurements (river regulations and technical constructions) as well as flood warning systems, which are not suitable to prevent big floods, but offer in-time-warnings to minimize the loss of properties and human lives.

LESSONS LEARNED

As recent 2002 and 2005 floods of Danube River provided following lessons by categorising in 3 steps of appropriate lessons learned: before, during and after flood.

[2] The August 2002 flood in Salzburg/Austria experience gains and lessons learned from the flood of the century, H. Wiesenegger, Regional Government of Salzburg, Hydrographical Service (e-mail: hans.wiesenegger@salzburg.gv.at) (http://www.cosis.net/abstracts/EAE03/12491/EAE03-J-12491.pdf accessed Jan 18, 2008)

Before flood event:

- standing as a most international river basin, future Danube flood actions depend on International and Regional Cooperation (International Commission for the Protection of the Danube River (ICPDR) stands as inter-governmental organisation for Danube countries). Danube countries agreed to strengthen their flood prevention and mitigation efforts through the ICPDR by coordinating at national level and adopted the 'Action Plan for Sustainable Flood Protection' for managing the risk of floods to human life and properties;
- a single system of water management: river basin management, the natural geographical and hydrological unit - instead of according to administrative or political boundaries, 'European Water Framework Directive', descripe all water-related aspects;
- flood forecasting and warning is a prerequisite for successful mitigation of flood damage. Its effectiveness depends on the level of preparedness and correct response. Therefore, it is necessary to develop a system for lead time and reliable flood warning, flood forecasting and information based on the relevant regional and national systems, covering the whole Danube River and integrating the tributaries;
- structural measures (defence structures: removable structures are prioritised due to the space and landscape) will remain important elements and should primarily focus on the protection of human health and safety and of valuable goods and property. Hydraulic structures should be regularly maintained in order to preserve their functionality and safety;
- flood protection is never absolute and things can go wrong. The question regularly arises as to what safety is available at what price, and how much of the remaining risk must be accepted by society. Risk management will be the appropriate method to deal with this challenge. Emergency and disaster planning in case of extraordinary situations are important, also in respect of environmental and health effects, which can occur in case of flooding of industrial sites, deposits of harmful substances, pesticides and herbicides, oil tanks and septic tanks of farms and households, etc.;
- besides public and individual measures, insurance can be an important factor in increasing the awareness and reducing the financial risk for individuals, enterprises and even whole societies where natural hazards are concerned. Proper insurance can considerably mitigate the effects that extreme events have on them and can prevent them from being ruined;
- communities live in the flood prone areas also need to know about the limits of flood protection measures and about what happens, if flood protection design values are exceeded. An integrated consortium should enable hydrologists to predict possible scenarios and impacts of floods. It is also necessary to make people, who already live in flood prone areas, aware of the dangers of floods.

During flood event:

- a specific preparedness to alert, rescue and safety measures should be planned and implemented at all levels by maintaining regular basic information and continuous ongoing training actions;
- co-ordination of rescue units (personnel in charge, policeman, solders, communities, volunteers, etc.) are also a subject to be looked at carefully;
- everyone who may suffer from the consequences of flood events should also take - if possible - his/her own precautions. To this end, appropriate information and timely and reliable flood warning and forecasting systems should be established.

After flood event:

- a strategy to mitigate floods in an ecological manner should be based on improving river

basin land use, preventing rapid runoff both in rural and urban areas, and improving a trans-national effort to restore rivers' natural floodplains. This will reactivate the ability of natural wetlands and floodplains to alleviate negative flood impacts. Besides flood mitigation, this will lead to ecological benefits in the form of maintaining biodiversity, frequent recharging underground aquifers and availability of cleaner water for drinking, areas for recreation, opportunities for tourism and so on;

- the appropriate strategy consists of three steps: retaining, storing and draining; therefore protection and restoration of infiltration areas in the upper parts of the catchments and conservation and restoration of wetlands are crucial for the water retention;
- individual constructions should be moved out of the flood-prone areas wherever possible. If this is not feasible, private property should mainly be protected with individual measures.

REFERENCES

Høst-Madsen, Jacob, M.B. Butts, C. Skotner, H. Madsen, H. Garsdal, DHI Water & Environment, Mekong River Commission-MRC website, *Lessons learned and improved technologies for real-time flood forecasting and warning* (http://www.mrcmekong.org/download/free_download/AFF-4/session3/3-Lessons_learned.pdf accessed Feb 1, 2008)

International Commission for the Protection of the Danube River (ICPDR), *Danube River Basin,* (http://www.icpdr.org/icpdr-pages/river_basin.htm accessed: Jan 16, 2008)

International Commission for the Protection of the Danube River (ICPDR), *'Flood Action Programme', Action Programme for Sustainable Flood Protection in the Danube River Basin,* (http://www.icpdr.org/icpdr-files/8115 accessed Jan 17, 2008)

Nikitina, Elena, *Flood Risk Reduction: Some lessons learned across countries* EcoPolicy, 117393 Russia, Moscow, Piluigina st. 14-1-182

United Nation Information Service-UNIS, *Future Danube Flood Actions Depend on International Cooperation*, *UNIS/INF/140* (http://www.unis.unvienna.org/unis/pressrels/2006/unisinf140.html accessed Jan 18, 2008)

Wiesenegger, H., *The August 2002 flood in Salzburg/Austria experience gains and lessons learned from the flood of the century.* Regional Government of Salzburg, Hydrographical Service (http://www.cosis.net/abstracts/EAE03/12491/EAE03-J-12491.pdf accessed Jan 18, 2008)

LESSONS LEARNED FROM APPLICATION OF NEW TECHNOLOGIES FOR FLOOD PROOFING RESIDENTIAL CLUSTERS IN THE LOWER MEKONG RIVER BASIN

MARSHALL L. SILVER[1], ROBERT BARTON[2] AND PHAM VAN LE[3]

[1]*UNDP, Hanoi, Vietnam*
[2]*USAID Office of Foreign Disaster Assistance, Bangkok, Thailand*
[3]*Department of Water Resources, An Giang Province, Vietnam*

ABSTRACT

New construction technologies were introduced and tested to reduce the vulnerability of poor coastal and inland households in the Lower Mekong River Basin to the negative impacts of annual flooding by piloting new technology for flood proofing housing, residential clusters and small-scale infrastructure in An Giang province in Vietnam.

Demonstration of enhanced flood proofing for houses, villages and infrastructure was implemented by using low cost and state-of-the-art geosynthetic materials. These geosynthetic materials were installed for construction for raised platform foundations to flood proof individual households, multi-household village clusters and small-scale public infrastructure. The geotextile was also used on foundation slopes to protect side-slopes from wave action and to allow free passage of large volumes of flood water without erosion of the foundation.

Grassroots consultation and trainings were provided for local construction workers and building authorities on how to build raised platform foundations to flood proof houses for poor commune and village level households. Additional technical training on the use of geosynthetic materials for construction of small-scale infrastructure was also provided to protect the flood lifelines of poor coastal and inland households.

INTRODUCTION

New construction technologies were introduced and tested to reduce the vulnerability of poor coastal and inland households in the Lower Mekong River Basin to the negative impacts of annual flooding. This was accomplished by piloting new technology for flood proofing housing, residential clusters and small-scale infrastructure in An Giang province in Vietnam. This pilot is in line with the Vietnam Government's strategy for disaster risk reduction in the Mekong River Delta of '*Living with Floods*'.

Demonstration of enhanced flood proofing for houses, villages and infrastructure was implemented by using low cost and state-of-the-art geotextile materials. These geotextile materials were installed for construction of raised platform foundations to flood proof individual households, multi-household village clusters and small-scale public infrastructure. These materials consisted of non-woven filter geotextile for soil separation, erosion control and soil strengthening. The geotextile was used at the ground surface to separate two different soil layers of clay and gravel to keep the homestead surfaces dry and sanitary during the flood season. The geotextile was also used on foundation slopes to protect side-slopes from wave action and to allow free passage of large volumes of flood water without erosion of embankment foundations.

Grassroots consultation and trainings was provided for local construction workers and building authorities on how to build raised platform foundations to flood proof houses for poor commune and village level households. Additional technical training on the use of geotextile materials for construction of small-scale infrastructure was also provided to protect the flood

lifelines of poor coastal and inland households.

CONSTRUCTION OF TEST EMBANKMENTS

With the objective of testing new approaches for enhancing the provincial and Mekong River Delta regional Strategy and Action Plan for disaster risk reduction, demonstration construction using new flood resistant technologies was performed in two deep flooded districts of An Giang province. The commune, district and provincial People Committees and local communities in selected communes were the key stakeholders. Prototype construction was undertaken to protect the following classes of housing and small-scale infrastructure:

- slopes of residential cluster housing in danger of slope failure due to erosion from wind induced flood waves;
- small scale platforms used to raise individual household homesteads above the design flood level;
- slopes of access roads and bridge abutments in danger of slope failure caused by erosion from wake induced waves from local boat traffic.

A schematic representation of the geotextile technologies used is given in Figure 1 showing how geotextiles can be used to build elevated platforms for flood proof homesteads using ordinary soils that exist in the Mekong River Delta. Using geotextiles, there is no need to import hard to find and expensive gravel for construction. In effect, one piece of geotextile has the effect of adding 0.3 m of gravel for strengthening the construction of flood proof homesteads and household clusters.

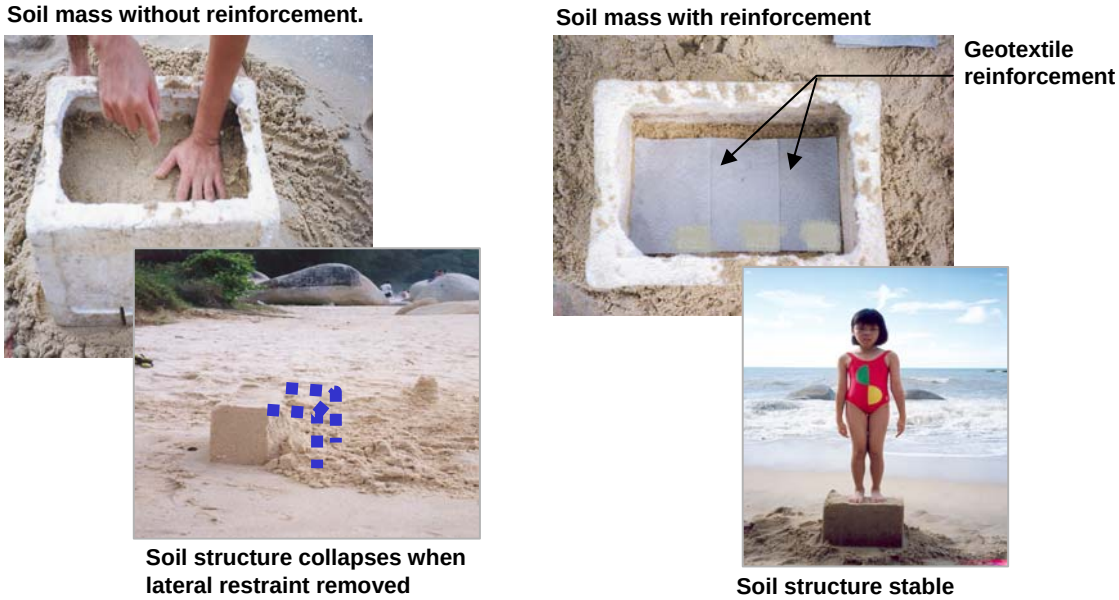


Figure 1. Schematic representation showing how geotextiles are used to strengthen soil

A second example of the use of geotextiles is shown in Figure 2 where geotextiles are used to strengthen the slopes of elevated platforms for flood proof homesteads. This slope strengthening is fundamental for the protection of side slopes from erosion from flood induced river currents and wind induced wave action. The type of damage common in An Giang province prior to the introduction of these new geotextile technologies is shown in Figure 3.

Figure 2. Example showing how geotextiles are used to strengthen the side slopes of residential clusters

Figure 3. Example showing slope failure from wave and wind erosion on the side slopes of residential clusters in An Giang Province in Vietnam

LESSONS LEARNED

Extensive post-construction evaluation was performed of the national institutional framework and provincial capacity for the design, contracting, construction, commissioning, technology transfer and sustainability of new technologies to provide safety for communities exposed to annual deep flooding in the Lower Mekong River Basin. The principal lessons learned were:

- the institutional framework between the central government, province and district must be understood and properly considered in the design of demonstration and full-scale construction projects introducing flood management technologies. The traditional top down approval process for the testing of new construction technologies at the grassroots level needs to be modified to become a cooperative learning process between the central,

provincial and local levels of government. In addition, new simplified approval mechanisms must be used to introduce new flood proofing technologies in the shortest period of time;

- competitive local bidding is not appropriate for the introduction and testing of new flood mitigation technology at the grassroots level. Construction companies are not willing to bid on construction using unknown methods. When such competitive bidding is occasionally successful, the bidding process is abnormally long and the bid prices are typically very high;
- value engineering and benefit-cost analysis must be introduced into the engineering analysis and design process for the introduction of new flood management technologies. Flood management agencies are often very conservative in their outlook and often fail to understand the importance of matching the value of the infrastructure to be protected; versus the relative cost of the flood management methods used. For example, the same costly riverbank revetment technology is often used to protect a multi-million dollar bridges; and a small cluster of some thousands of dollars worth of homesteads. The need to use a balanced approach between the value of the flood protection construction, and the value of the property being constructed is not always well understood;
- other lessons learned involve training, analysis, design, construction, implementation, commissioning, replication and sustainability of the use of new, appropriate technology solutions for flood management in the Lower Mekong River Basin.

IMPLEMENTATION OF LESSONS LEARNED

Drawing on these and other lessons learned, the following recommendations provide detailed methods for overcoming impediments in the institutional framework and capacity at all levels of government to provide cost effective flood safety for individual households and residential clusters in the Lower Mekong River Basin.

Local design and construction planning capacity is needed to provide preliminary design drawings and cost estimates for the design of test embankments and embankments for flood proofing of residential clusters. In this way, local understanding of the technologies used will promote the rapid approval of new technologies for flood management for all types of structures. Local empowerment at the lowest possible level of government is required for approval of for the testing of new flood management technologies. This all requires capacity building at the earliest stage of the project.

Full-size test sections demonstrating new flood management technologies are a fundamental requirement for capacity building. Further, these demonstration test sections should be built using unit price contracting without competitive bidding. In this way, government officials, design staffs, local constructors and the target beneficiaries are shown the feasibility and economies inherent using new construction methods. The result is to clearly show the advantages and risks associated with the new technology, with the objective of promoting champions for the introduction of the new technologies. An additional result is local construction knowledge with subsequent cost effective bidding and timely construction of prototype flood management structures.

Cost-benefit analysis must be used for justification of the use of both traditional methods and new technologies for the building flood proof structures. The relative difference in the value of protecting high cost rural infrastructure and lower cost residential clusters must be the starting point for the selection of the most appropriate flood management method.

Classroom training on new flood management technologies must be combined with the building of full size field test sections. This applies to all target beneficiaries – officials, designers, constructors and beneficiaries. Beneficiary understanding of these new flood management methods is a fundamental first step in promoting the testing and acceptance of new

flood management technologies at the most needed locations in the shortest period of time.

CONCLUSIONS

The extensive effort and long time needed to introduce new flood management technologies in the Mekong River Basin are easily underestimated. Simple one year projects can stretch into multi-year efforts waiting for understanding and approvals for the use of new flood management methods and procedures. Knowledge of simple ways to speed up the approval and construction process are a fundamental first step in making the Mekong River Basin flood proof at the lowest cost and in the shortest possible time.

A fundamental first step for the introduction of any new flood proofing technology is the use of local training and capacity building combined with the construction of full size test structures designed to compare the advantages and disadvantages of known existing technologies, with promising cost effective and time saving unknown new technologies.

ACKNOWLEDGEMENTS

This demonstration project for advanced flood preparedness in the Lower Mekong River Basin was financed by the USAID Office of Foreign Disaster Assistance through a grant to the United Nations Development Programme in Vietnam. The support of the Vietnam National Committee of Flood and Storm Control and the Department of Agriculture and Rural Development of An Giang Province is gratefully acknowledged.

FLOOD FORECASTING ACCURACY FOR THE MEKONG RIVER BASIN

WILLEM KANNING[1], SAMBO PICH[2] AND BOB PENGEL[2]

[1]*Delft University of Technology, Delft, the Netherlands*
[2]*MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC), Phnom Penh, Cambodia*

ABSTRACT

Within the Flood Management and Mitigation Program (FMMP) of the Mekong River Commission (MRC), flood forecasting is one of the core activities. Up to now, the forecasts are being made with a Streamflow Synthesis and River Routing (SSARR) model and with regression models. At this moment new model are being developed, based on a combination of URBS and Deltares' Flood Early Warning System (FEWS) with, amongst others, the objective of producing more reliable and more accurate output.

In this paper the flood forecast accuracy and reliability of the current model is investigated and key parameters of the new system are examined. Herein, accuracy is defined as the deviation of a forecast from the observed value and reliability is defined as the number of forecasts that were actually disseminated compared to the number that should have been disseminated. The analysis of the 2006 and 2007 forecasts shows clearly that the longer the lead time, the lower the accuracy and the more upstream the forecast location, the lower the accuracy. The forecast reliability analysis shows an average failure percentage of about 20%. For the accuracy of the new models, the following key two parameters can be distinguished: Satellite Rainfall Estimates (SRE) inputs and ratings. The SRE are compared to ground data and it appears that the predicted depth is comparable, although there appears to be significant spatial/temporal variation. The ratings show uncertainty of up to several hundreds of millimetres.

It can be concluded that there will always remain uncertainty in the forecast, mainly because of input uncertainty, but that this uncertainty is probably less with the new model system. The seriousness of the uncertainties in the input data is also related to the way the basin is modelled: as the objective at the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) is producing forecasts for the Mekong mainstream, the error in the SRE appears to be acceptable as the preliminary results of the new Flood Forecasting System (FFS) show promising results. The forecast reliability is expected to increase because the new system is less dependent on missing data points.

INTRODUCTION

Flood forecasting at the MRC Regional Flood Management and Mitigation Centre

Within the Flood Management and Mitigation Program (FMMP) of the Mekong River Commission (MRC), flood forecasting is one of the core activities. Up to now, the forecasts are being made with a Streamflow Synthesis and River Routing (SSARR) model and with regression models (Kanning, 2007a, b). At this moment new models are being developed, based on a combination of URBS and Deltares' Flood Early Warning System (FEWS) with, amongst others, the goal of producing more reliable and more accurate output.

Accuracy and reliability

In this paper the flood forecast accuracy and reliability of the current model is investigated and key parameters of the new system are examined. Herein, accuracy is defined as the deviation of a forecast from the observed value and reliability is defined and the number of forecasts that were actually disseminated compared to the number that should have been disseminated. The accuracy is in this study assessed by determining the mean error, the standard deviation and the upper and lower bounds.

General uncertainties in flood forecasting

In general, there are some main reasons for flood forecast inaccuracy. These involve systems failure (i.e. computer crashes), uncertain data, missing data, imperfect models etcetera. It is inherent to the hydrological approach that there will always remain some uncertainty because models are a representation of reality. Input data are also only a representation of the real world; a 24 hour cumulative rainfall figure will show considerable variability within one km^2, while it is routinely used to represent catchments of several thousands of km^2, even when disregarding the measurement error, which can easily be several percent. It should be stressed that even with a perfect model the quality of the data will still limit the accuracy of the forecast. It is essential to realize this inherent uncertainty when judging a forecast. As an example: in the Netherlands, it is communicated that the uncertainty in the one day river level forecast for the River Rhine and its branches is 0.1 m, in the two day forecast 0.15 m and in the three day forecast 0.2 m. For longer lead times it is only communicated whether the level will go up or down (MTPWWM, 2007)

FORECAST ACCURACY AND RELIABILITY OF THE CURRENT SYSTEM

The accuracy and reliability of the current flood forecasting system (FFS) is determined by analysing the 2006 and 2007 forecast and assessing the incidents of no forecast, the forecast accuracy with respect to lead time and location, and the forecaster adjustment. The analysis is done for all the mainstream stations. The time-series of the forecast and the observed water level is shown in Figure 1.The apparent time lag in the forecast and the gaps due to incidents of no forecast are clear.

Incidents of no forecast

An incident of 'no forecast' is a day when a forecast should have been issued for one location but this could not be done. The number of 'no forecasts' is a measure for the reliability of the system. For the 2006 and 2007 season, which lasted 153 days, forecasts should have been made for the 21 mainstream stations; hence 3212 forecast should have been made, see Table 1.

Table 1. Incidents of no forecast

	2006	2007
Needed forecasts	3,213	3,213
Incidents of no forecast	550	708
Failure percentage	17%	22%

For 2007, the relatively high failure percentage can be explained by the fact that the data delivery process was not fully operational in the beginning of the flood season. The main reason for incidents of no forecast is missing data.

