Climate Resilience for Provincial Road Improvement Project

Loan 2839-CAM (SF)/ 8254-CAM and Grant 0278-CAM

Vulnerability Mapping Report

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Royal Government of Cambodia

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials BD
ADB	Asian Development Bank
Bank	The Asian Development Bank
CDB	Commune Database
CCAM	Conformal Cubic Atmospheric Model
CNMRC	Cambodian National Mekong River Commission
CRC	Cambodia Red Cross
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CV	Curriculum Vitae
DEM	Digital Elevation Model
DGPS	Differential GPS
DoM	Department of Meteorology
DRR	Disaster Risk Reduction
EMP	Environmental Management Plan
EMS	Emergency Management System
EPRS	Emergency Preparation and Response System
EWS	Early Warning System
FS	Feasibility Study
FRMI	Flood Risk Management Interface
GFDRR	Global Facility for Disaster Reduction and Recovery
GCM	Global Climate Model
GIS	Geographic Information System
GPS	Global Positioning System
IDF	Rainfall Intensity Duration and Frequency curves
IPPC	Intergovernmental Panel on Climate Change
ITC	Institut de Technologie du Cambodge
JICA	Japan International Cooperation Agency
MEF	Ministry of Economics and Finance
MOE	Ministry of Environment
MOU	memorandum of understanding
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
MRD	Ministry of Rural Development
NDMC	National Disaster Management Committee
NDF	Nordic Development Fund
OJT	On-The-Job Training
PMU	Project Management Unit
PPCR	Pilot Project for Climate Resilience

PDPWT	Provincial Department of Public Works and Transport
RAMS	Road Asset Management System of MPWT
SMS	Short Message Service
SPCR	Strategic Program for Climate Resilience
SRTM	Shuttle Radar Topographic Mission
TOR	Terms of Reference
UAVS	Unmanned Aerial Vehicle System
USD	United States Dollar

CURRENCY EQUIVALENTS
(As at 7 August 2014)
Cambodia currency Unit: Cambodian Riel (KHR)
1 USD=4,052 KHR; 1 KHR=0.00025 USD

1 Introduction

1.1 Project Background

The Royal Government of Cambodia (RGC) is one of the pilot countries participating in the Pilot Program for Climate Resilience (PPCR). The PPCR is one of the three sub-programs of the Strategic Climate Fund (SCF). The priority sectors for PPCR in Cambodia include water resources, agriculture and infrastructure. In June 2011, the PPCR sub-committee endorsed Cambodia’s Strategic Program for Climate Resilience (SPCR) with a funding envelope of up to $86 million ($50 million in grants and up to $36 million in concessional credit). Of this, an allocation of $17 million ($10 million loan and $7 million grant) was endorsed for “Climate-proofing of Roads in Prey Veng, Svay Rieng, Kampong Chhnang and Kampong Speu Provinces” as part of the Asian Development Bank (ADB) funded Provincial Roads Improvement Project (PRIP). This project is one of eight SPCR projects in Cambodia and one of two in the transport sector.

This project addresses the need for greater integration between sectors (transport, water, and environment) and the need for training and capacity building in innovative approaches to vulnerability mapping, road design standards for climate proofing, adaptive measures and emergency response systems.

There are five outputs of the Provincial Road Improvement Project (PRIP) including:

(i) civil works for provincial roads improvement;
(ii) road asset management;
(iii) road safety and safeguards;
(iv) climate resilience; and
(v) efficient project management support to the MPWT.

Under output (iv) of PRIP, a Climate Resilience for Provincial Road Improvement Technical assistance (CR-PRIP) was developed and funds allocated to improve infrastructures.

The objective of the CR-PRIP is to provide safe, cost effective measures to make climate-resilient selected infrastructures and roads of agricultural provinces of Kampong Chhnang, Kampong Speu, Prey Veng, and Svay Rieng. It will do so by: (i) protecting the road infrastructure from the impacts of climate change and climate variability, and (ii) piloting adaptation measures to protect the road against long-term risks posed by climate change.

From this, six tasks have been identified in connection with Output (iv):

- Task 1 Vulnerability Mapping
- Task2 Standard Design Adjustments (with adjustments in civil works are integrated into output (i)
- Task 3 Adaptation Measures: Planting, Water Capture and Storage Systems etc…
- Task 4 Emergency Response
- Task 5 Procurement
- Task 6 Training and Workshops

This Vulnerability mapping report corresponds to the first task.