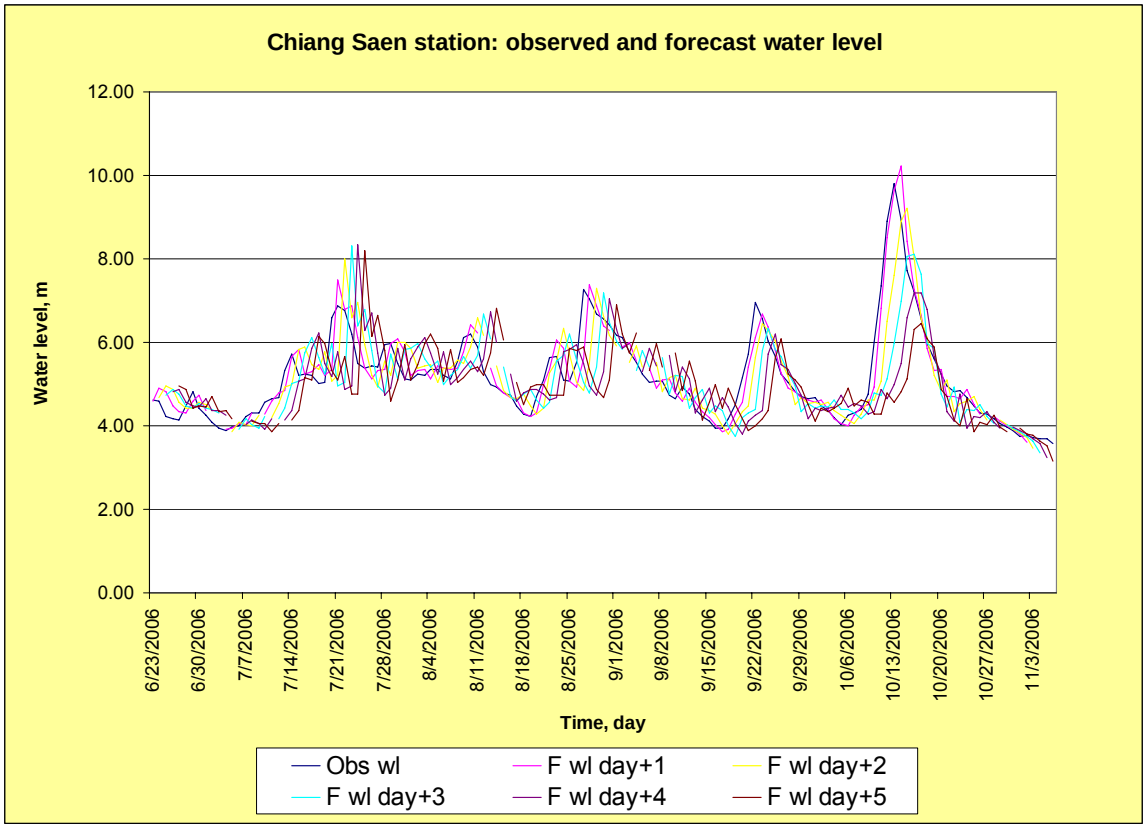


Figure 1. Observed and forecast water level in Chiang Saen

Forecast accuracy – lead time

The forecast accuracy is determined by deriving the difference between the 1 to 5 day forecast and the observed water level. In case the difference is positive, the forecast was higher than the observed level, in case the difference is negative; the forecast was lower than the observed level. The 2006 and 2007 flood seasons were analysed for all 21 mainstream stations. For every station, the 1 to 5 day lead times were analysed. Several statistics are derived. Figure 2 shows a histogram of the forecast error for Kratie station with a 1 day lead time, while Figure 3 shows the error histogram with a five day lead time. These histograms are derived by dividing the error in different classes, hence the number of forecast error that lies between 0 and 0.2 m, between 0.2 and 0.4 etcetera. It can clearly be seen that the error of the 1 day forecast concentrates around 0, while the 5 day forecast error is much more spread.

The spread in the forecast error can be characterized by its mean, standard deviation and minimum and maximum. The mean of the error is the bias in the forecast. A positive mean value means that on average the forecast is overestimating the water level. The standard deviation is a measure of spread. In case the error follows a Gaussian distribution, approximately 70% of the forecasts should lie within the mean plus or minus one standard deviation. The minimum and maximum errors give a less representative measure of spread since these are usually extreme outliers. The results of the forecast error for Kratie are plotted in Figure 4. It can clearly be shown that the longer the lead time, the higher the error. Both mean and standard deviation increase for longer lead times. This can be explained by the input uncertainties (which become more uncertain for longer lead times) and by model imperfections.

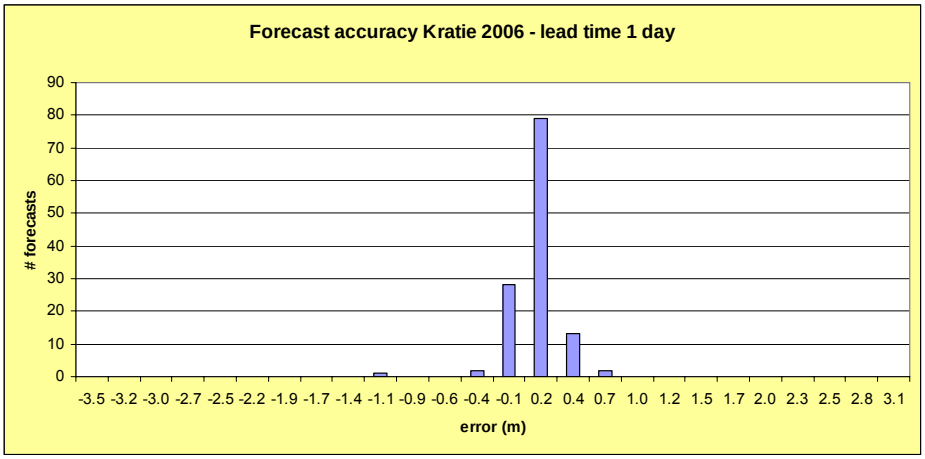


Figure 2. Forecast accuracy Kratie with 1 day lead time

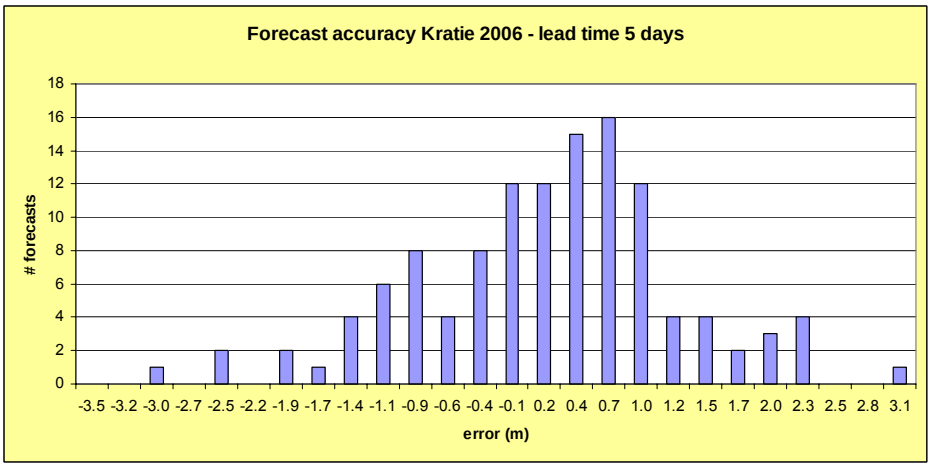


Figure 3. Forecast accuracy Kratie with 5 days lead time

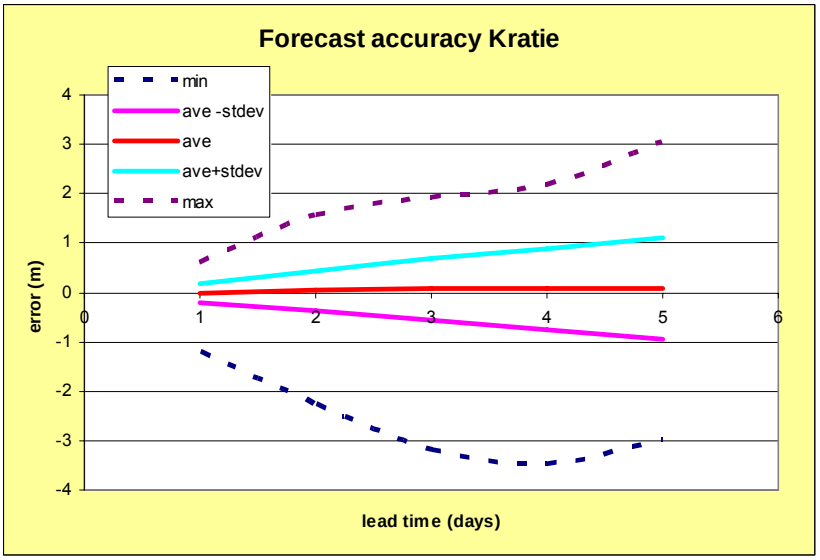


Figure 4. Forecast accuracy Kratie

Forecast accuracy – location

The forecast accuracy of the whole system can be shown by plotting the bias (mean error) and the standard situation for all mainstream stations. For both 2006 and 2007, it can clearly be seen that further downstream the forecast becomes more accurate as both bias and standard deviation decrease. This can be explained by the fact that upstream the contribution from (uncertain) tributaries to the total mainstream flow is relatively large. More downstream the flood propagation component, which is relatively easy modelled, dominates.

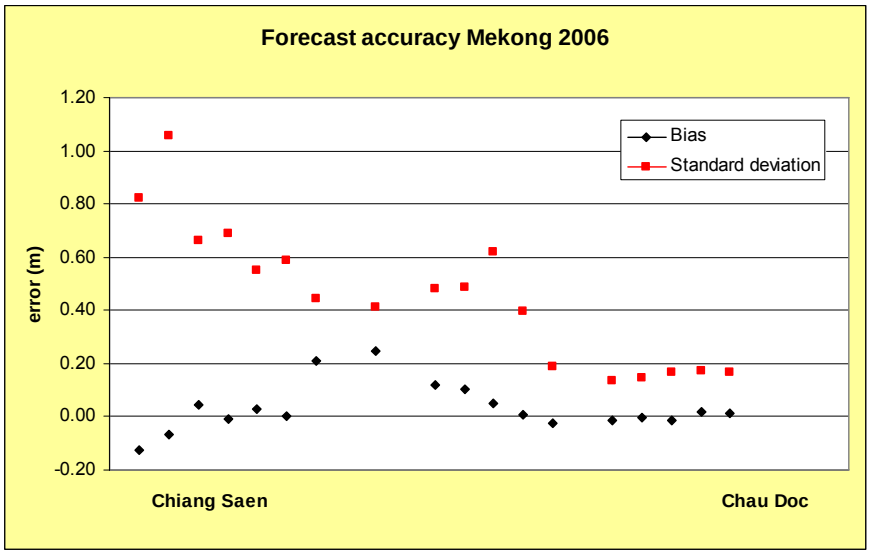


Figure 5. Forecast accuracy Mekong river basin 2006, average 1-5 days lead time

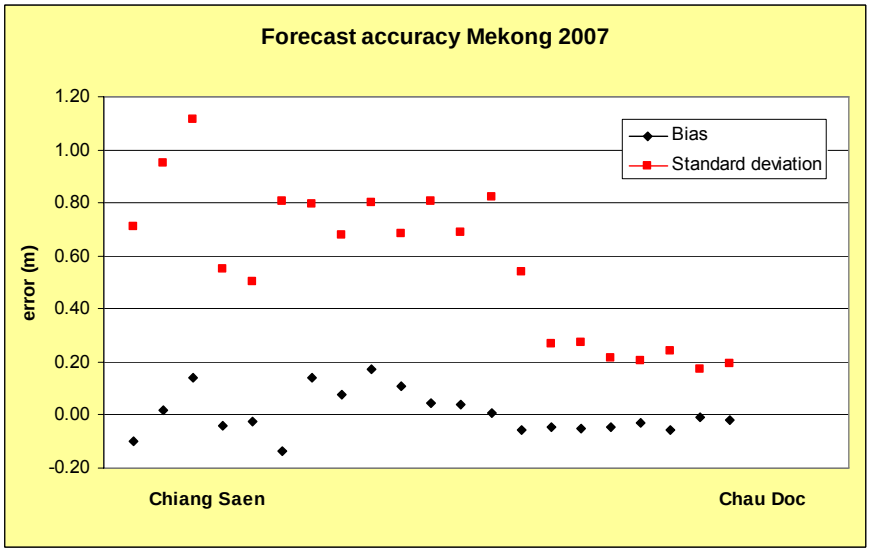


Figure 6. Forecast accuracy Mekong river basin 2007, average 1-5 days lead time

Forecaster adjustment

In the current system, the flood forecast model results are analysed by the flood forecaster in charge, who may change the forecast values based on his knowledge of the system. It can be observed in the data that these forecaster adjustment improves the forecast, though only slightly, see Figure 7.

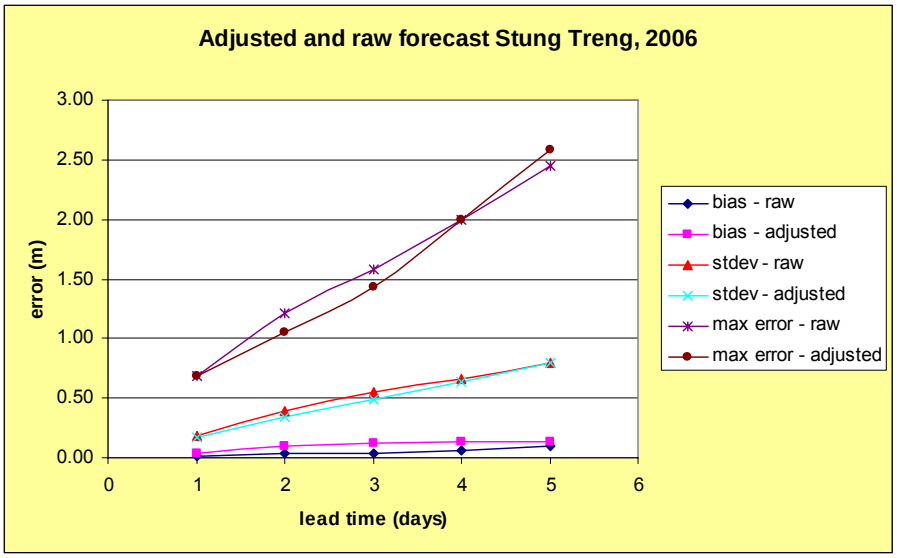


Figure 7. Forecaster adjustment

Causes of forecast inaccuracy and unreliability

The unreliability of the system can be explained by the sensitivity of the model for data input in combination with an unreliable data supply. The SSARR model cannot produce a forecast in case of missing data. The inaccuracy of the current forecast can be explained by the following:

- It is a lumped, low resolution model with only 10 basins for rainfall input;
- There is no parameter interaction and no model support, and adjustment of ratings has not taken place recently due to a lack of knowledge of the model system

FORECAST ACCURACY AND RELIABILITY FUTURE SYSTEM

New flood forecasting system

At this moment a new system is being developed, based on a combination of URBS and Deltares Flood Early Warning System (FEWS) with, amongst others, the objective of producing more reliable and more accurate output. The calculation core is formed by URBS, while the data management is performed by FEWS. The model requires input data (mainly water levels, SRE and National Weather Prediction Model (NWP). The model is calibrated on historical observation, using ratings and other model parameters. The output will be amongst others flood forecasts, which will be interpreted in the operational situation (see Figure 8).

As of April 2008, the model is not yet fully operational. Hence, it is not yet possible to assess the accuracy of the new system. Nonetheless, it is possible to investigate some of the input and model parameters to get insight into the functioning of the new system:

- Precipitation (SRE accuracy, NWP accuracy);
- Model parameters (ratings, other).

Both URBS and FEWS have error correction modules, which can improve the accuracy of the forecast considerably by taking into account the actual recorded water levels and adjusting the bias of the model output in a systematic manner.

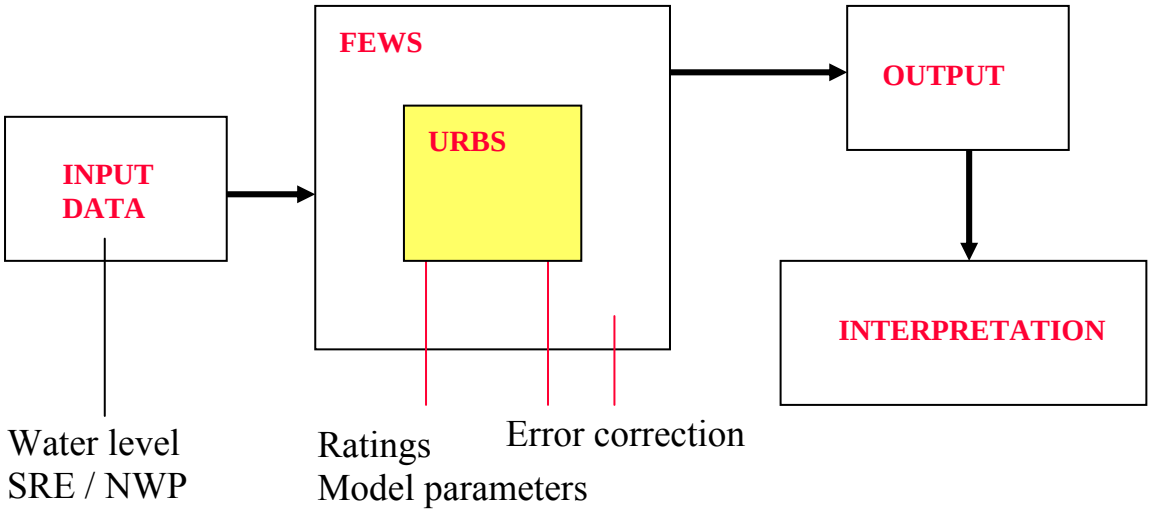


Figure 8. Schematic outlook new flood forecasting system

SRE accuracy

The Satellite Rainfall Estimate is a key input parameter in the forecast model. The SRE is obtained from NOAA, and is derived from satellite observations of cloud top temperature. Bias is minimized by using (a limited number of) ground observations available through the World Meteorological Organisation Global Transmission Network (GTS). It is resampled and filtered and then used in the model as a grid of 824 virtual rain stations, one for each 0.375 degree square grid cell within and close to the Mekong Basin. As there are only a few ground stations reported through the GTS, there is considerable uncertainty in the SRE. In this study, the SRE is compared to 42 ground stations for which data series are available for 2006. It is a rather limited amount of ground truth (GT), but this is the only overlap since the GT is only complete up to 2005 and the SRE are only available from 2006. The 42 GT stations are shown in Figure 9. The GT is compared to the virtual SRE stations by comparing the rainfall of the GT with the distance weighted average of the 2, 4 and 8 nearest virtual SRE stations (using the SUBRAIN routine of URBS). For each station, the cumulative rainfall can be compared, see Figure 10.

When analysing the result, the SRE 'observes' on average more rainfall days than the GT (196 to 113); this is probably due to the fact that a relatively large area is considered in calculating the representative point rainfall (3200, 6400 or 12800 km^2). The total annual volume is on average quite well represented, but there is significant spatial/temporal variation. Figure 11 shows the annual rainfall of the GT and of the SRE and the bias. Although the bias is small on average, the figure shows quite some variation.

NWP accuracy

The Rainfall forecast is also input in the model. The forecast is made with the Numerical Weather Model (NWP) from NOAA. It must be noted there is currently a two day time lag in the process, thus yesterday's and today's observed rainfall is actually the 1 and 2 day NWP forecast. An example of the NWP forecast compared to the observed SRE is shown in Figure 12.

The NWP forecasts are compared to the SRE for the 10 basins that are used in the SSARR model. These basins are large, thus the analysis does not fully represent the spatial and temporal variation. The analyses shows that on average the volumes are right, but the variation is high. A small trend can be detected: the longer the lead time, the higher the uncertainty, but this is not really significant (Figure 13).

Figure 9. Ground truth stations

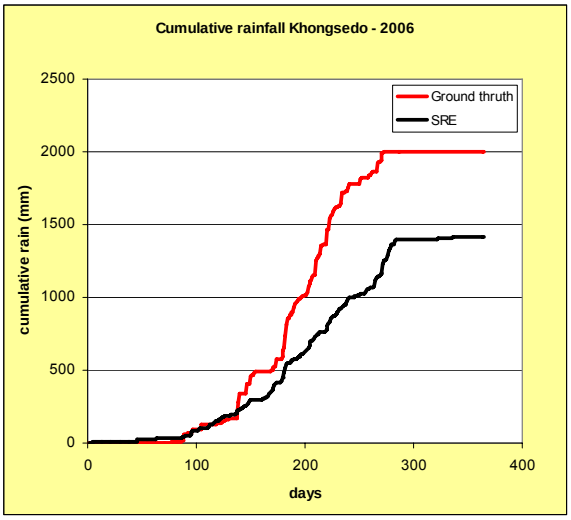


Figure 10. Cumulative rainfall Khong Sedone station

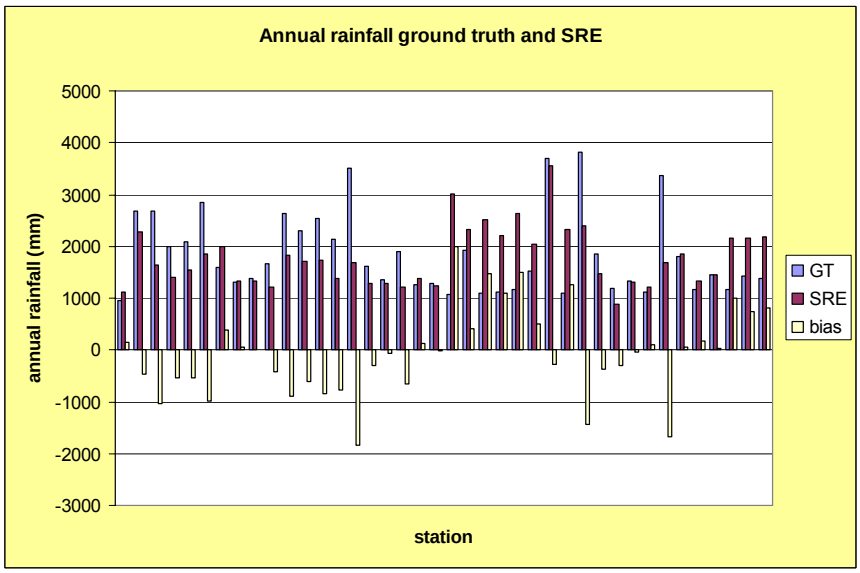
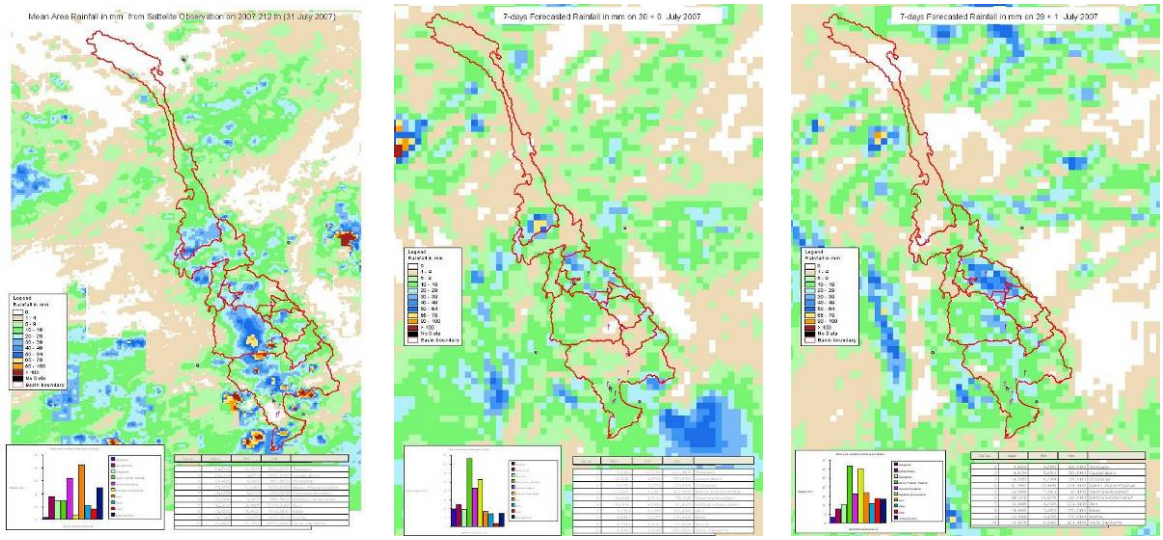


Figure 11. Comparison annual rainfall between GT and SRE

Ratings

The rating curves or ratings define the relation between the discharge and the water level. There is quite some uncertainty in the Mekong ratings, see Figure 14. This may be due to measurement errors, changing morphology, and infrastructure or gauge zero changes (Figure 15).



SRE observed NWP Forecast + 1 NWP Forecast +2

Figure 12. NWP forecasts compared to SRE

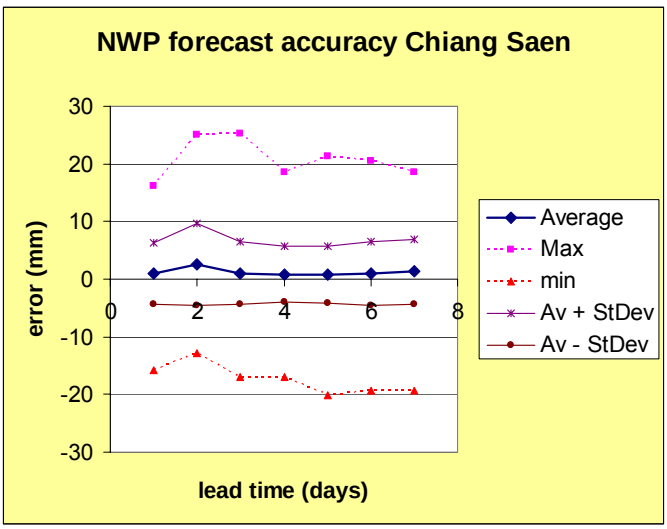


Figure 13. NWP forecast accuracy at Chiang Saen

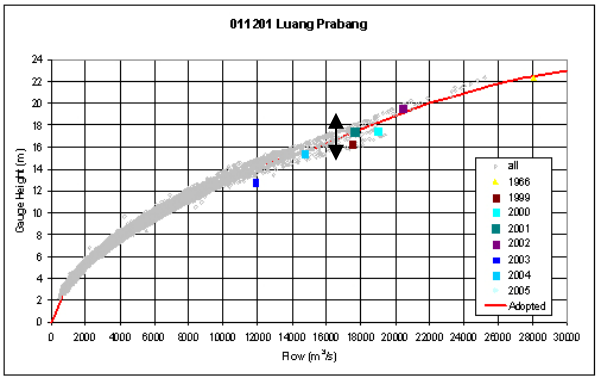


Figure 14. Rating curve Luang Prabang

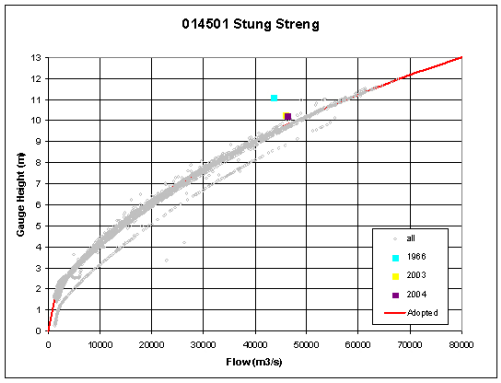


Figure 15. Gauge zero change?

The uncertainty in the ratings is also quantified. Figure 16 shows the uncertainty in the Nong Khai rating curve. It shows that the uncertainty in the rating curve can be up to several 100s of millimetres. Fortunately the ratings are fairly flat, thus reducing the uncertainty in the

peak discharges (an error in discharge forecast only results in a relatively small error in water level forecast).

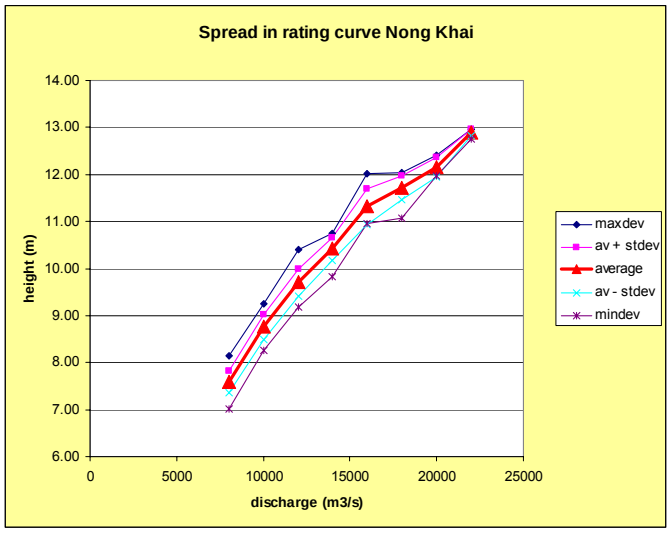


Figure 16. Rating uncertainty

The URBS model propagates discharges which are finally converted into water level predictions (input water levels are also converted to discharges). Hence, errors in the ratings are immediately converted into errors in the forecast (the error correction will not help), emphasizing the importance of the rating.

Expected improvements with the new system

The new system is less vulnerable for missing data, hence the incidents of no forecast should decrease and thus the reliability increase. Furthermore, the inputs are better used in the new system, it can (and should when appropriate) be adapted in real-time operations which should increase the accuracy of the forecast. The error correction in both URBS and FEWS should also increase accuracy. Nonetheless, the inputs could be improved and there will always remain a certain amount of uncertainty in the forecast, depending on lead time and the forecast location on the river.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The forecast inaccuracy of the present system can be significant and strongly depends on lead time and forecast location, while the reliability (expressed in incidents of no forecast) is also considerable. Although the new system is not yet operational, it can be concluded that the SRE inputs are in general fairly good, but that there is high spatial and temporal variation. The other main parameter in the new system, the ratings, can contribute to considerable uncertainties in the water level forecast, up to hundreds of millimetres.

It can be concluded that there will always remain uncertainty in the forecast, mainly because of input uncertainty, but that this uncertainty is probably less with the new model system. It must be stressed that the data quality and availability highly influences the forecast. The seriousness of the uncertainties in the input data is also related to the way the basin is modelled: as the objective at the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) is producing forecasts for the Mekong mainstream, the error in the SRE appears to be acceptable as the preliminary results of the new Flood Forecasting System (FFS)

show promising results. The forecast reliability is expected to increase because the new system is less dependent on missing data points.

Recommendations

It is recommended to perform an accuracy analysis on a regular basis (automated, weekly or monthly) and after each flood season, and publish the result. After the new system is implemented, it is recommended to do a hindcasts of the full 2006 and/or 2007 flood season to show the capabilities and possibly weaknesses of the new system. The data quality and availability is very important. It is therefore recommended to constantly improve data quality (rainfall, ratings). One example is to extend the comparison of SRE with GT when more data is available. Together, this contributes to a continuous updating of the model and system.

REFERENCES

Kanning, W., 2007a. *Flood Forecasting Manual*. MRC-RFMMC mission report August 2007.

Kanning, W., 2007b. *Operational Procedures for Flood Forecasting and Flood Products Dissemination*. MRC-RFMMC mission report August 2007.

MTPWWM –Ministry of Transportation, Public Works and Water Management, the Netherlands (2007). *Hoogwater op de Rijn en Maas* (in Dutch, High water levels on the rivers Rhine and Meuse). www.rijkswaterstaat.nl/rws/riza/home/publicaties/brochures/hoogwater_rijn_maas.pdf

THE ROLE OF GOVERNMENT IN FLOOD MANAGEMENT AND THE LESSONS FROM HURRICANE KATRINA

J. LIGH AND M. SCHNABEL

Army Corps of Engineers, USA

ABSTRACT

The impact of Hurricane Katrina has changed the way we view the Government's role and the way we communicate risks. The Interagency Performance Evaluation Task Force (IPET) formed to provide a technical evaluation concluded:

- the flood management system of protection did not perform as a system;
- there were four design failures, all other breaches were caused by overtopping/erosion;
- 80% of New Orleans was flooded, some areas 15 ft in depth;
- risk assessment provides a new and more comprehensive method to understand the inherent vulnerabilities of flood management systems.

Hurricane Katrina showed the need to be able to communicate risk information. Federal, State and local governments together with the private sector need to develop risk informed decisions. The responsibility for managing flood risks (in the USA) is shared across Federal, state and local governments. Land use choices lie with private owners and building code requirements are entirely determined and enforced by state and local governments. Choices made at the state and local levels directly impact the effectiveness of Federal programs and Federal programs and infrastructures impact local choices. It is critical that strategies at all levels (Government and private) are risk informed, integrated, and eliminates conflict:

In communicating:

- how do you quantify 'better and stronger' especially on a systems-wide perspective?
- how do you compare plans to develop the best level of protection?
- what are the residual risks and what are the best choices to manage the consequences?
- how do we become sensitive to costs?
- how are we reducing risk?

The US Army Corps of Engineers has developed initiatives and risk models in improving and using flood risk information from the lessons learned for Hurricane Katrina.

FLOOD FORECASTING FOR BEST MANAGEMENT OF FLOODPLAINS

KUNIYOSHI TAKEUCHI

International Centre for Water Hazard and Risk Management (ICHARM), under the auspices of UNESCO, Public Works Research Institute (PWRI), Tsukuba, Ibaraki, Japan

ABSTRACT

A concept of new-generation living with floods has to be developed and to replace the current floodplain management in populated floodplains where people are no longer living on direct benefits of floods. In order to sustain the benefits of floods and floodplains, it is necessary to introduce a principle of best use of a basin supported by advanced flood forecasting technology using both satellites and ground based observations. Such forecasting system should be owned and operated by local people with a good sense of local ownership of hydro-meteorological models and data.

INTRODUCTION

All civilizations started along big rivers utilizing the benefits of floods as resources for agriculture. Farmers in floodplains have long been living with floods. Once urbanization started, however, urban people do not live on flood dependent agriculture and floods became hazards rather than benefits. Urban dwelling is now dominant even in deep rural communities all over the world and a new-generation living with floods has to be introduced.

In the new-generation living with floods, the important principle is the best use of a basin which tries to maximize the benefits of floods and floodplains while internalizing the cost of disaster risk management. In order to maximize the benefits, the advanced technology in various aspects of basin water management is indispensable. Especially, early warning and community preparedness supported by advanced observation, forecasting, hazard mapping, communication etc. are the key.

In order to use the advanced hydro-meteorological models for early warning in local communities, the quality input of ground truth observation of hydro-meteorological data is indispensable as remote sensing data such as of satellites cannot yet replace them. The ground truth data collected by the local communities are very important and valuable for better management of their floodplain.

This paper presents needs and methods of establishing a new-generation living with floods supported by a flood forecasting system with a good sense of local ownership.

NEW-GENERATION LIVING WITH FLOODS

A principle of best use of a basin

A new-generation living with floods is a concept based on the principle of best use of a basin for all human activities, farmland, urban residence, industries, parks, forests, pastures, etc. Whatever the objective of floodplain use is, its flood management cost including inevitable flood damage losses has to be counted and internalized into its overall benefit counting. Although the clear economic assessment of alternatives is a difficult matter especially with multiple objectives and a question of time horizons to be assessed is involved, the assessment process will clearly reveal the advantages and disadvantages of locating some activities in

floodplains or flood free portions of the basin. This severe comparison and selection process will theoretically lead to the best use of a basin.

In most of the cases, the disaster prevention cost of land use has been treated separately from the land use benefits and are not included as part of necessary cost. In other words, natural disaster risk management cost is typically not considered as a responsibility of private enterprise but as that of the public as a whole. It has been considered reasonable as its cost is large and the private enterprise cannot usually bear. Also the cost bearers and the benefit receivers are not necessarily identical. But such a system is no longer acceptable under the principle of best use of a basin in a new-generation living with floods. Tables 1 and 2 summarize the concepts of a new-generation living with floods and principle of best use of a basin.

Table 1. Components of new-generation 'Living with Floods'

1.	Keep traditional flood benefits maintained in sustainable manner in compatible with urban development as long as there are people who live in traditional agriculture.
2.	Design new urban settlements in the way to best utilize a basin by internalizing the costs of disaster risk management with the benefits of use of floodplain.
3.	Best utilize floodplain with the most advanced hydro-meteorological forecasting technology.

Table 2. Related components of the principle of best use of a basin

1.	Restructuring land use, habitation/activities and infrastructure development by fully internalizing disaster prevention cost with land use benefit.
2.	Establish an institutional framework to assure the internalization.
3.	Strict socio-economic/environmental assessment of alternative plans to select the better.
4.	New land development rule based on beneficiaries payment principle (BPP).
5.	Institutional guidance to social refugees who illegally occupy high disaster risk lands.
6.	Disaster prevention is not a humanitarian issue but a development issue.
7.	It needs much money and time. Disaster management is not a matter of a single generation but over many generations.

Early warning system for the people

The objective of flood forecasting is to better manage floodplains by avoiding flood losses and maximizing the productivity of floodplains. Obviously it is crucial to protect human lives, properties and livelihood in urbanized areas by providing accurate flood forecasts for effective dam control, levee protection, preparation for evacuation, sheltering and other emergency supports against flash foods, continental floods, waterlogging, etc. Much attention has been paid to this direction and is further progressing.

At the same time, it is also important and of high value to provide flood forecasts for farmers who depend on flooding water for their rice paddy irrigation as typically exercised in the Mekong, Irrawaddy, Ganges-Brahmaputra, etc. Flood forecasts are especially useful there for preparation of ploughing, scheduling planting, weeding, harvesting, transporting and any other practices of rice paddy agriculture. Such farming exercises are not an underdeveloped style of agriculture but rather an example of low energy consumptive ecological one. If properly managed with the advanced flood forecasting, it can remain as an efficient way of living with nature. The urban development should be planned not to destruct this effective use of floodplains.

LOCAL OWNERSHIP OF FLOOD FORECASTS

Trustable flood forecasts and the people's trust on them are essential to an effective early

warning system in any localities. The system has to utilize the most advanced observation technologies such as satellites, radars and tele-metered ground measurements; simulation models for hydrological and hydraulic forecasting; and the latest communication devices such as Google Earth and cell phones. In order for flood forecasts to be reliable and useful, it is necessary for the forecasting system to satisfy the following conditions listed in Table 3.

Table 3. Basic conditions necessary for good flood forecasts

1.	Provided by a reliable source.
2.	Have a decent accuracy (no wolf boy).
3.	Provided with an enough lead time with frequent updates.
4.	Provided by popular channels (TV, radio, cell phones) in a user friendly manner with an absolute clarity (such as on Google earth).
5.	Provided with necessary instructions for responding actions.

In order to make flood forecasts reliable, the best available technology such as models, data observation and processing has to be utilized. Besides, the forecasters themselves have to understand models, data and the local hydro-meteorological conditions. The good command of models with the best available data is essential. A sense of ownership of forecasts can only be created through the ownership of hydro-meteorological models and data by local forecasters. Table 4 summarizes conditions of establishing local ownership of forecasts.

.

Table 4. How to establish the local ownership of flood forecasts?

1.	By local forecasters themselves understanding the models in use, the best available data and the local hydro-meteorological conditions.
2.	By using data and models by themselves.
3.	By feeling the accuracy of forecasts by themselves.

The traditional flow of ground observation data has been predominantly from developing countries to developed countries. This is mainly because the data users such as modellers and model users are mostly in developed countries rather than in developing countries. Such a flow has, however, been proven never efficient for necessary data use. As a result, modellers and model users face serious lack of data leading to regretful underuse of advanced sciences. ICHARM tries to resolve such problem by providing models with training to data owners rather than asking them to provide data. By letting them use models with their own data, data flow from developing countries to developed countries is stopped. At the same time, it promotes ownership of models, data and their model results, i.e., flood forecasts in this case. The local early warning system will then improve from the bottom. The ownership of hydro-meteorological data by local people is the key to good floodplain management.

CONCLUDING REMARKS

In a new-generation living with floods, the role of local people is increasingly important. The land safety is increasingly difficult to be provided by central or provincial governments using tax money but the local people have to take responsibility to judge where to live and how to live in floodplain internalizing the benefit and cost of living in a site. It is a difficult question to any individual. Therefore the local community is obliged to provide the most reliable forecasts to the public with an enough lead time in a user friendly manner. Under the current advancement of observation technology and forecasting model sciences, it is indeed possible but only with a good sense of local ownership of hydro-meteorological models and data. This requires a change of traditional flow pattern of data, from developing countries to developed countries. In a symbolic term, it is flood forecasts of the people, by the people, for the people.

SUMMARY OF PROCEEDINGS AND RECOMMENDATIONS FOR FOLLOW-UP OF THE 6TH ANNUAL MEKONG FLOOD FORUM (AMFF-6)

BART SCHULTZ

UNESCO-IHE, Delft, the Netherlands and Rijkswaterstaat, Utrecht, the Netherlands

INTRODUCTION

Flood management and mitigation is of increasing concern for the authorities and citizens of many countries with flood prone areas. Flood vulnerability is generally increasing due to the population growth and the increasing value of public and private property in such areas, as well as due to land subsidence and impacts of climate change. The MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) of the Mekong River Commission (MRC) and the MRC Member Countries - Cambodia, Lao PDR, Thailand and Viet Nam – are putting major efforts in modernising and improving their flood forecasting systems and approaches. For the MRC Member Countries this also concerns the early warning approaches and products.

In light of these developments in the Mekong River Basin (MRB), during the preparation of the 6th Annual Mekong Flood Forum (AMFF-6) there was a commonly felt need to select as a theme for the Forum *Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin*. Stakeholders from the MRC Member Countries, MRC Dialogue Partners (China and Myanmar), donor agencies, MRC Programmes, scientists from the MRB and the international community, international and national civil society organisations, and local communities were expected to join the Forum, as it has become a common practice. In order to enable a proper presentation and discussion of the various relevant aspects under the theme, it was decided to focus on four topics:

I. new developments with respect to flood forecasting and early warning;
II. land use based requirements for flood forecasting and early warning systems;
III. costs and benefits of flood forecasting and early warning;
IV. lessons learned from past flood events.

Topic I would focus on the methods and means to obtain the required information to enable short-term and medium-term (6 - 10 days) flood forecasting and early warning in the MRB. These forecasts need to be based on up to date technology for data collection, processing, retrieval and subsequent river modelling, with an emphasis on flood forecasting, related to the risks in the flood prone areas. With respect to this a wide range of new developments may be observed regarding weather models, remote sensing techniques, global positioning systems, geographic information systems, automation in data collection, transmission, storage and retrieval, etc. The applicability of new developments for the interrelated database and flood forecasting systems in the conditions of the MRB were an important element of Topic I.

Related to differences in land use and the on-going changes in it, there are different requirements to flood forecasting and early warning. For densely populated areas early warning is of utmost importance. On the other hand, for the recession agriculture and fisheries in the Tonle Sap Great Lake area and the Cambodian floodplain a seasonal forecast of the expected flood is more relevant. The responsible agencies in the MRC Member Countries are in charge of the early warning and the organisation of the flood preparedness measures. This requires an effective interaction between the MRC-RFMMC and the concerned agencies, as well as with international organisations (IO) and civil society organisations (CSO). In addition there is the requirement of the issuing of flood forecasts to land and property owners, organisations in

charge of public facilities and infrastructure provisions in the areas that potentially may suffer from a flooding. The requirements that the different types of land use and different types of measures pose to the flood forecasting systems for the conditions of the MRB would be important aspects of Topic II.

Flood forecasting and early warning is provided for more than 30 years in the MRC Member Countries. Systems have been and are being improved and more people are aware of the systems. There is, however, limited insight in the extent to which flood forecasting and early warning may reduce victims and/or damage due to a flooding. The perception is, however, that this is undoubtedly the case. Analyses under different conditions in flood prone areas may give insight in the various relations and interactions. Based on relevant indicators justification can generally be found for the investments in the development, operation and maintenance of flood forecasting and early warning systems. Therefore the focus of Topic III would be on to what extent flood forecasting and early warning have resulted, or can result in information that has enabled, or will enable institutions or individuals to take the best possible measures to reduce damage and number of victims.

The MRC Member Countries, Dialogue Partners, IOs, CSOs and individuals have obtained an impressive treasure trove of experiences from past flood events. These experiences may concern the hydraulic behaviour of rivers under extreme conditions, the effectiveness of flood forecasting and early warning, the effectiveness of communication and measures taken during the event of a flood, and the measures to be taken to reduce at least the risk of flooding in future. For Topic IV the focus would be on the lessons learned in the broad sense in the various river basins of the world.