Although this technical assistance is not formally labelled as a pilot project, it shares most of the characteristics of a pilot project. It is part of the Pilot Program for Climate Resilience and it is tasked to “include piloting approaches to strengthen civil works design and planning, as well as to reduce risks of damages resulting from climate change impacts”. It includes “piloting emergency management systems” and piloting the nursing of plants to be introduced along the roads or borrow pits. The limitation of the initiatives to four provinces makes it ideal to assess the methods and intervention success and to make possible their continuation in other provinces of Cambodia. This is the spirit in which the technical assistance studies were conducted.

1.2 Purpose of the report

The purpose of the Vulnerability Mapping Component is to provide MPWT with a key tool to assess the risk of flooding on national and provincial roads and the communities that depend on the roads. Using this tool, areas of high risk can be identified and climate proofing and appropriate adaptation strategies can be developed to reduce these risks.

The Mapping activities have produced National Vulnerability Maps of the Road Network indicating vulnerable areas due to flooding as well as maps capturing the vulnerability of roads and communities to natural hazards and climate change impact.

1.3 Project timeframe and resource inputs

The Project Team was mobilized in March 2014 and began to work closely with the Ministry of Public Works and Transport (MPWT). CR-PRIP assistance consisted of about 43 person months of international expert inputs and 73 person months of national expert inputs.

Early on, meetings with stakeholders and data collection at national and district levels were arranged. The consultants have received excellent co-operation from Project Management Unit Three (PMU3), other MPWT Departments, Korea Consultants International (KCI), and provincial and district leaders as well as community members. The consultants have also established contacts with Ministry of Water Resources and Meteorology (MOWRAM), Ministry of Rural Development (MRD), Mekong River Commission (MRC), Ministry of Environment (MOE), National Committee for Disaster Management (NCDM) and the ADB Cambodia Office.

The Team also visited the field at several occasions in Kampong Chhnang province and met with community leaders in Kampong Leaeng and Tuek Phos Districts to listen to their concerns and to develop local initiatives related to transport infrastructure, water supply and livelihoods. Similarly, the Team visited Prey Veng and Svay Rieng with PMU3 on a reconnaissance trip. The team visited the districts to collect land use and socio-economic data to be used as input to the vulnerability maps.

Most of the assistance initiatives conducted by international experts will be completed by May 2015. The construction of the adaptation civil works, mostly water capture reservoirs, was planned for mid 2016 and the technical assistance contract due to expire in early 2017, to allow for all planting activities to be completed.General Approach and Assumptions

1.4 General Approach

Throughout all this technical assistance, the Consultant put much emphasis on knowledge transfer and on participative approaches, in order to increase the sustainability of the methods he introduced and the acceptance of improvement solutions both at national and local levels. This meant that the methods developed such as those presented in this report, were adapted to the strengths and weaknesses of the recipient organization, i.e. the MPWT, and their complexity made suitable for the capacity of local experts taking into account the skills transferred through the training program of the technical assistance itself.

For example, it was deemed more productive to use climate modeling data from a third party rather than to develop a new model requiring comprehensive and extensive climate modeling skills, being skills normally not associated with a Public Works and Transport organization. On the other hand, much attention was given to maximize the use of the MPWT Road Asset Management System (called RAMS), a unique dataset with good availability of expert skills in the Ministry and to develop simple hydrological models that can be easily understood and used to assess flood damage risks. Similarly, the identification of water capture on sites vulnerable to droughts was found to be more relevant when driven by community discussions rather than by a theoretical modeling of climate change parameters.

1.5 Vulnerability Definition

There are many different definitions of vulnerability from a wide range of academic and aid related disciplines. The definition of vulnerability used in different applications reflects very different conceptualizations, and sometimes these definitions can be mutually incompatible.

The Intergovernmental Panel on Climate Change (IPCC) Assessment Reports contain two definitions, one that defines vulnerability as a function of sensitivity, while the other views it as a component of sensitivity (Brooks 2011).

The IPCC Third Assessment Report has the alternative definition of vulnerability, as the "degree to which a system is susceptible to injury, damage or harm, (one part – the problematic or detrimental part – of sensitivity)" (Smit and Pilifosova, 2001). This definition represents the concept of vulnerability widely used in the natural hazards literature, in the field of disaster risk reduction, and in the social sciences in general. This conceptualization, in which vulnerability is seen as arising from the internal properties of a system or society/population, are sometimes described as referring to 'social vulnerability' so as to distinguish them from the definition in the IPCC glossary (Brooks, 2003).

The glossary of the IPCC Fourth Assessment Report defines vulnerability as "a function of the character, magnitude and rate of climate change or variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2007: 883). This IPCC definition is sometimes described as defining 'biophysical vulnerability' in order to distinguish it from other definitions.