This has resulted in a set up of the programme along the following main lines:

- presentation of a summary of the 5th Forum (AMFF-5) on the theme *Improving Inputs towards medium-term flood forecasting and warning in the Mekong River Basin* and of the set-up and expectations with respect to the 6th Forum;
- presentations on *Lessons learned from 2007 floods and flooding and National and MRC-RFMMC flood forecasting and early warning experiences* by the MRC Member Countries and Dialogue Partners, as well as by the MRC-RFMMC;
- presentations by staff and consultants of MRC-RFMMC on the new approach *Towards an improved medium-term flood forecasting and early warning.* With respect to this it is of importance that the MRC-RFMMC takes care for flood forecasting with respect to the mainstream of the Mekong River and that the MRC Member Countries take care for flood forecasting and early warning in their respective countries;
- the above presentations were followed by parallel group discussions on Topics I and IV of which initial reports were made by rapporteurs. On Topic III there was a workshop on *Costs and benefits of flood forecasting and early warning*;
- the initial observations and results of the plenary sessions and of the group discussions were presented by the Chief Technical Advisor and the rapporteurs and briefly discussed in the plenary session at the start of the second day. In addition four papers were presented, two on regional and global programmes, respectively the Asian Flood Network (AFN) and the programme of the World Meteorological Organisation (WMO). The other two presentations were on two of the other Components of the Flood Management and Mitigation Programme (FMMP), respectively: Component 3 to identify potential transboundary issues for negotiation, mediation and conflict prevention; and develop mediation and conflict management capacity, and Component 4 on flood emergency management strengthening;
- after the plenary session the participants split again in groups, this time on all the four Topics. The parallel groups started with the presentation of papers by other specialists, working in the region, as well as of papers from international experts. This was followed by discussions, which resulted in updates of the initial reports by the rapporteurs of Topics I, III and IV and a new report on Topic II;

- the draft final reports of the groups and a draft summary report were presented during the final plenary session. In addition a special presentation was given by Prof. Kuniyoshi Takeuchi, director of the International Centre for Water Hazard and Risk Management (ICHARM) in Japan, on *Flood forecasting for best management of floodplains*. At the end of this session the Forum Statement was adopted. It is published separately in these proceedings.

SOME GENERAL POINTS

The Forum was held on 27 and 28 May 2008 in Phnom Penh, Cambodia. About 125 participants coming from the MRC Member Countries and Dialogue Partners, organisations working in the MRB, international organisations, civil society organisations, institutions and companies, attended it. There were 34 presentations in the plenary and parallel sessions, a workshop and 6 booths in the exhibition.

Definitions, abbreviations and acronyms

World wide the terms of flood and flooding may have a different meaning. Therefore the definitions as used in the Forum were:

- *flood: natural abundance of water in response to storm, rainfall, snowmelt, etc ... ergo the flood season on the Mekong ..... however, this does not necessarily lead to flooding;*
- *flooding: the inundation of areas, which usually are not submerged.*

Related to the floods and flooding a wide range of others terms are relevant. While there are often different interpretations of the same term a draft glossary was prepared at the occasion of the 5th Annual Mekong Flood Forum[1]. Based on new terms in the papers of this Forum the draft glossary has been updated and was widely circulated among the authors for comments. Their comments have been incorporated in the glossary that is published in these proceedings as well. In addition an huge number of abbreviations and acronyms is used in the various papers. These have been explained in the overview of Abbreviations and Acronyms that is also published in these proceedings.

Objectives of AMMF-6

The objectives of AMMF-6 may be summarised as follows:

- to promote regional cooperation to solve transboundary and regional issues related to floods and to share lessons learned on successful concepts and practices for coping with floods from the region and other parts of the Globe;
- to promote and support the development of the full potential of sustainable benefits to all riparian countries of the MRB;
- to promote the implementation of the strategy underlying the comprehensive Flood Management and Mitigation Programme (FMMP) that was formulated in 2002;
- to provide a platform to exchange experiences, to inform on new technologies and based on this to secure commitment as well as to strengthen cooperation for regional flood management
- to contribute to the development and improvement of a sustainable network among participants and participating organizations;
- to provide the stage to present past activities, to discuss emerging needs and to review the

[1] This glossary was mainly based on the terms as published in the Multilingual Technical Dictionary (MTD) of the International Commission on Irrigation and Drainage (ICID).

progress each MRC Member Country and the MRC-RFMMC has made towards a holistic and balanced flood management plan;
- to share knowledge and experiences to strengthen regional cooperation and finally:
- to promote a regional approach for flood management and mitigation in the MRB.

The broader goal is that the countries will use the Annual Mekong Flood Forums as a mechanism to review and improve their own flood policies, strategies, plans and projects.

Envisaged outcome of AMMF-6

The envisaged outcome of the AMMF-6 was summarised as follows:
- AMFF-6 will focus on the theme and be 'result-oriented' in order to assure that the results can be applied by the MRC-RFMMC and the MRC Member Countries in their pursuit of improving data collection and sharing, which is the prerequisite for the attainment of reliable and dependable short-term and medium-term flood forecasting and early warning;
- based on the outcome of AMFF-6, the MRC-RFMMC and MRC Member Countries will be able to improve their flood forecasting services, and strengthen their systems, capabilities and collaboration mechanisms for real and near real-time data collection, transmission, processing and presentation in order to address the needs of the MRC Member Countries, which prefer the MRC-RFMMC to produce and timely disseminate medium-term flood forecasts and early warning information;
- AMFF-6 is set to discuss key issues related to the establishment in the MRC-RFMMC of data transmission systems, database systems, interface platforms, models and model environments. The challenge is the integration of systems and subsystems into an overall concept, allowing future extension to processing more data and data sources and applying a greater variety of models and model environments.

INAUGURAL SESSION

In the opening addresses there were three items mentioned that may be of relevance for the proceedings. These concern:
- MRC programmes need to contribute to research, training and technological development, and deliver useful results to the MRC Member Countries;
- the theme of AMMF-6 reflects the needs of the MRC Member Countries in providing better forecasting systems for their people, thus avoiding death and damage of unexpected floods;
- the present phase of the FMMP programme expires by the end of 2010. The Netherlands representative indicated the intention to support a second phase. However, he clearly stated that this could only be the case when there would be a strong commitment from the MRC Member Countries and other donors as well.

After the opening addresses an overview was given of the results of the previous Forum (AMFF-5) and an Overview of and expected outcomes from the present Forum (AMFF-6).

COUNTRY REPORTS AND PRESENTATIONS OF DIALOGUE PARTNERS

During the Forum the four MRC Member Countries presented their country flood reports for 2007. In addition there were presentations by the Dialogue Partners China and Myanmar. The country flood reports contain a good overview on the situation with respect to flood and

flooding in 2007, as well as how the countries are organising their flood forecasting and early warning approaches, what progress has been made, both technically and institutionally, how they organise the issuing of flood warnings and how they interact with the MRC-RFMMC. In addition the reports contain an impressive list of recommendations. Based on these lists, the presentations, discussions and the report by the rapporteur several key points have been derived that are listed underneath:

- *general:*
  - floods can be a benefit (nice flood) or a threat. An important and very substantial benefit is obtained by the use of floodwater for fisheries and recession agriculture in the Tonle Sap Great Lake area and the floodplain area in Cambodia. In fact for these purposes larger floods are more appreciated than smaller floods. Flood forecasting is also of importance for these purposes. Another benefit is the fertility that the floods bring to the Mekong Flood Plains and Delta. In case of the beneficial floods seasonal forecasts for the mainstream of the Mekong River are considered to be very useful;
  - in most of the MRC Member Countries and in the countries of the Dialogue Partners extreme floods are the most prominent natural disaster. In such conditions flood forecasting and early warning play an important role in flood management, flood mitigation and flood preparedness measures;
  - during last years Forum (AMFF-5) it was generally felt that substantial improvement of data collection and storage was needed. This would first of all require good measuring stations, but also a good database, that facilitates easy exchange of data between the MRC Member Countries, Dialogue Partners and the MRC-RFMMC. With respect to these items it was reported that most of the MRC Member Countries are making good progress with the development of their flood forecasting and early warning systems, as well as with the development of adequate flood preparedness measures;
- *2007 flood events:*
  - as far as flooding is concerned 2007 was a moderate year. However, in several countries there were damaging flash floods. Floods on the mainstream of the Mekong started late, were below average, similar or even below 2006 and the total damage was lower than in the last 5 years.
  - there was one damaging typhoon - Lekima - with locally in total 250 - 500 mm rainfall;
  - there were flash floods in tributaries of the Mekong River in Laos, Thailand and the Central Highlands of Viet Nam that caused significant damage. The impression is that flash floods are increasing in frequency and damaging effect. Therefore there is an increasing need for improved information on the probability of occurrence of flash floods through a flash flood guidance system, especially for the tributaries of the Mekong River;
- *flood forecasting and early warning:*
  - flood forecasting, preparedness and early warning have helped to significantly reduce loss of live, damage to infrastructure and crops in recent years. Basic data collection such as rainfall and weather conditions, river discharges and water levels, land cover and land use, etc. are of utmost importance for flood forecasting, therefore funds need to be properly allocated for these activities;
  - tasks of all institutions and people concerned need to be clarified and coordination among them need to be promoted in order to avoid duplication of tasks and to encourage the sharing of data and information;
  - MRC daily forecasting news would have to be disseminated before 10:00 hr, in order to enable the MRC Member Countries to refer to it;
  - information on the new system on flood forecasting as it is now being tested by

MRC-RFMMC needs to be frequently exchanged between MRC-RFMMC and the line agencies;

* the MRC Member Countries and the Mekong River Commission Secretariat (MRCS) apply different water level datums. In order to ensure that the water levels reported in the documents are in agreement the different datums need to be carefully checked. This comment is related to the comment as made during the previous Forum (AMFF-5) where it was considered to be very important to develop a good quality digital elevation model (DEM) of the MRB, while it is in fact the basis for all model simulations and forecasts;
* since the devastating floods of 2000 and 2001, non-structural measures such as flood forecasting systems, pre-schemes of flood control operation have been significantly strengthened. However, the intensive human activities on land use in certain parts of the Mekong River Basin may have strongly influenced how representative long-term series of hydrological data are, with as a result that the calibration of parameters with historical data cannot reflect the current practical situation, and several gauged sub-basins have become ungauged areas;
* MRC-RFMMC needs to help to install more hydrological stations to extend the coverage areas, so that they can cover main tributaries too. Assistance is also needed to help taking care of some manual hydrological and meteorological systems as they will continue to serve as a back up;
* little is known on flash flood behaviour due to lack of data and information on the concerned sub-basin. Therefore, building knowledge on flash floods and finding a mechanism, methodology and facilities for flash flood forecasting and preparedness must be encouraged. More hydrological stations need to be installed;
* satellite information is very useful, especially for dealing with flash floods. However, one should always be aware of the relative accuracy of such information related to the intended use;
* in most of the MRC Member Countries institutional changes have been implemented, or are taking place with the objective to promote a better flood forecasting, early warning and flood preparedness;
* a strengthened coordination between MRC-RFMMC and National Flood Forecasting Centres is considered necessary;
* MRC-RFMMC is located in the same compound as the Department of Hydrology and River Works (DHRW) that is responsible for flood forecasting in Cambodia. This provides a good opportunity for a regular exchange of knowledge and information;
* in some of the MRC Member Countries there is a lack of capacity and funding;
* there is a strong need for training and capacity building, especially for operational staff of National Flood Forecasting Centres. MRC-RFMMC needs to help strengthening capability of national forecasting institutions, from data collection, processing to development of forecasting models;
* it is recommended to prepare Guidelines on Flood Management and Mitigation, among others for improving horizontal coordination and raising awareness. The guidelines need to focus on different sectors so that concerned staff in these sectors is better aware of flood issues;

- *flood preparedness:*
  * in the past activities for disaster (flood) management have focused mainly on relief operations with little effort on other aspects or lack of funds to cover other activities;
  * based on an analysis of the water levels at Tan Chau station (as experienced by the farmers) in Viet Nam, floods and flooding in the Mekong Delta have been classified in 4 levels. The concept *'Living with floods'* has been successfully

applied in the Mekong Delta. The measures for living with floods include: building residential clusters, flood proof housing, embankments, shifting of the cropping calendar, improvement of flood release capacity, establishment of child care centres, children safety training, and water borne disease prevention;

* flood mapping of flood risk areas is considered very important;
* better management of water resources requires better prediction in the ungauged or poorly gauged sub-basins. The most important scientific problems with respect to this aspect concern:
  + hydrological predicting approaches for large poorly-gauged basins;
  + prediction of hydrological responses to human activity and climate change in ungauged basins;
  + prediction of eco-environmental responses to human activity, such as soil erosion and non-point source water pollution in ungauged basins;
* meetings would have to be held before (April or May) and after (December or January) the flood season, including participants from MRC-RFMMC and the MRC Member Countries. The objectives of the meetings would be: exchanging and sharing knowledge, experiences and technology in flood forecasting, disaster assessment, emergency response, preparedness land use planning in the floodplain, etc.;
* MRC is suggested to publish the forecasting news on rainfall, floods, especially early flood forecasting in early April every year, so that the line agencies in the MRC Member Countries can prepare action plans responding to the hydrological circumstances;
* capacity of the media to report to the public on expected flood events need to be extended;
* as far as the vulnerable communities are concerned, more attention would have to be paid to the strengthening of coping mechanisms in case of floods. Awareness on basic flood risk reduction and mitigation measures and knowledge to use hydro-meteorological information have to be provided to these communities so that they can help themselves to reduce flood risk;

- *disaster management:*
  * within the MRC Member Countries the capacity for flood aftermath surveys is still very weak or non existent. The agencies in charge of disaster management focus rather on damages and humanitarian assistance. The countries would have to find ways how to improve this situation;
- *relief and reconstruction:*
  * reconstruction and relief measures need to be improved, financial assistance would have to be made to affected communities so that their daily life can be sustained, the technical and financial assistance need to be effectively and efficiently mobilized as soon as possible afterwards, and a financial reserve needs to be established for flood emergency response;
  * currently, flood damage assessment in Lao PDR is carried out by the local authorities in their own format, there is no standard format for damage data collection. Therefore, a standard format for flood data collection needs to be established in support of better flood management and mitigation;
- *benefit - cost aspects:*
  * in order to identify an effective set of flood management and mitigation measures, first of all a good process for assessment of flood damage will be relevant. Such a process is also necessary because comprehensive assessment of damages gives important data that will reflect the economic loss of the country. This will result in significant supporting information for setting up of both structural and non-structural measures for flood prevention and mitigation;

- *other items:*
  - a large quantity of water would have to be retained during the rainy season and later used. This will not only relieve the flooding problem but it will also help in prevention of drought to follow;
  - insufficient attention to flood risk aspects in the development of infrastructure can result in increasing the degree and/or harmfulness of flooding;
  - it has been recommended that consideration be given to the translation of the Annual Flood Report into the languages of the MRC Member Countries. By doing this it can be more widely read and understood by the relevant stakeholders and line agencies and make a meaningful contribution to institutional strengthening and the available reference material.

MRC-RFMMC APPROACH TOWARDS AN IMPROVED SHORT-TERM AND MEDIUM-TERM FLOOD FORECASTING AND EARLY WARNING

The MRC-RFMMC has made good progress with the development of its new short-term and medium-term forecasting system for the mainstream of the Mekong River, as presented in the video during the inaugural session. Important components are the HYDMET software for exchange, handling and storage of hydro-meteorological data, the URBS hydrological and flood routing model, and the forecasting environment Delft FEWS. This system will enable linking of the models that are applied by the MRC-RFMMC and the MRC Member Countries. Input to the new hydrological models is primarily rainfall data with point and grid based products. In several papers as presented and discussed during the forum and published in the proceedings the general set-up and details of the new approach is shown. The new system will be run in parallel with the old forecasting system in a test mode during the 2008 flood season and the new system would also help to promote the interaction between the MRC-RFMMC, the MRC Member Countries and the Dialogue Partners on data exchange.

The flood forecasting products from MRC-RFMMC to the line agencies are sent by e-mail, and published on the MRCS website. The MRC Member Countries use the flood forecasting information of MRC-RFMMC for reference, and for rapid dissemination as an early warning.

Work is being done to develop Flood Vulnerability Indexes. Such indexes are important for better flood risk management at the community level. They can also provide information for recourses allocation. In addition a Flash Flood Guidance System (FFGS) is being developed. This system can be an important guidance to improve flood forecasting in the Lower Mekong River Basin (LMB). Basic components are Flash flood guidance (FFG) and Flash Flood Threat (FFT).

RESULTS OF THE PLENARY AND PARALLEL SESSIONS

The content and summarised results of the plenary and the parallel sessions on the four topics are as shown underneath. Based on the presentations and discussions more detailed recommendations were presented on each topic. These will be used by the MRC-RFMMC during the further development of the new approach.

General items

There were five plenary presentations. Two papers concerned international experiences and developments of respectively the *Asia Flood Network: Flood Mitigation and Preparedness Program in Asia* by the Office of U.S. Foreign Disaster Assistance of U.S. Agency for

International Development (USAID/OFDA) and the program on *Integrated flood management in the context of regional to global integrated observing and information systems* by the World Meteorological Organization (WMO). Two other papers concerned presentations on the progress made in two other Components of the Flood Management and Mitigation Programme (FMMP) of the MRC-RFMMC, respectively Component 3 on *Enhancing cooperation between MRC Member Countries in addressing transboundary flood and related issues* and on Component 4 on *Flood emergency management strengthening (FEMS).*

A Special presentation on *Flood forecasting for best management of floodplains* was given by Prof. Kuniyoshi Takeuchi, Director of the International Centre for Water Hazard and Risk Management (ICHARM) in Tsukuba, Japan. In his presentation he stressed that: action is needed, the benefits of floods need to be maintained and that disasters start when the developments start, which is a multi-generation problem. He also stated that trust in the forecaster is very important. He presented some aspects of the work of ICHARM.

Topic I. New developments with respect to flood forecasting and early warning

Under Topic I five papers were presented of the seven papers that were submitted. The summarised points as taken from the presentations of the rapporteur of the topic were:

- an efficient data collection, processing and retrieval system for meteorological forecast data is of utmost importance for river flow modelling and issuing of forecasts;
- new methods of forecast to be applied for the Mekong River Basin have been discussed;
- topographic and morphologic conditions in Mekong Delta have changed much after the 2000 flood event. Therefore models need to be recalibrated;
- it is time to improve gathering of historical and operational data;
- forecast messages should be understandable for the farmers.

Topic II. Land use based requirements for flood forecasting and early warning systems

For Topic II only two papers were submitted, of which only one could be presented. An additional paper on Extreme weather conditions, drainage, flood management and land use was presented as well. Some recommendations were:

- different types of land use require different types of flood forecasts and different measures. Agriculture and fisheries may need seasonal forecasts, while rural and urban areas need (flash) flood forecasts. All may need short and medium-term forecasts;
- a good mapping and zoning/land use planning is of importance, as well as identification of vulnerability.

Topic III. Costs and benefits of flood forecasting and early warning

For Topic III three papers were submitted and presented and a special workshop on *Costs and benefits of flood forecasting and early warning* was held. Some conclusions and recommendations were:

- estimation of costs and benefits of flood forecasting systems is a difficult task;
- there was a general consensus that benefit/cost ratios of flood forecasting and early warning were in the order of 10/1 – 15/1;
- in the comparison of benefits and cost primary damage and secondary damage need to be considered;
- damage should not only be expressed in monetary terms. Intangibles like: loss of life, cultural losses and long-term impacts on public health need to be considered as well;
- it is hard to convince people to invest in flood management and mitigation measures, as the benefit of this is hard to assess. However, it is easier to convince them that the benefits/cost are higher in urban as compared to rural areas.

Topic IV. Lessons learned from past flood events

For Topic IV four papers were submitted, of which three were presented. Some conclusions and recommendations were:

- floods are very harmful to children. Therefore the flood awareness activities need to be more oriented to children;
- it is considered to be more effective to start with collaboration with communities in flood hazard identification;
- more affordable and effective modelling and systems need to be considered (less sophisticated and making use of correlation).

FOLLOW-UP

Follow-up actions at three levels were formulated, being follow-up actions directly after the Forum, recommendations for the theme of the 7th Annual Mekong Flood Forum (AMFF-7) and on the more comprehensive follow-up.

Follow-up directly after the Forum

The follow-up actions directly after the Forum were of a practical nature and have resulted in the proceedings. These concerned:

- all authors have received their edited paper back with the request to check the editorial changes and complete the paper. In addition they have received the glossary and the list of abbreviations and acronyms for their comments/corrections;
- papers have been published in the proceedings on CD-ROM. MRC Member Countries, Dialogue Partners and other partners will receive the CD-ROM through the MRCS. The PDF files of the papers will also be available on the MRC web site. The CD-ROM can be ordered through the MRC website as well;
- the CD-ROM will also be available during the 7th Forum.

7th Annual Mekong Flood Forum (AMFF-7)

For the 7th Annual Mekong Flood Forum (AMFF-7) the following main theme was discussed and formulated:

Integrated flood risk management in the Mekong River Basin

It is expected that this main theme will be the basis for the formulation of the sub-themes and the programme for (AMFF-7).

More comprehensive follow-up

Fore the more comprehensive follow-up of AMFF-6 several recommendations were given. These concern:

- continue with annual flood forums, based on actual topics of joint interest of the MRC Member Countries and Dialogue Partners. However, the programme of the Forum needs to be modified in light of the progress made within the MRC Member Countries and the FMMP;
- work for the present phase of the FMMP will continue along the lines as presented, with input from Forum results for improvement;
- During the coming flood season the new system for flood forecasting will be tested in

practice. Based on the test results decisions will be taken on introduction of the new system for flood forecasting in the MRC-RFMMC in close consultation with the Member Countries;

- preparations for follow-up of FMMP beyond 2010 need to be started at short notice.

CONCLUDING REMARKS

This summary of proceedings will be concluded with some final remarks:

- there were good presentations by the MRC Member Countries and Dialogue Partners, making clear their situation with respect to floods in 2007 and how they are improving their institutions and data collection, storage and retrieval systems;
- the parallel group discussions were interesting and lively. They have provided useful additional information;
- a lot of hard and good work has been done by the rapporteurs in preparing their reports on the plenary and parallel sessions at a very short notice.

At the end of the Forum the participants adopted the Forum Statement. This Statement has been posted on the MRC web site and is included in the proceedings.

Prof. Bart Schultz, PhD, MSc
Forum facilitator
Phnom Penh, Cambodia
30 May 2008

6th Annual Mekong Flood Forum (AMFF-6)

FORUM STATEMENT

Preamble

About 130 participants - including those from the Mekong River Commission (MRC) Member States of Cambodia, Lao PDR, Thailand and Viet Nam and their National Mekong Committees and line agencies, Dialogue Partners: China and Myanmar, regional and international scientists and experts, and representatives of international and national civil society organizations and local communities - attended the 6th Annual Mekong Flood Forum on the theme *'Integrated approaches and applicable systems for medium-term flood forecasting and early warning in the Mekong River Basin'*. They were involved in two days of interesting presentations, discussions and exchanges of information on the theme and topics of the Forum. Based on this the following statements were produced and supported by the participants at the concluding session of the Forum.

I. The participants express their feelings of grief with the victims of the recent natural disasters, cyclone Nargis in Myanmar and the Sichuan earthquake in China, both countries being MRC Dialogue Partners.

II. The increasing population and infrastructure, the value of private and public property, impacts of climate change and the on-going changes in land use bring with them the potential to make the flood prone areas within the Mekong River Basin (MRB) increasingly vulnerable to flooding and flood damage. Therefore the integrated approaches and applicable systems for short-term and medium-term flood forecasting, early warning and effective management and mitigation in the MRB, are increasingly required, most importantly to save human lives, but also to protect property, agricultural land and livestock.

III. The MRC Member States and Dialogue Partners have established or are continuously updating their approach to enable them to issue improved flood forecasts and early warnings, as well as to improve their flood preparedness measures. The recent devastating cyclone Nargis that struck the region and the frequently occurring flash floods have proved again the importance of such measures. Interstate collection and exchange of information with respect to flood forecasting allows the MRC Regional Flood Mitigation and Management Centre (MRC-RFMMC) of the Mekong River Commission (MRC) to provide daily short-term flood forecasting during the flood season. This will support the countries in preparing their own flood forecasting and early warning messages, improving flood preparedness measures and emergency management, relief and reconstruction. The efforts may substantially contribute to reduction of casualties and damages.

IV. Flood forecasting systems are composed of a set of interlinked tools and activities. The MRC-RFMMC is modernising its tools in order to improve its flood forecasts. In light of this it is testing an improved system, which works with the HYDMET software for data handling and transfer of hydrological hydro-meteorological data, the HYMOS database and the hydrological flood routing model URBS. In addition the Flood Early Warning

System (FEWS) is tested. This approach enables automatic exchange of data and immediate generation of information for accurate short-term and medium-term flood forecasting for the mainstream of the Mekong River. In addition the new system would allow better exchange of information between the MRC Member States, Dialogue Partners and the MRC-RFMMC. The new system may also enable the MRC Member States to improve their own flood forecasting and early warning systems, as well as expand knowledge on drought mitigation and multi hazard planning and management.

V. There has been a range of recommendations for the themes of the next Annual Mekong Flood Forum (AMFF-7). With respect to this it is of importance that the broader goal of the Annual Mekong Flood Forums is that the MRC Member States will use them as a mechanism to exchange experiences and improve their own flood policies, strategies, plans and projects. Based on the status of the development of the flood forecasting systems, the broader goal, the on-going concerns with respect to floods and flooding in the MRB, the following main themes is recommended for the AMFF-7:

Integrated flood risk management in the Mekong River Basin

VI. The participants expressed their strong wish to continue with their efforts to improve preparedness for floods and to increase their cooperation based on the overarching objective to reduce flood risk and flood damage in the Mekong River Basin.

VII. The participants like to thank the donors, especially the Netherlands, for their support of this 6th Annual Mekong Flood Forum, the MRC Regional Flood Management and Mitigation Centre for organising AMFF-6 and the Cambodian National Mekong Committee for hosting this important event. They support continuation of the Annual Mekong Flood Forum.

Phnom, Cambodia
Wednesday 28 May 2008

CLOSING ADDRESS

JEREMY BIRD

CEO of the Mekong River Commission Secretariat, Vientiane, Lao PDR

Distinguished Delegates;

This Sixth Flood Forum has provided a window onto the work of the MRC Flood Mitigation and Management Programme, or FMMP. We have had two days of interesting presentations and discussions, giving us the opportunity to share technologies and tools that will ultimately help reduce loss of lives and property caused by flooding, while enhancing people's abilities to capitalise on the benefits of floods.

What we have learned at this forum will guide us in our future work and enable us to further improve what are obviously very effective instruments: our flood forecasting service and early warning system. These tools are backed by flood preparedness management, and are also being complemented by more structure-oriented measures such as flood proofing and improved land management.

I would like now to return to a comment I made yesterday, that the programme is moving from infancy to maturity. In the early 2000s the FMMP was conceived and brought into the world with the assistance of development partners, who could be called the midwives for the programme.

It might be said that the birth of this baby was rather overdue, but it came out well formed, and after some growing pains we saw it start to walk. We were lucky that in the early years there were no tantrums or screaming fits – clearly this can be put down to the result of good parenting by the FMMP management.

Over time the character of this 'child' has developed. As with any childhood there has been a testing phase for working out what works and what doesn't. This was the time for building our knowledge base, skills and capacity, for testing the boundaries and potential of the programme, and what it can produce. This justifies the initial vision of FMMP's 'parents'.

Now the programme is reaching adolescence and, as with any teenager coming into the wider world, there are going to be differences of opinion – with the parents and with the brothers and sisters. However, the MRC is a strong family. It can reason, and will find ways of moving the programme through this period and into the complex world that requires it. It is complex in that there are many partners and actors in the four countries that the FMMP needs to work with, as we have heard over the past two days - for example the Viet Nam National Disaster Committee. There are also very complex systems. For instance, there is the challenge of meeting the data management and transfer standards outlined by the World Meteorological Organisation, and the need for discussions concerning the accuracy, the pros and cons, of different forecasting models.

The Flood Management and Mitigation Programme is growing older, and can now start looking forward to longer-term career plans. This will involve finding ways of working together with line agencies in each country, building links between these, the National Mekong Committees and the Regional Flood Mitigation and Management Centre, and ultimately building the capacity to deliver information to communities. These are perhaps issues that will be addressed in more detail at next year's Seventh Annual Mekong Flood Forum, at which we will also need to work on securing the long-term financial future of the Centre after 2010 through a second phase of the FMMP.

Ladies and Gentlemen, I would like to thank all the delegates assembled here today for your help over the years in nurturing the MRC Flood Mitigation and Management Programme, and

also for coming here and contributing to a successful forum.

Lastly our thanks must go to our development partners including the Netherlands, Germany, Japan, Denmark, USAID, the Asian Development Bank, the European Union and others. Also thanks to the United States Army Corps of Engineers, the Asian Disaster Preparedness Centre, and our NGO partners for their great contribution to the meeting. With that I would like to declare the forum closed and may I wish all of you staying in Cambodia for a few days more a very pleasant time.

Thank you

CHARACTERISTIC DATA ON THE MEKONG RIVER BASIN

WATER RESOURCES SITUATION

The Lower Mekong River Basin is the Cambodian, Laotian, Thai and Vietnamese parts of the Mekong River Basin. It has a population of some 62 million people and an area of 606,000 km^2. The entire Basin includes parts of Myanmar and of the Yunnan Province of China as well, and has an area of 795,000 km^2. The Basin covers 86% of the area of Cambodia; 97% of the area of Lao PDR; 36% of the area of Thailand; and 20% of the area of Vietnam (Figure 1).

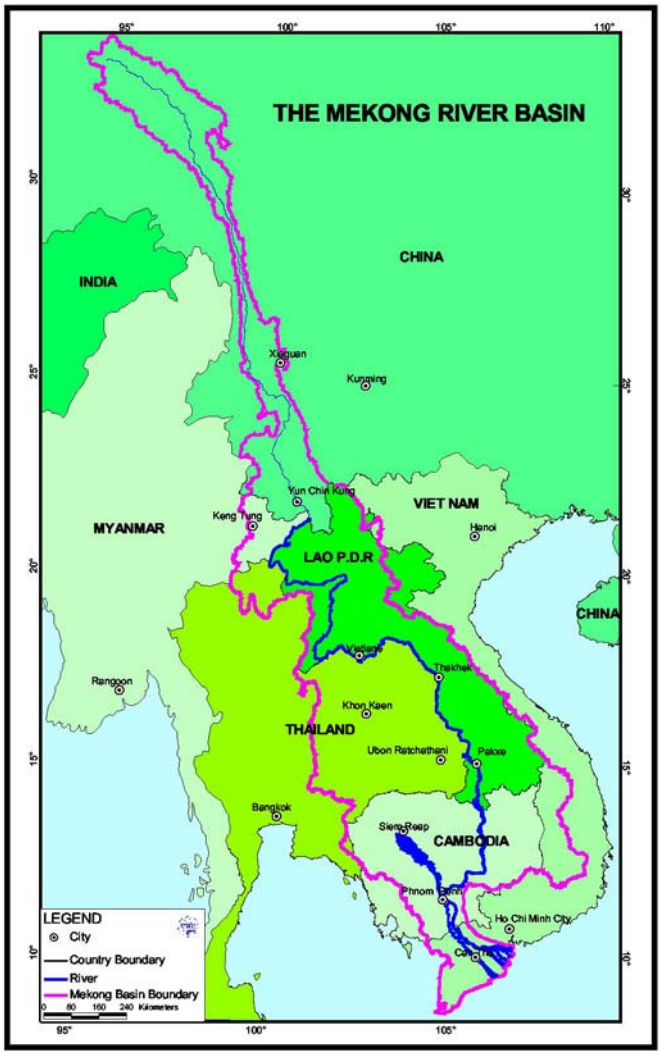


Figure 1. Mekong River Basin

The water resources of the Lower Mekong River Basin are described in some detail in the Mekong River Commission State of the Basin Report of the Mekong River Commission (2003). In strategic terms, important characteristics of Mekong water resources include:

- *abundance.* Annual runoff averages around 475 km^3/year. Per capita resources currently stand at over 8,500 m^3/person/year – compared with 2,200 for the Nile; 1,400 for the Rhine; 2,265 for the Yangtze and 1,700 - 4,000 for the Ganges;
- *low level of exploitation for extractive uses.* Average annual withdrawals are estimated at around 60,000 million m^3, or 12% of total annual flows; the total volume of regulated storage in the basin (including the Upper Basin) for hydropower and irrigation is less than 20,000 million m^3 (less than 5% of annual flows); and it is estimated that only 5% of hydropower potential has

been developed;

- *high dependence on in-stream uses (particularly by the poor).* The Mekong fishery is the largest inland fishery in the world, estimated to be worth at least US$ 2,000 million annually, and providing the major protein source for many people in the basin. Inland navigation is an important mode of transport for many areas where road access is limited;
- *extreme seasonality.* In most parts of the Basin, flows in the driest three months constitute less than 10% of total annual flows while flows in the wettest three months make up over 50% of total annual flows (MRC DSF);
- *importance of the flood pulse for the ecology of the floodplain and the Mekong fishery.* During the wet season, between 1 and 4 million hectares of floodplain are submerged, including the Tonle Sap Great Lake;
- *dry season water shortages.* Dry season shortages occur as a result of the rainfall seasonality, concentration of extractions in the driest period and drought events during the onset of the wet season;
- *water quality.* Water quality in the mainstream is generally good, and is rarely a constraint to water use. The exception is saline intrusion, acid sulphate drainage and pollution in intensively used areas of the Mekong Delta;
- *groundwater.* Groundwater resources are very widely used as a source for domestic and industrial supply. Use for irrigation is limited, but expanding. Groundwater systems in the flood plain are closely coupled to the river;
- *Upper Basin.* Flows (from China and Myanmar) constitute around 18% of total Mekong flows. The proportion is higher in the dry season, when snowmelt contributes a significant component of flow.

WATER UTILIZATION IN THE LOWER MEKONG RIVER BASIN (LMB)

Agriculture and irrigation

Agriculture is the cornerstone of the economy in the Lower Mekong River Basin. 22% of the area is cultivated with rice being the major crop (typically harvesting one crop per year, except in the Delta, where 2 or 3 crops can be grown). More than 80% of the rural labour force is employed in the agricultural sector. Throughout the basin, however, most rural households have highly diversified and multiple sources of income and combine farming with a range of non-agricultural activities. Within the basin, income from wages and salaries currently accounts for up to 25-30% of household income. Government policies that target larger scale commercialised agriculture as well as the growth of rural industries will further influence the economic activities of the rural population.

The total water-managed cultivation areas (irrigated areas) are around 390,000 ha (Cambodia); 155,000 ha (Lao PDR); 540,000 ha (Thailand); 40,000 ha (Vietnamese Highlands); and 1,000,000 ha (Vietnamese Delta). In both Cambodia and Lao PDR, there is a large potential for development of irrigation infrastructure within existing water-managed areas. In the same two countries, there is a potential for expanding the irrigated area by around 600,000 ha in each country. In Northeast Thailand, the tributaries are fully exploited, and in the Delta, the flow is fully utilized for irrigation and to curb salinity intrusion.

Fisheries

The present fisheries yield of the Basin is 1.5 – 2 million tons per year. Some 15% comes from aquaculture and the rest from freshwater capture. Fish is an important part of the staple diet supplying most of the protein, over 80% in Cambodia, for instance. Today, the capture stock is utilised close to its capacity. The aquaculture production is escalating rapidly in Cambodia and in the Delta. The capture fishery is exposed to habitat degradation, and barriers to migration, while aquaculture production is exposed to a deteriorating water quality, partly due to polluted irrigation tailwater.

Wetlands and other habitats

The wetland areas of the Basin, such as Tonle Sap, Plain of Reeds, and others, are important ecological habitats. Tonle Sap is among the World's most productive freshwater fisheries areas. Also the flood plains serve as fish breeding grounds. Tonle Sap functions as a large natural storage reservoir that reduces the maximum flow and increases the minimum flow downstream of the confluence at Phnom Penh.

For a multitude of reasons, the forests, wetlands, coastal ecosystems and other natural habitats are in a state of continuous degradation. On the other hand, there is an attractive potential for development of controlled, sustainable forestry.

Hydropower

There is a big hydropower potential in the Lower Mekong River Basin. MRC has estimated it to around 30,000 MW depending on the feasibility criteria applied. Of this, 13,000 MW are on the mainstream; 13,000 MW on Lao tributaries; 2,200 MW on Cambodian tributaries; and 2,000 MW on Vietnamese tributaries. To date, 11 schemes have been completed in the LMB, totalling some 1,600 MW, or 5% of the potential. All of these are tributary projects. The largest ones are located in Vietnam (Ialy, 720 MW) and Lao PDR (Theun Hinboun, 210 MW, Nam Ngum, 150 MW, and Houay Ho, 150 MW). In the Lower Mekong River Basin, the planning emphasis has shifted from the mainstream to the tributaries.

In Yunnan, two hydropower projects have been completed on the mainstream: Manwan (1,500 MW) and Da-Chao-Shan (1,350 MW). Additional large mainstream projects have been initiated (Xiaowan) or planned (Jinghong and Nuozhadu), with a storage capacity of 15,000 Mm^3.

Navigation

Waterway transport has traditionally been the principal means of travel for much of the population, both locally and for international trade. Around a third of the population in rural areas of Cambodia and Lao PDR live further than 10 km from a road that can be used year round. Waterborne transport represents 85% of all means of transportation in the Mekong Delta of Vietnam.

The use of the river for transportation does not only depend on the physical potential of the waterways but also on the demand for trade. In 2002, trade estimated at 4.7 billion US$ was distributed by inland waterway transport (88 million US$ between Thailand and China; 350 million US$ between Lao PDR and Thailand; 235 million US$ in Cambodia; and 4 billion US$ in the Mekong Delta).

Floods

Severe floods occur regularly, in recent years for example in 1996, 2000, and 2001. The consequences have been extensive, in terms of human casualties, production loss, and damage to infrastructure and private property. Flood management and mitigation is an important issue with a strong regional emphasis.

Tourism

Tourism is a major foreign currency earner in Thailand, although today it is most dominant outside of the Mekong River Basin. In Cambodia, Lao PDR and Vietnam, the sector has an attractive potential for development, which can be pursued in a basin-wide collaboration.

SOCIO-ECONOMIC CONDITIONS

The last two decades have witnessed rapid economic development in the lower basin countries. At the same time, however, the quality of life of the poorest people has barely improved at all.

Most of the rural population, that is more than 80% of the total population in all basin areas, continues to live in great poverty. The socio-economic indicators in Cambodia and Lao PDR remain low, and in Thailand and Vietnam, the indicators within the basin area are substantially lower than in the areas outside of the basin. Significant investments are urgently needed in the agriculture sector and in rural development in general, as well as in education and basic health.

Education levels are generally low. The average school attendance is less than 5 years. There is a shortage of schools and higher education facilities, particularly in rural areas. Poverty can impede children from going to school, not to speak of higher education. In this way, huge human resources are critically under-utilized and do not reach their potential. Currently, 75 - 80% of the basin's population lives in rural areas. Population growth remains high throughout the basin despite declining fertility rates and improved health conditions and life expectancy. Projections for year 2000-2020 show annual total population increases ranging from 1% in Thailand to 1.4% in Vietnam, 2.3% in Cambodia and 2.6% in Lao PDR. Moreover, rate of growth of the urban population is 2 - 2.5 times higher than national rates, due to migration towards secondary as well as major urban centres. If these conditions persist, the proportion of people living in urban areas in 2025 will be in the range of 25 - 30%.

PROGRAMME 6th ANNUAL MEKONG FLOOD FORUM (AMFF-6)

TUESDAY, 27 MAY 2008

08:00-08:30	Registration
08:30-12:30	*MORNING SESSION*
08:30-09:30	***Inaugural Session*** Master of Ceremony: Mr. Nico Bakker
08:30-09:30	Welcome Remarks by Mr. Jeremy Bird, Chief Executive Officer, the Mekong River Commission Secretariat (MRCS)
	Opening Address by H.E. Sin Niny, Vice Chairman of Cambodia National Mekong Committee, MRC Joint Committee Member for Cambodia
	Statement by Dr. Armand Evers, Royal Netherlands Embassy, Hanoi, Viet Nam
	Summary of the 5th Annual Mekong Flood Forum (AMFF-5) by Dr. Hatda Pich An, Operations Manager, MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC)
	Overview and expected outcomes of the 6th Annual Mekong Flood Forum (AMFF-6) by Mr. Nico Bakker, Chief Technical Adviser, Flood Management and Mitigation Programme (FMMP)
	Visual presentation of the Mekong River Flood Forecasting System of the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC)
09:30-10:00	Coffee Break and Exhibition
10:00-12:30	***Session 1: Lessons Learned from 2007 Flooding and National and MRC-RFMMC Flood Forecasting and Early Warning Experiences*** Chairperson: HE. Pich Dun, Head of the Cambodian Delegation Rapporteur: *Ms. Nguyen Hong Phuong*, Coordinator of VNMC-FMMP
10:00-12:00	Cambodia's country flood report for 2007 *Sok Bun Heng, National Flood Expert (NFE) for the CNMC's National Flood Unit (CNMC-NFU)*
	Lao PDR's country flood report for 2007 *Virana Sonnasinh, National Flood Expert (NFE) for the LNMC's National Flood Unit (LNMC-NFU)*
	Thailand's country flood report for 2007 *Tosporn Suthijinda and Ssupapap Patsinghasanee. Water Crisis Prevention Centre, Department of Water Resources*
	Viet Nam's country flood report for 2007 *Trinh Hoang Ngan, National Flood Expert (NFE) for the VNMC's National Flood Unit (VNMC-NFU)*
	Flood disasters and flood forecasting progress in China *Guoqing Wang, Senior engineer, Nanjing Hydraulic Research Institute, Ministry of Water Resources*
	Floods, forecasting system and management in Myanmar *U Hla Myint Thein and U Sein Tun, Deputy Director General and Deputy Director, Directorate of Water Resources and Improvement of River Systems, Ministry of Transport*
	2007 Mekong flood report - flood hydrology of the Mekong tributaries *Ms. Janejira Tospornsampan, Flood Forecasting Expert MRC-RFMMC and Peter Adamson Consultant to MRC*
12:00-12:30	Panel Discussion (panel consists of the presenters and session chairperson)
12:30-13:30	Lunch