The general concept of vulnerability can be analyzed in three main categories: physical, systemic and organizational/social vulnerability. Using the dimension proposed by Fussel (2007) the vulnerable situation can be defined as: "vulnerability of a system's attributes of concern to a hazard in temporal reference". For the road infrastructure we could consider:

1. system: embankment, critical facilities (municipality, school, police and fireman station, etc..), industries and lifelines (roads, bridge, etc..) exposed in a catchment area,
2. attribute: safety of the infrastructure and its ability to provide the service for which it was designed,
3. hazard: flood probability
4. temporal reference: time series based on climate projection (i.e. 2012 to 2032).

An interesting framework for vulnerability has been proposed by Pelling et al.(2008) which encompasses vulnerability in terms of exposure, resistance, and resilience. In this model, exposure is related to the location of the system or element with respect to the hazard and the environmental surroundings; resistance is related to the economical, psychological, and physical health of systems of maintenance, as well as the capacity of individuals or communities to withstand the impact of the event and is related with livelihoods; while resilience is defined as the ability to cope with or adapt to the hazard stress through preparedness and spontaneous adaptations once the event has manifested itself.

The glossary of the IPCC Fifth Assessment Report (2014) defines vulnerability as "The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt". Contextual vulnerability also referred as Starting-point vulnerability is defined as "a present inability to cope with external pressures or changes, such as changing climate conditions. Contextual vulnerability is a characteristic of social and ecological systems generated by multiple factors and processes (O'Brien et al., 2007)". Outcome vulnerability, also named End-point vulnerability is defined as "Vulnerability as the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, and concluding with biophysical impact studies and the identification of adaptive options. Any residual consequences that remain after adaptation has taken place define the levels of vulnerability (Kelly and Adger, 2000; O'Brien et al., 2007)".

A vulnerability index is simply defined as "A metric characterizing the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability".

From these references, we can conclude that there is no strict definition of vulnerability definitions agreeable in the scientific community but rather an ensemble of definitions best adapted to specific cases. In this report, two vulnerability analyses have been proposed based on the latest IPCC definitions, the road infrastructure vulnerability to flooding and the socio-economic vulnerability of communities in regard to floods and droughts.

1.6 Review of previous reports and projects

MRC Technical Report # 35: Flood and Roads

This comprehensive report covers several aspects related to the impact of floods on roads. A number of useful recommendations are issued to guide future studies on flood impacts on roads since it is acknowledged as a very complex issue. Several of these recommendations have been taken up by CR-PRIP and included in the Consultant reports. A few case studies attempt to establish some parameters for predicting flood damages but the study generally concludes that further analysis is required before these become available to road designers. Detailed comments are provided in Appendix 1.

MRC Technical Report # 29: Impacts of climate change and development on Mekong flow regimes First assessment - 2009

This report is a first major attempt at predicting Mekong flow regimes for future climate conditions. Several scenarios were analyzed included rudimentary observed data trend (10 Y horizon), and downscaled / adjusted regional climate models for longer climate change and development modeling (50Y horizon). Development changes found to be at least as important as climate changes. The MRC has created the Climate change program which will likely update these findings in the coming years.

MRD Climate change adaptation project

The Climate change adaptation project of the Ministry of Rural Development shares many characteristics with the CR-PRIP output. It includes components for vulnerability mapping – including climate change modeling, identification of adaptation options – such as planting and development of early warning systems, review of current design standards and training. This project is using 48 person months of international experts and 94 person months of national experts. It started earlier than CR-PRIP and most of its technical assistance is to be completed by November 2015.

1.7 Data Collection and Analysis

1.7.1 Aims of data Collection and Analysis

National or regional datasets are increasingly useful and powerful tools for analyzing land based data and for correlating different types of information. They are at the core of the data collection exercise of the CR-PRIP.

The overall aim of that data collection was the selection of information, mostly geographically related (GIS enabled) or historical in view of monitoring infrastructure damages and losses from climate impacts, for better planning road maintenance, road investments and water capture and storage facilities (also called adaptation facilities) and for developing emergency warning procedures and systems.

From these datasets, the Consultant has identified biophysical vulnerability indicators (flood damage, risk to roads) and socio-economic vulnerability indicators particularly in terms of capacity to access basic services (hospitals, schools and markets) using the transport infrastructure during floods and to access water resources during droughts.

1.7.2 Methodology

More than 40 datasets were investigated for use in the CR-PRIP. The list is given in Appendix 2 with a full description of the process carried out to obtain these datasets. The datasets themselves have been installed in the MPWT mapping department new data analysis desktop computer. The maps derived from these datasets are accessible from the Flood Management Interface Application (MS Access – D:\FRMI\FRMI-DATABASE.accdb) on the same computer.