14:00-17:30	*AFTERNOON SESSION*
14:00-15:00	***Session 2: Towards an Improved Medium-term Flood Forecasting and Early Warning*** Chairperson: Mr. Dao Trong Tu, Head of the Vietnamese Delegation Rapporteur: Mr. Chanthachith Amphaychith, Coordinator of the LNMC-FMMP
	The Mekong River flood forecasting system at the MRC Regional Flood Management and Mitigation Centre (MRC-RFMMC) *Bob Pengel, Janejira Tospornsampan, Terry Malone, Marco Hartman and Ms. Astrid Janssen*
	Hydro-meteorological information exchanges and communication improvements. Support for URBS model in medium-term flood forecasting over the Mekong River Basin *Perapol Begkhuntod, Hatda Pich An and Katry Phung,*
	Identification and measurement of factors affecting flood vulnerability in the Lower Mekong River Basin *Nguyen Huy Dzung and Chris Joy*
	The Mekong regional flash-flood guidance system - a technical overview *Robert W. Jubach, Eylon Shamir, Christopher Spencer and Jason Sperfslage*
15.00-15.30	Questions, Discussion and Introduction to the Group Discussions and Workshop
15:30-16:00	Coffee Break and Exhibition
16.00-17.30	***Session 3: Parallel Group Discussions and Workshop*** *Topic I: New developments with respect to flood forecasting and early warning* Chairperson: Chanthavong Saignasith Facilitator: Bob Pengel Rapporteur: Trinh Hoang Ngan Group Discussion *Topic II: Group discussion will be in Session 5* *Topic III: Costs and benefits of flood forecasting and early warning* Workshop on cost and benefit of flooding/flood forecasting Facilitator: Peter Adamson Rapporteur: Sok Bun Heng *Topic IV: Lessons learned from past flood events* Chairperson: Pich Dun Facilitator: Erich Plate Rapporteur: Virana Sonnasinh Group Discussion *Side event: SPLASH consultation meeting*
18:30-20:30	**Forum Dinner**

WEDNESDAY, 28 MAY 2008

08:00-12:00	*MORNING SESSION*
08:00-10:00	***Session 4: Initial Reports on the Plenary Sessions, the Four Topics and Plenary Paper Presentations*** Chairperson: Mr. Chanthavong Saignasith, Head of Lao PDR Delegation Rapporteur: Mr. Burachat Buasuwan, Coordinator of TNMC-FMMP
08:00-09:30	Summary of Day 1 of AMFF-6 by Mr. Nico Bakker, FMMP-CTA, MRC
	Presentation of Initial Comments by the Rapporteurs of the Plenary Sessions, Parallel Group Discussions and Workshop
	Achievements and lessons learnt. Flood Emergency Management Strengthening (FEMS). Component 4 of the MRC Flood Management and Mitigation Program (FMMP) *Loy Rego*
	Asia Flood Network: USAID/OFDA Flood Mitigation and Preparedness Program in Asia *Ms. A. Sezin Tokar, Richard Paulson, Eric Wolvovsky, Angel Bennett, Kelly Sponberg, Robert Jubach, Saud Amer, Guleid Artan and Greg Husak*
	Enhancing cooperation between Mekong River Commission (MRC) Member States for addressing transboundary flood and related issues *Huynh Minh Ngoc and Nico Bakker*
	Integrated flood management in the context of regional to global integrated observing and information systems. Overview of current activities of the World Meteorological Organization *Wolfgang Grabs*
09:30-10.00	Panel Discussion – Facilitator: Prof. Bart Schultz
10:00-10:30	Coffee Break and Exhibition
10:30-12:00	***Session 5: Parallel Paper Presentations on the Four Topics*** *Topic I: New developments with respect to flood forecasting and early warning* Chairperson: Dao Trong Tu Rapporteur: Trinh Hoang Ngan I.1 Quality assessment of forecasts *Erich J. Plate and Falk Lindenmaier* I.2 Flood risk forecasting for poorly-gauged basins in the Mekong River Basin using a distributed hydrological model and a satellite derived precipitation dataset *Jun Magome, Kazuhiko Fukami, Hironori Inomata and Kuniyoshi Takeuchi* I.3 Improving the meteorological network in Cambodia *Long Saravuth, Katry Phung and Bob Pengel* I.4 Potential of satellite altimetry for flood model assessment *R.J.J. Dost, G. Parodi, T. Rientjes, Le Thi Hanh* I.5 Flood hazard in Savannakhet province, LAO PDR mapping using HEC-RAS, remote sensing and GIS *M.K. Hazarika, A. Bormudoi, S. Phosalath, V. Sengtianthr, L. Samarakoon* I.6 Mekong-HYCOS-Strengthening integrated hydrological management in the Mekong River Basin *Liko Solangkoun and Daniel Jouve* I.7 Simulation of extreme weather events using an advanced weather research forecast (WRF) modelling system P.V.S. Raju, Jayaraman Potty, U.C. Mohanty and A.R. Subbiah
10:30-12:00	*Topic II: Land use based requirements for flood forecasting and early warning systems* Chairperson: Adri Verwey Rapporteur: Watt Botkosal II.1 Outline of an approach to generate flood probability information and its possible use in land management *Georg Käsler* II.2 The lower Mekong Basin flood mapping service: development and delivery of near-real-time flood map products *A.M. Dean, O.T. Tsui, A. Syed and T. Boivin* Group Discussion on Topic II

10:30-12:00	***Session 5: Parallel Paper Presentations on the Four Topics (continued)*** *Topic III: Costs and benefits of flood forecasting and early warning* Chairperson: Peter Adamson Rapporteur: Sok Bun Heng III.1 The role of flood forecasting and early warning in integrated flood risk management *Guus Sutmuller* III.2 Long Lead Climate Forecast Application to Benefit Society: Experiences of 2007 Bangladesh Floods *A.R. Subbiah and S.H.M. Fakhruddin* III.3 Economic valuation of flood damage for decision makers in the Netherlands and the Lower Mekong River Basin *Jurjen Wagemaker, Ms. Jakolien Leenders and Jan Huizinga*
10:30-12:00	*Topic IV: Lessons learned from past flood events* Chairperson: Ms. Sezin Tokar Rapporteur: Virana Sonnasinh IV.1 August 2002 and 2005 floods in Danube River *Kim Seanvirak* IV.2 Lessons learned from application of new technologies for flood proofing residential clusters in the Lower Mekong River Basin *Marshall L. Silver, Robert Barton and Pham van Le* IV.3 Flood forecasting accuracy for the Mekong River Basin *Willem Kanning, Sambo Pich and Bob Pengel* IV.4 The role of government in flood management and the lessons from hurricane Katrina *J. Ligh and M. Schnabel*
12:00-13:30	Lunch and Preparation for Group Presentations
13:30-16:30	*AFTERNOON SESSION*
13:30-15:00	***Session 6: Plenary Session*** Chairperson: Prof. Suwit Thanopanuwat Head of Thai Delegation Rapporteur: Hak Socheat, Coordinator of CNMC-FMMP
	Presentations by the Topic Rapporteurs and by the Rapporteur of Plenary Session 4
	Questions and Answers; General Comments from the Floor
	Flood forecasting for best management of floodplains by Prof. Kuniyoshi Takeuchi
15:00-15:30	Coffee Break and Exhibition
15:30-16:30	***Session 7: Concluding Session*** Co-Chairpersons: Te Navuth, Director of Technical Support Division Nico Bakker, FMMP Chief Technical Advisor
	Summary of Proceedings and Recommendations for Follow-up by Bart Schultz
	Remarks by a Representative of Participants
	Closing Address by Jeremy Bird, CEO, MRCS

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Centre
AFF	Annual Flood Forum
AFN	Asia Flood Network, USAID/OFDA flood mitigation initiative in Asia
AHNIP	Appropriate Hydrological Network Improvement Project
AIDRECEP	Committee for Coordination and Reception of Foreign Aid
AIS	Advanced Information Service, Thailand
AIT	Asia Institute of Technology
AMFF-1	1st Annual Mekong Flood Forum, Flood Preparedness
AMFF-2	2nd Annual Mekong Flood Forum, Information Flow, Networking and Partnership, 28 - 29 October 2003, Phnom Penh, Cambodia
AMFF-3	3rd Annual Mekong Flood Forum, Flood Management and Mitigation in the Mekong Basin, 7 - 8 April 2005, Vientiane, Lao PDR
AMFF-4	4th Annual Mekong Flood Forum, Improving Flood Forecasting and Warning Systems for Flood Management and Mitigation in the Lower Mekong Basin, 18-19 May 2006, Siem Reap, Cambodia
AMFF-5	5th Annual Mekong Flood Forum, Improving Inputs Towards Medium-term Flood Forecasting and Warning in the Mekong Basin, 17 - 18 May 2007, Ho Chi Minh City, Viet Nam
AMFF-6	6th Annual Mekong Flood Forum, Integrated approaches and applicable models towards flood forecasting and early warning in the Mekong River Basin
APFM	Associated Programme on Flood Management
API	antecedent precipitation index
ARIMA	autoregressive integrated moving average
ARMA	autoregressive moving average
ARW	Advanced Weather Research Forecasting
AWS	Automatic Weather Station
BCM	billion cubic metres
BMD	Bangladesh Meteorological Department
BOH	Bureau of Hydrology
BWDB	Bangladesh Water Development Board
CAFFG	Central America Flash Flood Guidance
CBFRM	Community Based Flood (or general disaster) Risk Management
CBO	Community Based Organization
CCDM	Commune Committee on Disaster Management
CCFSC	Central Committee for Flood and Storm Control
CDP	Cambodian Defenders Project
CEGIS	Centre for Environmental and Geographic Information System
CEO	Chief Executive Officer
CFAB	Climate Forecast Application in Bangladesh
CFAN	Climate Forecast Application Network
CIFOR	Centre for International Forestry Research
CIP	Commune Investment Plan
CLUP	Commune Land Use Planning
CNMC	Cambodia National Mekong Committee
CONOPS	Concept of Operation
CRC	Cambodian Red Cross
CRED	Centre for Research on the Epidemiology of Disasters
CRHMC	Central Region Hydrometeorological Centre
CSA	Canadian Space Agency
CSO	Civil Society Organisation
CSPT	Committee on Sport and Physical Training
CTA	Chief Technical Advisor
CWRC	Yangtze (Changjiang) Water Resources Commission

DACA	Damage and Casualties Assessment
DAE	Department of Agriculture Extension
DANA	Damage and Needs Assessment
DANIDA	Danish International Development Agency
DCDM	District Committee for Disaster Management
DDMFCSP	Department of Dike Management, Flood Control, and Storm Preparedness
DEM	Digital Elevation Map
DEM	Digital Elevation Model
DFID	Department for International Development
DHRW	Department of Hydrology and River Works
DMB	Disaster Management Bureau
DMH	Department of Meteorology and Hydrology
DMR	Department of Mineral Resources
DOE	Department of Environment
DOLA	Department of Local Administration
DOM	Department of Meteorology
DONRE	Department of Natural Resources and Environment
DOR	Department of Roads
DORW	Department of River Works
DRR	Disaster Risk Reduction
DSF	Decision Support Framework
DTM	Digital Terrain Model
DUFLOW	Simplified 1D hydraulic flow model
DWIR	Directorate of Water Resources and Improvement of River Systems
DWR	Department of Water Resources
ECHO	European Commission Humanitarian Aid Department
ECMWF	European Centre for Medium-range Weather Forecasts
EFS	Empirical Forecasting Schemes
EGAT	Electricity Generating Authority of Thailand
EWS	early warning system
FAO	Food and Agriculture Organisation of the United Nations
FEMS	Flood Emergency Management Strengthening
FEWS	Flood Early Warning System
FEWS NET	Famine Early Warning Systems Network
FFG	Flash Flood Guidance
FFGS	Flash Flood Guidance System
FFP	
FFS	Flood Forecasting System
FFT	Flash Flood Threat
FFWC	Flood Forecasting and Warning Centre
FMM	Flood Management and Mitigation
FMMP	Flood Management and Mitigation Programme
FMMP-C2	Flood Management and Mitigation Programme, Component 2: aims at the development of guidelines for the preparation of flood risk management plans and for the evaluation of the impacts of flood risk management measures
FMMP-C3	Flood Management and Mitigation Programme, Component 3: to identify potential transboundary issues for negotiation, mediation and conflict prevention; and develop mediation and conflict management capacity
FPP	Flood Preparedness Plan
FPP	Flood Preparedness Program
FRMP	Flood Risk Management Plan
FSC	flood and storm control
FTP	File Transfer Protocol
FVI	Flood Vulnerability Index

GATECH	Georgia Institute of Technology
GCOS	Global Climate Observing System
GDAS	Global Data Assimilation System
GDP	Gross Domestic Product
GeoSFM	USGS Geospatial Streamflow Model
GIS	Geographic Information System
GMS	Greater Mekong Sub-region
GMT	Greenwich Mean Time
GNP	Gross National Product
GNSS	Global Navigation Satellite System
GOS	Global Observing System
GOV	Government of Viet Nam
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
GSMaP	Global Satellite Mapping of Precipitation
GT	ground truth
GTS	Global telecommunication system
GWP	Global Water Partnership
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HIS-SSM	'Hoogwater Informatie Systeem - Schade- en Slachtoffermodule'
HMDC	Hydrometeorological Data Centre
HOWISS	Hochwasser-Informations und Schutz-System (German)
HPC	High performance computing
HRC	Hydrologic Research Centre
HRM	High Resolution Model
HVCA	Hazard, Vulnerability and Capacity Assessment
HYCOS	Hydrological Cycle Observing System
HYMOS	Hydrological Modelling System
ICHARM	International Centre for Water Hazard and Risk Management
ICID	International Commission on Irrigation and Drainage
ICIMOD	International Centre for Integrated Mountain Development
ICPDR	International Commission for the Protection of the Danube River
IDS	International Development Statistics
IFM	Integrated Flood Management
IFRM	Integrated Flood Risk Management
IKMP	Information and Knowledge Management Programme
INGO	International Non-Governmental Organization
IO	International Organisation
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
ITC	International Institute for Geo-Information Science and Earth Observation
IWM	Institute of Water Modelling
IWRE	Institute of Water Resources and Environment
JC	MRC Council and Joint Committee
JICA	Japanese International Cooperation Agency
JMA	Japan Meteorological Agency
JTWC	Joint Typhoon Warning Centre
LA	Line Agency
LIDAR	Light Detection and Ranging
LMB	Lower Mekong River Basin
LMB-FMS	Lower Mekong Basin Flood Mapping Service
LNMC	Lao PDR National Mekong Committee
LNMCS	Lao National Mekong Committee Secretariat

LRIAD	Land Resources Inventory for Agricultural Development
M&E	monitoring and evaluation
MAF	Ministry of Agriculture and Forestry
MAFF	Ministry of Agriculture Forestry and Fisheries
MARD	Ministry of Agriculture and Rural Development
MCM	million cubic metres
MDV	Mekong Delta in Vietnam
M-HYCOS	Mekong Hydrological Cycle Observing System
MLMUPC	Ministry of Land Management Urban Planning and Construction
MM5	Fifth Generation Mesoscale Model
MOF	Ministry of Finance
MOFA	Ministry of Foreign Affairs
MONRE	Ministry of Natural Resources and Environment
MOU	Memoranda of Understanding
MOWRAM	Ministry of Water Resources and Meteorology
MPI	Ministry of Planning and Investment
MRB	Mekong River Basin
MRBV	Mekong River Basin of Vietnam
MRC	Mekong River Commission
MRC-IS	MRC Information System Portal
MRC-RFMMC	Mekong River Commission - Regional Flood Management and Mitigation Centre
MRCS	Mekong River Commission Secretariat
MRD	Mekong River Delta
MR-FFS	Mekong River Flood Forecasting System
MSL	Mean Sea Level
MTD	Multilingual Technical Dictionary of the International Commission on Irrigation and Drainage (ICID).
MTPWWM	Ministry of Transport, Public Works and Water Management
MWR	Ministry of Water Resources
NAM	Nedbør-Afstrømnings-Mode
NASA	National Aeronautics and Space Administration
NCDM	National Committee for Disaster Management
NCEP	National Centre for Environmental Protection
NCHMF	National Centre for Hydrometeorological Forecasting
NCSAR	National Committee for Search and Rescue
NDMC	National Disaster Management Committee
NDMO	National Disaster Management Office
NDVI	normalized difference vegetation index
NESDIS	National Environmental Satellite, Data, and Information Service
NFFS	National Flood Forecasting System
NFU	National Flood Unit
NGO	Non Government Organisation
NHMFC	National Hydro-Meteorological Forecasting Centre
NMC	National Mekong Committee
NMHS	National Meteorological and Hydrologic Service
NOAA	National Oceanic and Atmospheric Administration
NREM	Natural Resources and Environmental Management
NWP	Numerical Weather Prediction
NWS	National Weather Service
ODA	Overseas Development Assistance
OECD	Organisation for Economic Co-operation and Development
OEI	Overview Effects Infrastructure
O&M	Operation and Maintenance
OFDA	Office of U.S. Foreign Disaster Assistance
OIC	Office of Information and Culture

OOG	Office of the Government
PAFO	Provincial Agriculture and Forestry Office
PCDM	Provincial Committee for Disaster Management
PCFSC	Provincial Committee for Flood and Storm Control
PDIES	Procedures for Data and Information Exchange and Sharing
PDWRAM	Provincial Department of Water Resources and Meteorology
PHMFC	Provincial Hydrometeorological Forecasting Centre
PLUP	Participatory Land Use Planning
PHMO	Provincial Hydro Meteorological Office
PMHO	Provincial Meteorology and Hydrology Office
POD	Probability of prediction
POE	Probability of Exceedance
PSDD	Project to Support Democratic Development through Decentralization and Deconcentration
PUB	prediction in ungauged basin
PWRI	Public Works Research Institute
RANET	Radio and Internet
RFE	merged satellite- and ground-based rainfall estimation
RID	Royal Irrigation Department
RMSE	root mean square error
RORB	runoff and streamflow routing program
RTH	regional telecommunication hub
SA	sub-area
SCLS	synthesised constrained linear system
SFSP	School Flood Safety Program
SMAR	Soil Moisture Accounting and Routing
SPI	Standardized Precipitation Index
SPWG	Scientific Partnership Working Group
SRE	Satellite Rainfall Estimate
SRHMC	Southern Region Hydrometeorological Centre, Viet Nam
SRTM	Shuttle Radar Topography Mission
SSARR	Streamflow Simulation and Reservoir Regulation
STS	Severe Tropical Storm
SWOT	Surface Water Ocean Topography
TBFI	Transboundary flood issues
TBIDD	Transboundary flood issues, differences and disputes
TD	Tropical Depression
TIN	Triangulated Irregular Network
TMD	Thai Meteorological Department
TMPA	Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis
TOR	Terms of Reference
TOT	Training of trainers
TRMM	Tropical Rainfall Measuring Mission
TS	Tropical Storm
TSU	Technical Support Unit
UDMC	Union Disaster Management Committee
UNDP	United Nations Development Programme
URBS	actually not an acronym, but sometimes rendered as ‘Unified Run-off Basin Simulation’
USAID	U.S. Agency for International Development
USGS	U.S. Geological Survey
UTC	Universal Time Coordinate
VNMC	Vietnam National Mekong Committee

VNRC	Vietnam Red Cross
WAD	Waterways Administration Division
WAN	wide area network
WHH	Women headed household
WHM	Watershed hydrological models
WHYCOS	World Hydrological Cycle Observing System
WIGOS	WMOs Integrated Global Observing System
WIS	WMO Information System
WMO	World Meteorological Organization
WREA	Water Resources and Environment Administration
WRF	Weather Research Forecast

Glossary*

Annual-flood peak series	The tabulation or graph in order of decreasing magnitude of the maximum peak floods of each year.
Average annual flood	The mean of the annual floods over a number of years. The smallest of the annual floods during the period of record is called the 'minimum annual flood'.
Catastrophic flood	A flood due to meteorological conditions of exceptional rarity, and due either to catastrophical rainfall spread over a period considerably longer than the time of concentration for the area, or to violent rain of the cloud burst type. 2 - See 8179.
Controlled flooding	Unlike in free flooding, water is diverted to levelled lands and in a sequential manner in such a way as to deliver everywhere the desired dose: it includes flooding from ditches, border irrigation and corrugation irrigation.
Cyclone	Atmospheric system of low barometric pressure (depression) accompanied by strong winds that rotate counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. Called 'cyclone' in the Indian ocean and southern Pacific, it is called 'hurricane' in the western Atlantic and eastern Pacific and 'typhoon' in the western Pacific.
Depression	an area of lowered air pressure that generally brings moist weather, sometimes promoting hurricanes and tornadoes
Design flood	1 - The maximum flood that any structure can safely pass. 2 - The flood adopted to control the design of a structure. 3 - The flood against which a given area is to be protected.
Design flood hydrograph	The hydrograph of flow adopted to represent limiting volumes and concentration of runoff for use in determining design capacities of spillways for dams, etc., or other hydraulic studies.
Early warning	Information at the shortest notice that a flood may come, including on the expected magnitude of the flood
Extreme flood	The highest flood observed during a given period.
Flash flood	A flood of short duration and abrupt rise with a relatively high peak rate of flow, usually resulting from a high intensity of rainfall over a small area.
Flash flood guidance	Amount of rainfall for a given duration over a small basin needed to create minor flooding (bankfull) conditions at the outlet of the basin.
Flash flood threat	Rainfall of a given duration in excess of the corresponding flash flood guidance value. The *flash flood threat* then becomes an indication of areas where flooding is imminent or occurring and where immediate action is or will be shortly needed.
Flood	Natural abundance of water in response to storm rainfall, snowmelt, etc., ergo the flood season on the Mekong.....however, this does not necessarily lead to flooding.
Flood absorption	Reduction in flood discharge resulting from accommodation of flowing water in a reservoir, channel, valley or lake.
Flood damage	The destruction or impairment, partial or complete, of the value of goods or services, or of health, resulting from the action of flood waters and the silt and debris they carry. They are commonly divided into tangible - where monetary values can be assigned - and intangible - where direct monetary values cannot be assigned. Intangible damages include ecosystem loss and ill health, and attempts are being made to quantify in some way intangible damages. Flood losses can be direct - caused by the flood itself- or indirect,

* This glossary is mainly based on the Multi-Lingual Technical Dictionary of the International Commission on Irrigation and Drainage (ICID), New Delhi, India

	and caused by events triggered by the flood. Lost industrial production is an indirect loss. Flood losses are determined by flood depth, velocity, duration, timing (by season or time a day, for example), and sediment load.
Flood disaster	Disaster caused by an extreme flood, especially after the failure of dikes or dams.
Flood estimation	Approximate calculation or assessment of the probable height, frequency or magnitude of a flood.
Flood frequency	Over a period of years, the average number of times a flood of a given magnitude is likely to occur.
Flooding	The inundation of areas, which usually are not submerged.
Flood management	The organisation of responses to flood problems.
Flood control benefits	The value of the flood protection as estimated in terms of damage eliminated or other advantageous effects of the proposed works. 2 - The return from investment in flood alleviation schemes, either tangible or intangible. 3 - 'Direct benefits' based on reduction in flood damage to land and other property in terms of cost of restoration to preflood condition or reduction in its value and reduced damages to crops in terms of market value adjusted by replanting possibilities and production costs not incurred; and 'indirect benefits' based on higher grade use of land formerly flooded in terms of increased earnings, and reduced interruption of business, industry and commerce, traffic, communications and other activities both within and outside the area subject to flooding in terms of net loss of income or added operating costs and cost of evacuation, reoccupation, temporary quarters, emergency flood protection work, and relief and care of flood victims.
Flooded area	*Area covered by water when streamflow exceeds the carrying capacity of a channel or as a consequence of damming a river downstream. 2 - Area flooded due to (i) storm surges and/or subsequent dike breaches, (ii) impeded drainage of rain water.*
Flood forecasting	Prediction of the characteristics of an imminent future flood (timing, depth, discharge, etc.) given current information. The prediction of flood events on the basis of analysis of essential meteorologic data, such as storm trends, antecedent precipitation, air moisture, temperature trends, wind etc. Analysis of such information in relation to known stream response behaviour and basin characteristics can provide the basis for issue of flood warnings. The rapidity of data accumulation and analysis, and of dissemination of resulting warnings, is vital to the effectiveness of flood forecasting. 2 - The science of forecasting the stage, discharge, time of occurrence, and duration of a flood, especially of peak discharge at a specified point on a stream, resulting from precipitation and/or snowmelt and based on the existing meteorological and hydrologic conditions. The goal of flood forecasting is to obtain real-time precipitation and stream flow data through a microwave, radio, or satellite communications network, insert the data into rainfall-runoff and stream flow routing programs, and forecast flood flow rates and water levels for periods of from a few hours to a few days ahead, depending on the size of the watershed.
Flood irrigation	A method of irrigation in which water is swiftly taken towards one or more storage basins where it collects before infiltrating into the soil. In the case of more permeable and less deep soils, several waterings are required during the cultivation season. 2 - Colloquially, surface irrigation, especially those methods where the soil surface is indundated.
Floodplain	The portion of the landscape inundated by a flood. The extent of the floodplain is often defined by a particular frequency flood : the 100-year floodplain is the area inundated by a flood with an average return period between events of 100 years, or an annual probability of occurrence of 0.01 (illustrated). 2 - The flood prone areas adjacent to a river channel over which flood waters habitually and temporarily spill when river flows exceed the bank-full capacity of the river channel. In flatter areas, the floodplain serves as a substantial reservoir, storing excess run-off and attenuating the flood

	peak. Additionally, floodplains can also provide substantial discharge capacity, depending on ground slopes and shapes, and upon the depth of inundation. The formal designation of the floodplain can be a difficult task, involving the definition of appropriate flood volumes, levels, and return period. Generally a 100-year return period flood level is accepted as defining the limit of a floodplain.
Flood prone area	Area that may be subject to flooding, either periodically, or when flood protection measures fail.
Flood preparedness	Timely taking of measures to eliminate, reduce, or mitigate the possible damaging effects of floods.
Flood protection	The protection from flood damage afforded by a given programme of flood control.
Flood risk	A measure of the seriousness of the flood hazard : 1 - The chance of experiencing a flood. Risk is usually expressed in terms of the return period of peak discharges, but velocities, sediment loads and depths are sometimes also used in identifying risk zones. An assessment of risk may also be based on the life and property exposed. 2 - The probability of an event multiplied by its consequences (such as event damages). This is equal to the expected value of damage, and is a concept used in risk analysis.
Flood risk map	1 - A map that depicts the extent of former floods or the anticipated extent of any particular magnitude of flood. 2 - The identification and representation of flood risk areas on a map. 3 - Topographic maps of river floodplain areas that identify the estimated water levels associated with a series of floods typically of 10, 20, 50 and 100-year return period.
Flood stage	The elevation of the water surface fixed by local usage above which the stream is considered to be in flood.
Flood storage	The part of the active storage used exclusively for flood control. 'Flood storage' should not be confused with 'flood surcharge'.
Flood vulnerability	the susceptibility of a person or group to the adverse impacts of flooding.
Flood wave	A rise in stream flow to a crest consequent of runoff, generated by precipitation, and its subsequent recession constitutes a flood wave.A flood wave may also be regarded as a temporary unbalance in river regime resulting from the application of more water to the land in the form of precipitation or by the melting of snow that can be absorbed by the land itself. The regime during the resulting unsteady flow is determined, largely , by complex local transfers of energy and of volume.
Maximum computed flood	The largest momentary discharge believed possible from a consideration of meteorological condition and snow cover on the watershed. It pre-supposes simultaneous occurrence of all possible natural contingencies favourable to high floods.
Maximum flood	The highest of the recorded floods, at a section of a stream, during a specified period; the period may be a week, a month, a year or even the entire period of record.
Maximum probable flood	Flood which would be produced by the maximum probable precipitation and which is computed using a rainfall-runoff relationship (like unit hydrograph).
Minimum annual flood	The smallest of the annual floods during the period of record.
Monthly flood	The maximum flow occurring in a stream during a calendar month.
Nonstructural measures	The measures that alter the exposure of life and property to flooding (floodplain land use planning, flood forecasting and warning, flood-proofing, assistance).
N-Year flood	A flood which has a probability of being equalled or exceeded once every N-years or has one chance in N of occurring in any one year.
Resilience	The ability of a community and its infrastructure to recover from the adverse impacts of natural disasters; it is a measure of both the time and extent of the recovery.

River flood	A relatively high flow or stage in a river, markedly higher than the usual. A mass of water, rising, swelling and overflowing land.
Spillway design flood	1 - The flood that has been decided to be carried past the dam, without failure of that structure during a stipulated time period after a thorough study of the hydrology of the drainage area. 2 - The flood used in the design of a dam for sizing the spillway and for determining the flood storage or the flood subcharge during a determined time period.
Structural measures	The measures that alters the physical characteristics of the floods (reservoir operation, upstream catchment management, channel modifications, levees, operation of hydraulics works).
Tidal flood interval	Time between transit of moon over meridian of a place and the time of the following strength of flood.
Tropical cyclone	Cyclone originating in the tropics
Tropical storm	A cyclonic storm having winds ranging from approximately 48 to 121 kilometres per hour
Tsunami	Flood in coastal areas or in low lying lands, caused by sea waves after a submarine earthquake or a volcanic eruption.
Typhoon	Any violent tropical cyclone originating in the W Pacific, esp. in the South China Sea
Vulnerability	The characteristics of a person or group and their situation that influence their capacity to cope with, resist and recover from the impact of a natural hazard

SIXTH ANNUAL MEKONG FLOOD FORUM (AMFF-6)

Integrated Approaches and Applicable Systems for Medium Term Flood Forecasting and Early Warning in the Mekong River Basin

27 – 28 May 2008
Cambodiana Hotel, Phnom Penh, Cambodia

List of Participants

No	Name and Title	Organization and Address	Electronic contact
		Cambodia	
1.	H.E. Mr. Sin Niny Vice Chairman of CNMC	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-218-727 or 216-514 Mob: Fax: +855-023-218-506 Email:
2.	H.E. Mr. Pich Dun Secretary General/Head of Delegation	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-218-727 or 216-514 Mob: +855-012-949-877 Fax: +855-023-218-506 Email: dun@cnmc.gov.kh
3.	H.E Mr. Kol Vathana Deputy Secretary General	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-218-727 or 216-514 Mob: +855-012-388-502 Fax: +855-023-218-506 Email:
4.	Mr. Watt Botkosal Director	Planning Department, Cambodia National Mekong Committee, # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-216-514 Mob: +855-011-871-387 Fax: +855-023-218-506 Email: wattbotkosal@cnmc.gov.kh
5.	Mr. Hak Socheat FMMP National Coordinator	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-216-514 Mob: +855-011-796-998 Fax: +855-023-218-506 Email: socheat@cnmc.gov.kh
6.	Mr. Heng Phearith EP Coordinator	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-218-727 or 216-514 Mob: Fax: +855-023-218-506 Email:
7.	Mr. Suos Bunthan Vice Chief	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-216-514 Mob: +855-012-924-451 Fax: +855-023-218-506 Email: bunthan@cnmc.gov.kh
8.	Mr. Ku Khemlin IKMP Coordinator	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: Mob: Fax: Email:
9.	Mr. Sok Bun Heng National Flood Expert	Cambodia National Mekong Committee # 23 Mao Tse Toung Rd, Phnom Penh, Cambodia	Tel: +855-023-216-514, Mob: +855-012-773-590 Fax: +855-023-218-506 Email: bunheng67@yahoo.com
10.	Mr. Hang Bunnak Deputy Director General	Ministry of Land Management, Urban Planning & Construction, Phnom Penh, Cambodia	Tel: Mob: Fax: Email:
11.	Mr. Khun Sokha Director	Training and Preparedness Department, National Committee for Disaster Management, Phnom Penh, Cambodia	Tel: Mob: Fax: Email:
12.	Mr. Eng Cheasan Deputy Director	Fisheries Administration, Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia	Tel: Mob: Fax: Email:

No	Name and Title	Organization and Address	Electronic contact
13.	Mr. Chiv Hour Deputy Director	Hydropower Department, MIME, Phnom Penh, Cambodia	Tel: Mob: Fax: Email:
14.	Mr. Yin Savuth Deputy Director	Hydrology and River Works Department, Ministry of Water Resources and Meteorology # 576, National Road 2, Angre Krom, Meanchey, Phnom Penh, Cambodia	Tel: Mob: +855-012-974-322 Fax: +855-023-425-645 Email: savuthyin@yahoo.com
15.	Mr. Suy Sovann Chief	Hydrology and River Works Department, Ministry of Water Resources and Meteorology # 576, National Road 2, Angre Krom, Meanchey, Phnom Penh, Cambodia	Tel: Mob: +855-012-933-902 Fax: Email: suy-so-vann@yahoo.com
16.	Mrs. Chhun Sokun Vice Chief	Climate Office, Department of Meteorology, Ministry of Water Resource and Meteorology (MOWRAM), # 4, Sangkat Kakap, Khan Dongkor, Phnom Penh, Cambodia	Tel: Mob: +855-012-527-707 Fax: Email: sokunth11@yahoo.com
17.	Mr. Duch Sam Ang Disaster Response Preparedness Coordinator	Cambodia Red Cross, # 17, Street Cambodia Red Cross Phnom Penh, Cambodia	Tel: +855-023-212-876/362 876 Mob: +855-012-880-503 Fax: +855-023-212-875/362 140 Email: sam_ang.crcews@everyday.com.kh
18.	Mr. Ros Sophornna	Ministry of Public Works and Transport, Phnom Penh, Cambodia	Tel: Mob: +855-012-628-356 Fax: Email: sophornna_r@yahoo.co.uk
19.	Mr. Lieng Sopha	Fisheries Administration, Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia	Tel: Mob: Fax: Email:
	Lao PDR		
20.	Mr. Chanthavong Saignasith Director General	LNMC Secretariat, Prime Minister's Office, Lao National Mekong Committee Secretariat, Lane Xang Avenue, 01000, Vientiane, Lao PDR	Tel.: +856-021-260-981 - 3 Mob: Fax.: +856-021-260-984 Email: chanthavong@lnmc.gov.la
21.	Mr. Phonechaleun Nonthaxay Director	Water Resources Coordination Committee Secretariat, Vientiane, Lao PDR	Tel: 856-021-218-737 Mob: +856-020-559-9916 Fax: +856-021-218-737 Email: nonthaxay@yahoo.com
22.	Mr. Khamphay Sosengphet National CBP Coordinator	Vientiane, Lao PDR	Tel.: Mob: Fax.: Email:
23.	Mr. Chanthachith Amphaychith Acting Head of Water Resources Department/National FMMP Coordinator	LNMC Secretariat, Prime Minister's Office, Lao National Mekong Committee Secretariat, Lane Xang Avenue, 01000, Vientiane, Lao PDR	Tel.: +856-021-260-981 - 3 Mob: +856-020-590-9314 Fax.: +856-021-260-984 Email: chith3468@yahoo.com
24.	Mr. Khanmany Khounphonh Head of Technical Division	Department of Meteorology and Hydrology, Ministry of Agriculture and Forestry P.O. Box 811, Luong Prabang Road North No 13 Vientiane, Lao PDR	Tel: +856-021-215-010 Mob: 856-020-566-9837 Fax: 856-021-223-446 Email: dmhvte@laotel.com or khammany_dmh@etllao.com
25.	Mr. Khammay Vongsathien Director	Irrigation and Drainage Development Division, Department of Irrigation, Ministry of Agriculture and Forestry, P.O. Box 811, Vientiane, Lao PDR	Tel: Mob: +856-020-591-5892 Fax: Email: std159@hotmail.coom
26.	Mr. Phoumyenh Khounthikoummane, Senior Engineering	Department of Inland Waterway Transport, Ministry of Public Works and Transports, Lanxang Road, P.O. Box 2158, Vientiane, Lao PDR	Tel: +856-021-453-279 Mob: +856-020-541-4877 Fax: +86-021-416-430 Email: phoumyenh@yahoo.com

Participants list

No	Name and Title	Organization and Address	Electronic contact
27.	Mr. Vilayphong Sisomvang Acting Deputy Director General	National Disaster Management Office, Ministry of Labour and Social-Welfare, P.O Box 347, Pangkhan Road, Chanthabuli Vientiane, Lao PDR	Tel: +856-021-219-450 Mob: +856-020-565-4494 Fax: +856-021-213-287 Email: hamyai1@yahoo.com or ndmo@laopdr.com
28.	Mr. Virana Sonnasinh National Flood Expert	LNMC Secretariat, Prime Minister's Office, Lao National Mekong Committee Secretariat, Lane Xang Avenue, 01000, Vientiane, Lao PDR	Tel: +856-021-260-981 - 3 Mob: +856-020-540-7583 Fax: +856-021-260-984 Email: virana@lnmc.gov.la
29.	Ms. Hongkham Vongsay Technical Official of IKMP	LNMC Secretariat, Prime Minister's Office, Lao National Mekong Committee Secretariat, Lane Xang Avenue, 01000, Vientiane, Lao PDR	Tel: +856-021 260 981-3 Mob: Fax: +856-021 260 984 Email: hongkham@lnmc.gov.la
Thailand			
30.	Mr. Boontham Sirichai Director	Bureau of Research and Development Hydrology Division, Department of Water Resources (DWR), 180/3 Rama 6 Road, Soi 34, Phayathai, Bangkok 10400, Thailand	Tel: +66-2-271-6000 Mob: Fax: +66-2-271-6000 Email:
31.	Mr. Tosporn Suddhajinda Director	Water Crisis Prevention Center, Department of Water Resources (DWR), 180/3 Rama 6 Road, Soi 34, Phaya Thai, Bangkok 10400, Thailand	Tel: +66-2-271-6000 Mob: Fax: +66-2-271-6000 Email: supapap@dwr.go.th
32.	Mrs. Varunee Charoensamran Director	Research and Development Hydrology Division, Department of Water Resources(DWR), 180/3 Soi Phibulwatana 34, Rama 6 RD, Sam Sean Nai District, Bangkok 10400, Thailand	Tel: +662-298-6614 Mob: Fax: +662-298-6614 Email: varunee46@hotmail.com
33.	Mr. Supapap Patsinghasanee Civil Engineer	Water Crisis Prevention Center, Department of Water Resources (DWR), 180/3 Rama 6 Road, Sam Sean Nai, Phaya Thai, Bangkok 10400, Thailand	Tel: +66-2-271-6000 Ext. 6411 Mob: +66-89-772-4611 Fax: +66-2-271-6000 Email: supapap@dwr.go.th
34.	Mr. Paitoon Naktae Senior Civil Engineering	Department of Disaster Prevention and Mitigation, Bangkok, Thailand	Tel: Mob: +66-819-771-146 Fax: Email: paitoon-bk@yahoo.com
35.	Mr. Suwit Thanopanuwat Professional Engineer for Planning	Royal Irrigation Department, Bangkok, Thailand	Tel: Mob: Fax: Email: thanopanuwat@yahoo.com
36.	Ms. Sotharat Insawang Chief/Meteorologist	Hydrological Group, Thai Meteorological Development, # 4353 Sukhumvit Road, Bangna, Bangkok, Thailand	Tel: +662-399-2666 Mob: Fax: +662-399-2595 Email: sorat-i@yahoo.com
37.	Dr. Chaiyuth Sukhsri, Head of Dept.	Water Resources Engineering Department, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand	Tel: Mob: Fax: Email:
38.	Mr. Burachat Buasuwan Senior Policy and Planning Analyst/National FMMP Coordinator	TNMC, Department of Water Resources, 180/3 Rama 6 Road, Soi 34, Phayathai, Bangkok 10400, Thailand	Tel: +66-2-298-6605 Mob: +66-818-445-323 Fax: +66-2-298-6605 Email: burachatster@gmail.com
Vietnam			
39.	Dr. Dao Trong Tu Deputy Secretary General	Vietnam National Mekong Committee 23 Hang Tree, Ha Noi, Vietnam	Tel: +844-934-3565 Mob: +840-913-234-562 Fax: +844-825-6929 Email: tudaotrong49@yahoo.com.vn
40.	Ms. Nguyen Hong Phuong National FMMP Coordinator	Vietnam National Mekong Committee 23 Hang Tre, Ha Noi, Vietnam	Tel: +844-934-3565 Mob: +844-0913-034-410 Fax: +844-825-6929 Email: hongphuong.nguyen@gmail.com

No	Name and Title	Organization and Address	Electronic contact
41.	Mr. Nguyen Viet Tien Programme Officer	Department of Dyke Management Storm and Flood Control, MARD, Hanoi, Vietnam	Tel: +844-733-5695 Mob: 844-091-355-4352 Fax: +844-733-5701 Email: nguyennettien2001@yahoo.com
42.	Mr. Bui Duc Long Chief	National Center for Hydrometeological Forecasting, Ministry of natural Resources and Environment, # 3 Dang Thai Than Street, Hanoi, Vietnam	Tel.: +844-824-4921 Mob: +844-091-267-1565 Fax: +844-933-0259 Email: bui_duclong@yahoo.com
43.	Mr. Pham Van Duc Director General	Southern Regional Hydrometeological Centre, Ho Chi Minh, Vietnam	Tel: Mob: Fax: Email:
44.	Mr. Nguyen Van Duong Director	DARD of Dong Thap Province, Vietnam	Tel: +84-067-240-850 Mob: +84-091-396-7288 Fax: +84-067-851-513 Email: vanduong@yahoo.com
45.	Ms. Ly Thi Tuanh Tuyen Expert	DARD of An Giang Province, Vietnam	Tel: +84-076-852-155 Mob: +84-091-897-4523 Fax: +84-076-852-037 Email: lythanh_tuyen@yahoo.com
46.	Mr. Pham Tan Dung Deputy Head	Water Resources Sub-Department of Tien Giang Province, Vietnam	Tel: +84-073-855-108 Mob: +84-091-839-0897 Fax: +84-073-855-338 Email: landungtg@yahoo.com
47.	Mr. Trinh Hoang Ngan National Flood Expert	Vietnam National Mekong Committee # 135, Pasteur, District 3, Ho Chi Minh City Vietnam	Tel: +848-827-2652 Mob: +840-903-685-960 Fax: +848-827-2609 Email: nganth2701@yahoo.com.vn
48.	Mr. Huynh Minh Ngoc Programme Officer	Vietnam National Mekong Committee 23 Hang Tre, Ha Noi, Vietnam	Tel: +844-934-3565 Mob: +844-912-018-584 Fax: +844-825-6929 Email: ngocvnmc@yahoo.com
Dialogue Partners from Upstream Countries			
China			
49.	Dr. Guoqing Wang Senior Engineer	Research Center for Climate Change, Ministry of Water Resources, Nanjing Hydraulic Research Institute, No. 223 Guangzhou Road, Nanjing, 210029, P.R. China	Tel: +86-371-6602-8444 Mob: +86-139-1392-5820 Fax: Email: gqwang0258@yahoo.com.cn
50.	Mr. Luo Xiangsheng Deputy Director	Bureau of International Cooperation, Science & Technology, Division of International Cooperation, Changjiang Water Resources Commission (CWRC) Ministry of Water Resources of P.R.C. # 1863, Liberation Ave. Wuhan, 430010, China	Tel: +86-27-8282-8609 Mob: Fax: +86-27-8282-0219 Email: luoxsh@cjw.com.cn ; luoxsh1966@hotmail.com
Myanmar			
51.	Mr. U Hla Myint Thein Deputy Director General	Department of Water Resources and Improvement of Rivers Systems, Ministry of Transport, Lower Pazundaung Road, Pazundaung Post Office, Yangon, Union of Myanmar	Tel: +951-292-136 Mob: +95-095-161-569 Fax: +951-290-230 Email: dwir@myanmar.com.mm
52.	Mr. U Sein Tun Deputy Director	Directorate of Water Resources and Improvement of River System, Pazundaung Post Office, Yangon, Union of Myanmar	Tel: +951-292-961 Mob: +95-09-503-5127 Fax: +951-290-230 Email: dwir@myanmar.com.mm
Donor Representatives			
Asian Development Bank (ADB) – Philippines			
53.	Mr. Ian W. Makin Senior Water Resources Specialist	Asian Development Bank, Mandaluyong City, Manila, Philippines	Tel: +632-632-5803 Mob: +63-917-519-1954 Fax: +632-636-2231 Email: imakin@adb.org