Data has been collected mainly from the MPWT Public Works Center Research Unit but also from a number of regional and national agencies including MRC, MOWRAM and MRD.

Socio-economic data and land use planning data for specific districts including Kampong Leaeng and Tuek Phos in Kampong Chhnang province has been provided by the National commune database and the District Governors and Councils.

All topographic base maps used in this technical assistance were derived from the Satellite Radar Terrain Mission (SRTM) model data with a grid resolution of 90 meters.

1.7.3 Summary results of data collection process

Various types of data were sought in order to assess their use in identifying vulnerable infrastructures or communities in relation to climate change. The data types can be summarized in Figure 1. The variety of data meant that a significant number of organizations be reached. The process of collecting data has been generally slow and complicated, given the large number of data types sought and the number of sources who ranged from government agencies to international organizations and depending if the datasets were either officially approved, or in project, or in endorsement process.

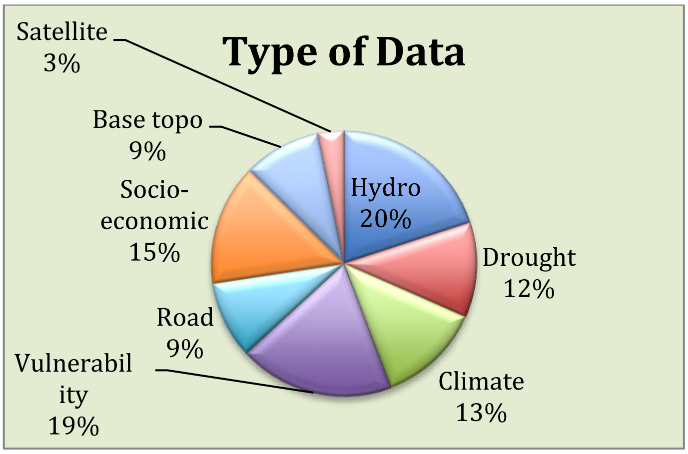

Figure 1 Types of datasets investigated

The review of the existing climate change vulnerability maps led to the following observations in terms of scaling, time horizon and transport specific products.

Existing vulnerability maps are available at many different spatial scales, from regional maps covering an entire world region down to individual towns and parts of individual countries, like for example the Mekong Delta or the region of Sihanoukville. The Consultant has to point out that existing local, provincial and national vulnerability maps are often not connected to each other. There is no systematic coverage of the entire country or even entire provinces as most vulnerability maps were produced independent of each other but when available, national level data sets were used.

Most existing vulnerability maps are based upon model data collected over the recent 20 - 30 years. The standard timescale aimed at is in the order of 20 - 50 years, so climate change impact is usually estimated for the year 2030, 2050 and 2100. Most of the maps are based on global climate change models, concentrating on changes in precipitation and temperature.

The consultant has also noticed that the transport sector is often ignored, or at least only incorporated as a static value, in the existing vulnerability maps. Climate change impact on transport infrastructure is relatively small compared to climate change impact on vegetation, agriculture and health of people, as roads, bridges and other infrastructure are relatively stable physical entities. However, the infrastructure sector can suffer considerable damage as a consequence of climate freak events and the impact of the damages to the population can be severe. In addition, infrastructures can be strengthened and provide resilience against climate change impacts.

It may be important to note that “informal development” is not much mapable. Official land tenure / ownership / concession maps are also not completed for many provinces and are often not publically available. Other GIS data on economic land concessions from NGO sources is incomplete, unofficial and may contain substantial errors.

The data collection expert of the team also observed that more data is becoming available from the internet, usually from large international non-profit organizations. The percentage of downloadable data from the internet was found to be 30%.

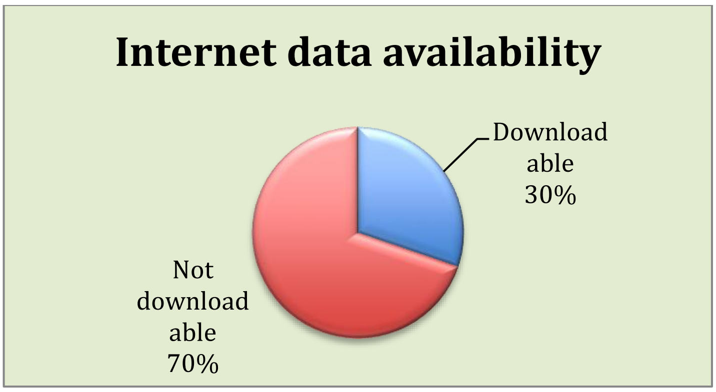

Figure 2 Internet data availability

The data collection process required a range of initiatives from the simple emailing to formal letters as shown in the graph of Figure 3. Most of the datasets could be obtained through emails or by arranging meetings and very few had to be retrieved unofficially. In summary, about 70 % of the requests led to successful data acquisition.