Participants list

No	Name and Title	Organization and Address	Electronic contact
The Royal Netherlands Embassy – Vietnam			
54.	Dr. Armand Evers First Secretary Water Management	Royal Netherlands Embassy Daeha Office Tower, 6th Floor, 360 Km Ma Street, Ba Dinh District, Hanoi, Vietnam	Tel: +844-831-5650 Mob: +849-03-260-022 Fax: +844-831-5655 Email: armand.evers@minbuza.nl www.netherlands-embassy.org.vn
The World Bank – Thailand			
55.	Mr. Toru Konishi Senior Economist	The World Bank, 30th Floor, Siam Tower, 989 Rama Road, Pathumwan, Bangkok 10330, Thailand	Tel: +662-686-8300 Mob: Fax: +662-686-8201 Email: tkonishi@worldbank.org
USAID Office of US Foreign Disaster Assistance – USA			
56.	Dr. Tokar, Ayse Sezin Hydrometeorological Hazard Advisor	USAID Office of US Foreign Disaster Assistance, DCHA/OFDA RRB 8.06.46, 1300 Pennsylvania Ave., NW Washington, DC 20523-8602, USA	Tel: +202-712-4033 Mob: Fax: +202-216-3706/07 Email: stokar@usaid.gov
International Organizations and Civil Society Organizations			
3S Rivers Protection Network, Cambodia			
57.	Mr. Meach Mean Deputy Director	3S Rivers Protection Network, P.O. Box 89007, Banlung, Ratanakiri, Cambodia	Tel: +855 75 974 112 Mob: +855 11 758 970 Fax: Email: sesan@online.com.kh
Archetype Cambodia Co. Ltd. – Cambodia			
58.	Mr. Kin Seanvirak Site Engineer	Archetype Cambodia Co. Ltd., Phnom Penh Centre Entrance B1, 1st Floor, Phnom Penh, Cambodia	Tel: +855-023-987-211 Mob: +855-17-460-097 Fax: +855-023-993-630 Email: seanvirak@gmail.com
Asian Disaster Preparedness Center (ADPC) – Thailand			
59.	Mr. S.H.M. Fakhruddin	Climate Risk Management/Early Warning System, Asian Disaster Preparedness Center, P.O. Box 4, Klong Luang, Pathumthani 12120 Thailand	Tel: +66-2-516-5900, Ext. 206 Mob: +66-8-799-29694 Fax: +66-2-524-5360 Email: fakhruddin@adpc.net
60.	Mr. Jaiganesh Murugesan Disaster Reduction Specialist	Climate Risk Management/Early Warning System, Asian Disaster Preparedness Center, P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand	Tel: +66-2-516-5900-10 Mob: +66-8966-27948 Fax: +66-2-524-5360 Email: jaiganesm@adpc.net or jaiganesh09@gmail.com
61.	Dr. Pvs Raju Climatologist	Early Warning System, Asian Disaster Preparedness Center, Asian Institute of Technology Campus P.O. Box 4, Klong Luang, Pathumthani 12120, Thailand	Tel: +66-2-516-5900-10 Mob: +66-8329-92678 Fax: +66-2-524-5360 Email: pvsraju@adpc.net
Canadian Space Agency – Canada			
62.	Mr. Steve Iris Project Manager	Canadian Space Agency 6767 Route de l'aéroport, Saint-Hubert, Qc, Canada J3Y 8Y9	Tel: +450-926-4439 Mob: +514-502-5528 Fax: +450-926-4613 Email: steve.iris@space.gc
Deltares – The Netherlands			
63.	Ir. Adri Verwey Senior Specialist Modeling Systems	Deltares, P.O. Box 177 2600 MH Delft The Netherlands	Tel: +31-15-285-8925 or 285-8585 Mob: +31-6-5197-0120 Fax: +31-15-285-8582 Email: Adri.Verwey@deltare.nl
64.	Mr. Ruben Dahm Consultant Water Management	Deltares, P.O. Box 177 2600 MH Delft The Netherlands	Tel: +31-15-285-8925 or 285-8585 Mob: Fax: +31-15-285-8582 Email:

No	Name and Title	Organization and Address	Electronic contact
Disaster Management Systems Team (DMS) – Cambodia			
65.	Mr. Thanongdeth Insisiengmay Program Manager	Disaster Management Systems Team (DMS) Asian Disaster Preparedness Center (ADPC) # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: +855-012-715-874 Fax: +855-023-425-363 Email: thanongdeth@adpc.net
66.	Mr. Aslam Perwaiz Project Manager	Disaster Management Systems Team (DMS) Asian Disaster Preparedness Center (ADPC) # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: Fax: +855-023-425-363 Email:
67.	Mr. Chum Vuthy National Project Manager	Disaster Management Systems Team (DMS) Asian Disaster Preparedness Center (ADPC) # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: +855-012-709-488 Fax: +855-023-425-363 Email:
68.	Mr. Nguyen Huu On Program Coordinator	Disaster Management Systems Team (DMS) Asian Disaster Preparedness Center (ADPC) # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: Fax: +855-023-425-363 Email:
Flemish Office – Cambodia			
69.	Mr. Ra Chanroat MBA Candidate of CUS/Project Assistance	Flemish Office for Cooperation Development and Technical Assistance, C/c: PTTC Siem Reap, Mondol 3, Siem Reap, Cambodia	Tel: +855-63-761-153 Mob: +855-012-751-685 Fax: +855-63-761-153 Email: chanroatvvob@online.com.kh
Hatfield – Indonesia			
70.	Dr. Andrew Dean Vice Psident	PT Hatfield, LIPI Building, 3rd Floor, JI, Ir. H. Juanda No. 18, Indonesia	Tel: +62+(0)-251-324-487 Mob: +62-(0)-81-318-321-331 Fax: +62-(0)-251-340-414 Email: adean@hatfieldgroup.com
HKV Consultants – The Netherlands			
71.	Mrs. Jakolien Leenders Adviser Disaster Management	HKV Lijn in Water P.O. Box 120, 8203 AC Lelystad, The Netherlands	Tel: +31-320-294-244 Mob: Fax: +31-320-253-901 Email: j.k.leenders@hkv.nl
72.	Mr. Jurjen Bernardus Wagemaker Cost Benefit Expert	HKV Consultants, Botter 11-29, 8232 JN Lelysad, The Netherlands	Tel: +31-320-294-242 Mob: +31-613-744-533 Fax: +31-320-253-901 Email: wagemaker@hkv.nl
73.	Mr. Arne Roelevink Consultant Water Management	HKV Consultants, P.O. Box 2120, Botter 11-29, 8232 JN Lelysad, The Netherlands	Tel: +31-320-294-242 Mob: +31-619-654-643 Fax: +31-320-253-901 Email: a.roelevink@hkv.nl
Hydrologic Research Centre – USA			
74.	Mr. Robert Water Jubach General Manager	Secretary – Board of Directors, Hydrologic Research Center 12780 High Bluff Drive, San Diego, CA 92130, California, USA	Tel: +858-794-2726 or +858-345-1360 Mob: +240-422-3626 Fax: +858—792-2519 Email: RJubach@hrc-lab.org Website: www.hrc-lab.org
International Centre for Water Hazard and Risk Management (ICHARM) - Japan			
75	Mr. Kuniyoshi Takeuchi Director	ICHARM, under the auspices of UNESCO, Public Works Research Institute 1-6 Minamihara, Tsukuba, Ibaraki 305-8516, Japan	Tel: +81-29-879-0854 Mob: Fax: +81-29-879-6709 Email: kuni.y@pwri.go.jp
76	Mr. Jun Magome Researcher	ICHARM, under the auspices of UNESCO, Public Works Research Institute 1-6 Minamihara, Tsukuba, Ibaraki 305-8516, Japan	Tel: +81-29-879-6779 Mob: Fax: +81-29-879-6709 Email: magome@pwri.go.jp
77	Mr. Kazuhiko Fukami Team Leader	ICHARM, under the auspices of UNESCO, Public Works Research Institute 1-6 Minamihara, Tsukuba, Ibaraki 305-8516, Japan	Tel: +81-29-879-6779 Fax: +81-29-879-6709 Email: k-fukami@pwri.go.jp

Participants list

No	Name and Title	Organization and Address	Electronic contact
International Institute for Geo-Information Science and Earth Observation (ITC), The Netherlands			
78.	Mr. Gabriel Norberto Parodi Docent and Researcher	International Institute for Geo-Information Science and Earth Observation (ITC), Hengelossesstraat 99, Enschede, The Netherlands	Tel: +31-53-487 4585 Mob: Fax: +31 53 487 4336 Email: parodi@itc.nl
79.	Mr. Tom Rientjes Assistant Professor	ITC Netherlands, Postbus 6, 7500 AA Enschede, The Netherlands	Tel: +31-53-487-4232 Mob: Fax: Email: rienties@itc.nl
Oxfam America – Cambodia			
80.	Mr. Abdul Latif Khan Regional Humanitarian Response Programme Officer	Oxfam America, East Asia Regional Office, 3rd Floor, # 54, Street 108, Wat Phnom, Daun Penh, Phnom Penh, Cambodia	Tel: +855-023-210-357 Mob: +855-012-873-300 Fax: +855-023-223-119 Email: lkhan@oxfamamerica.org
Pyser-SGI (Asia) Pte Ltd./Teledyne RD Instruments - - Singapore			
81.	Mr. William Koh Tiam Huat Executive Director	Pyser-SGI (Asia) Pte Ltd./Teledyne RD Instruments Inc. 65 Ubi Crescent, # 060-01 HOLA Centre, Singapore 408559	Tel: +65-6749-7784 Mob: +65-9767-8515 Fax: +65-6749-3992 Email: williamkoh@pyser-sgi.com.sg
Royal Haskoning/FMMP-C2 – Cambodia			
82.	Mr. Guus Sutmuller Team Leader	Royal Haskoning/FMMP-C2, Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: +855-17-559-080 Fax: +855-023-425-363 Email: g.sutmuller@royalhaskoning.com
83.	Mr. Sok Saing Im National Programme Specialist of Cambodia	FMMP-C2, Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-885-387 Mob: +855-011-602-890 Fax: +855-023-885-387 Email: saing_im@online.com.kh
84.	Mr. Alexanander Mueller Senior Development Economist	Royal Haskoning/FMMP-C2, Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: +855-092-130-457 Fax: +855-023-425-363 Email: alexander_m_mueller@hotmail.com
85.	Mr. Mao Vanchann Regional Environment Specialist	FMMP-C2, Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: +855-011-956-131 Fax: +855-023-425-363 Email: mvanchann@yahoo.com
86.	Mr. Fortunato Carvajal Monar Senior River/Hydraulics Specialist	Royal Haskoning/FMMP-C2, Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353 Mob: Fax: +855-023-425-363 Email: f.carvajalmonar@royalhaskoning.com
Sea and Land Technologies Pte Ltd., - Singapore			
87.	Mr. Floyd Ng	Sea and Land Technologies Pte Ltd., 65 Tuas Avenue 1, Singapore 639508	Tel: +65-6518-0777 Mob: Fax: +65-6563-0366 Email:
88.	Mr. Mark Tepper	Sea and Land Technologies Pte Ltd., 65 Tuas Avenue 1, Singapore 639508	Tel: +65-6518-0777 Mob: Fax: +65-6563-0366 Email:
SPLASH-DFID-WEDC – United Kingdom			
89	Dr. Julie Fisher WEDC International Conference Manager and Research Associate	SPLASH-DFID-WEDC, Water, Engineering and Development Centre (WEDC), The John Pickford Building Loughborough University, Leicestershire LE11 3TU, United Kingdom	Tel: +44-0-1509-222-393 or 222-885 Mob: Fax: +44-0-1509-211-079 Email: j.fisherl@lboro.ac.uk

No	Name and Title	Organization and Address	Electronic contact
		SPLASH-German Development Institute – Germany	
90	Mr. Tanja Buhles Research Fellow	SPLASH-German Development Institute, Tulpenfd 6, D-53113 Bonn, Germany	Tel: +49-(0)-228/949-27-180 Mob: +49-(0)-173-584-7637 Fax: +49-(0)-228/949-27-130 Email: tanja.buhles@die-gdi.de
		SPLASH-Hydrophil – Austria	
91	Mr. Aard Hartveld	SPLASH-Hydroliphil, SPLASH Work Package 4 leader, Lerchenfelder Guertel 43 top 6.3 a-1160 Wien, Austria	Tel: +43-494-64590 Mob: +43-664-861-8410 Fax: Email: aard.hartveld@chello.at
92	Dr. Gerald Eder Consultant	Advisor to the Austrian Development Cooperation, SPLASH Work Package 4 leader, Lerchenfelder Guertel 43 top 6.3 a-1160 Wien, Vienna, Austria	Tel: +43-494-6459 Mob: +43-664-533-6083 Fax: +43-494-645-940 Email: gerald.eder@hydrophil.at
		United Nations Development Program (UNDP) – China	
93.	Mr. Marshall L. Silver	United Nations Development Program T-13 2302 Seasons Park Towers, B36 Dong Zhi Men Wai Street, Dong Cheng District, Beijing 100027, China	Tel: +86-10-8453-2346 Mob: +86-136-8309-2233 Fax: +86-10-8453-2346 Email: marshall.silver@marshallsilver.us
		United Nations Development Program (UNDP) – Vietnam	
94.	Mr. Ong Thi Ngan Tien Project Assistant	United Nations Development Program, UNDP Project, 15/05 Thu Khoa Huan, My Binh, Long Xuyen, An Giang Province, Vietnam	Tel: Mob: +84-98-514-4841 Fax: Email: ongngantien@gmail.com
		University of Karlsruhe – Germany	
95.	Prof. Dr. Erich J Plate Professor for Hydrologic and Water Resources	University of Karlsruhe Am Kirchberg 49, 76229 Karlsruhe Germany	Tel: +49-721-468-752 Mob: Fax: +49-721-9463-984 Email: plate@Iwk.uka.de
96.	Mr. Muhammad Khurram Shahzad Msc. Hydrology	University of Karlsruhe, Hydrology Section, Institute for Water and River System Development, Kaiserstrasse 12, D-76128 Karlsruhe, Germany	Tel: +49-721-608-3903 Mob: +49-176-238-91029 Fax: +49-721-608-5651 Email: gg49@iwk.uka.de or shahzad@iwg.uka.de
		US Army Corps of Engineers – USA	
97.	Mr. John Emmerson Program Manager	US Army Corps Engineers, Building 525, Fort Shafter, Hawaii 96858-5440, USA	Tel: +808-438-6968 Mob: +808-721-6897 Fax: +808-438-9110 Email: jonh.g.emmerson@usace.army.mil
98.	Mr. Mark M. Schnabel Program Manager and Liaison to PACOM	US Army Corps of Engineers, 91-1019 Hokuimo Street, Kapolei, HI 96707, USA	Tel: +808-477-0880 Mob: +808-783-6236 Fax: +808-477-0876 Email: mark.schnabel@pacom.mil or markschnabel@hotmail.com
99.	Dr. Jack Davis Technical Director Flood Risk Management	US Army Corps of Engineers, 3909 Halls Ferry, Vicksburg MS 39180, USA	Tel: +601-634-3006 Mob: +601-831-0786 Fax: +601-634-2645 Email: jack.e.davis@us.army.mil
		US Army Corps of Engineers, Pacific Ocean Division – USA	
100.	Mr. James Ligh Chief	Business Management Division, Directorate of Regional Business, US Army Corps Engineers - Pacific Ocean Division, Building 525, Fort Shafter, Hawaii 96850-8440, Honolulu, USA	Tel: +808-438-9500 Mob: Fax: +808-438-0326 Email: james.ligh@usace.army.mil
101.	Mr. John Peabody Division Commander	Business Management Division, US Army Corps Engineers - Pacific Ocean Division, Building 525, Fort Shafter, HI 90819, USA	Tel: +808-438-1500 Mob: Fax: +808-438-8387 Email: john.peabody@us.army.mil

Participants list

No	Name and Title	Organization and Address	Electronic contact
		World Fish Center – Cambodia	
102.	Dr. Mrigesh Kshatriya	World Fish Center No. 35, Street 71 (Corner Mao Tse Tong Blvd.) P.O. Box 1135 (Wat Phnom), Phnom Penh, Cambodia	Tel: +855-023-223-208 Mob: +855-012-626-124 Fax: +855-023-223-209 Email: M.Kshatriya@cgiar.org Webpage: www.worldfishcenter.org
		World Meteorological Organization – Switzerland	
103.	Dr. Wolfgang Eric Grabs Chief	Hydrological Forecasting Division, Climate & Water Department, World Meteorological Organization (WMO), Case postale No. 2300, 7 bis, Avenue de la Paix, 1211 Geneva 2, Switzerland	Tel: +41-22-730-8358 Mob: +41-79-253-7349 Fax: +41-22-730-8043 Email: wgrabs@wmo.int
		MRC Secretariat	
104.	Mr. Jeremy Bird Chief Executive Officer	MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 4131 Mob: +856-020-550-5344 Fax: +856-021-263-264 Email: jbird@mrcmekong.org
105.	Mr. Te Navuth Director of TSD	MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, ext. 3031 Mob: Fax: +856-021-263-264 Email: navuth@mrcmekong.org
106.	Dr. Pornsook Chongprasith Director of ENV	MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 2031 Mob: Fax: +856-021-263-264 Email:
107.	Mr. Sompong Boonprasert Senior Hydrologist	IKMP/TSD, MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 3710 Mob: Fax: +856-021-263-264 Email:
108.	Mr. Do Manh Hung Director of OPD	MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 4030 Mob: Fax: +856-021-263-264 Email: hung@mrcmekong.org
109.	Mr. Liko Solangkoun Project Manager	Mekong HYCOS, MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 3715 Mob: Fax: +856-021-263-264 Email:
110.	Mr. Aiden Glendinning Communication Officer	Mekong HYCOS, MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 4703 Mob: Fax: +856-021-263-264 Email:
111.	Mr. Daniel Jouve Mekong HYCOS	Mekong HYCOS, MRC Secretariat P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: +856-021-263-263, Ext. 3709 Mob: Fax: +856-021-263-264 Email:
		Regional Flood Management and Mitigation Centre	
112	Dr. Truong Hong Tien FMMP Coordinator	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2021 Mob: +855-011-202-576 Fax: +855-023-425-363 Email: tien@mrcmekong.org
113	Ir. Nicolaas Bakker Chief Technical Advisor	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2022 Mob: +855-012-301-857 Fax: +855-023-425-363 Email: bakker@mrcmekong.org
114	Dr. An Pich Hatda Operations Manager	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2091 Mob: +855-011-913-786 Fax: +855-023-425-363 Email: hatda@mrcmekong.org

No	Name and Title	Organization and Address	Electronic contact
115	Ir. Bob Pengel Technical Advisor of FMMP Component 1	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2101 Mob: +855-92-730-010 Fax: +855-023-425-363 Email: pengel@mrcmekong.org or amff6@mrcmekong.org
116	Dr. Perapol Begkhuntod Meteorologist	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2117 Mob: +855-016-455-799 or 99-612-357 Fax: +855-023-425-363 Email: perapol@mrcmekong.org or pira@tmd.go.th
117	Dr. Phung Katry Hydrologist	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2116 Mob: +855-011-837-056 Fax: +855-023-425-363 Email: katry@mrcmekong.org
118	Mr. Nguyen Huy Dzung Flood Warning and Dissemination Expert	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2112 Mob: +855-012-709-312 Fax: +855-023-425-363 Email: dzung@mrcmekong.org
119	Dr. Janejira Tospornsampan River Flood Forecasting Expert	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2141 Mob: +855-012-261-245 Fax: +855-023-425-363 Email: janejira@mrcmekong.org or janejira.forever@hotmail.com
120	Mr. Sambo Pich Hydrologist Assistant	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2113 Mob: +855-012-925-508 Fax: +855-023-425-363 Email: sambo@mrcmekong.org
121	Mr. Sokhavuthea Phet Riparian Support Consultant	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2011 Mob: +855-012-287-255 Fax: +855-023-425-363 Email: sokhavuthea@mrcmekong.org
122	Mr. Nuon Kunthea Mapping/GIS Assistant	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2113 Mob: +855-016-873-354 Fax: +855-023-425-363 Email: kunthea@mrcmekong.org
123	Ms. Sotheavy Cheap Secretary	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2111 Mob: +855-012-628-624 Fax: +855-023-425-363 Email: sotheavy@mrcmekong.org
124	Mr. Vandy Khim Secretary	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2012 Mob: +855-012-808-840 Fax: +855-023-425-363 Email: vandy.khim@mrcmekong.org
125	Mr. Boly Chen IT Assistant	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 2171 Mob:+855-017-789-555 Fax: +855-023-425-363 Email: boly@mrcmekong.org
126	Ms. Prang Sophiny Senior Librarian Assistant	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 1021 Mob: +855-012-833-488 Fax: +855-023-425-363 Email: sophiny@mrcmekong.org
127	Mr. Chantra Ney Maintenance Supervisor	Regional Flood Management and Mitigation Centre, # 576 National Road No. 2, Chak Angre Krom, Meanchey, P.O. Box 623, Phnom Penh, Cambodia	Tel: +855-023-425-353, Ext. 1101 Mob: +855-012-909-544 Fax: +855-023-425-363 Email: chantra@mrcmekong.org
MRC-RFMMC International Consultants			
128.	Prof. Dr. Bart Schultz International Consultant Forum Facilitator (AMFF-6)	UNESCO-IHE, Karveel 15-05, Lelystad, Postal code: 8231 AV, Delft, The Netherlands	Tel.: +31-3152-151-734 Mob: +31-887-972-749 Fax.: +31-152-122-921 Email: b.schultz@unesco-ihe.org

Participants list

No	Name and Title	Organization and Address	Electronic contact
129.	Dr. Peter Adamson International Consultant	# 3 The Manor, PEWSEY, Viltshire, SNO 5DW, United Kingdom C/c: MRC Secretariat, P.O. Box 6101, # 184 Fa Ngoum Rd., Unit 18, Ban Sithane Neua, Sikhottabong, Vientiane 01000, Lao PDR	Tel: 44 1672 563 066, UK Fax: E-mail: petadamson@aol.com or adamson@mrcmekong.org