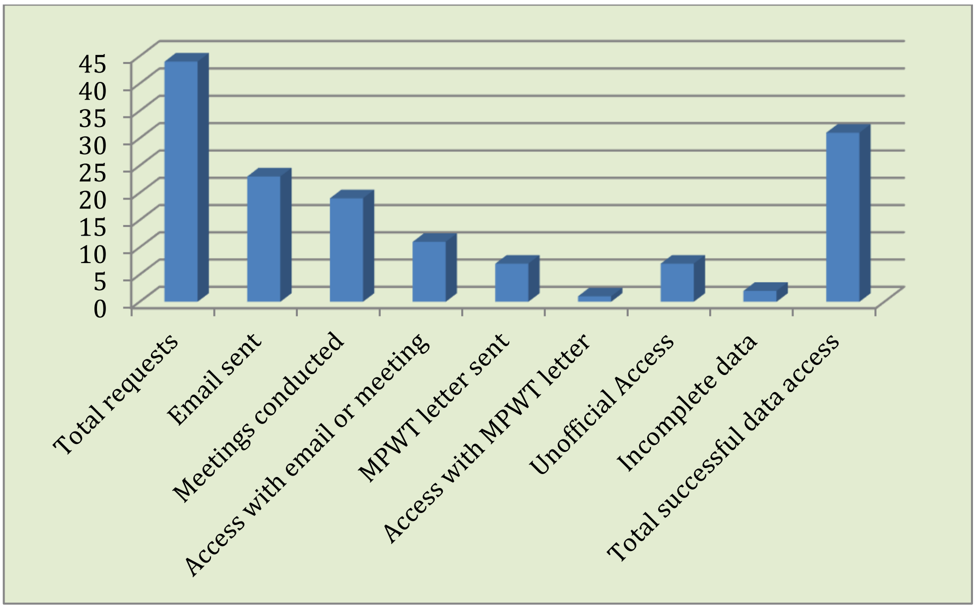

Figure 3 Procedures to acquire datasets

Finally, the quality of the datasets collected was assessed and their usefulness rated. That measure of usefulness is not restricted to the actual usage of data in the final models developed but also represent their ability to offer comparisons between the datasets in the process of selecting the most relevant information for MPWT decision makers. The MPWT datasets for example were acquired easily with the help of PMU3, but showed some slight incompatibility issues. The RAMS data was also very useful, although not always up to date, and fully integrated in the models.

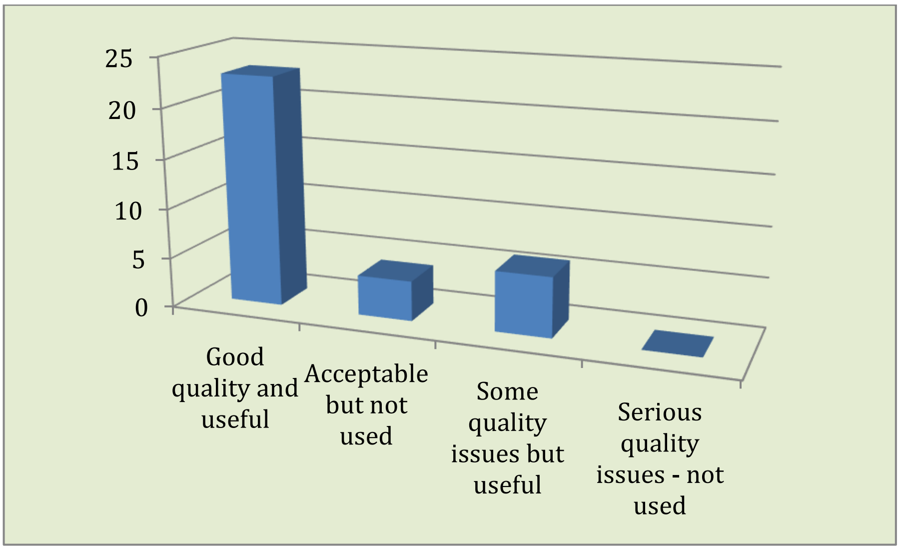

Figure 4 Quality of the datasets collected

In summary, the overall exercise in data collection was generally successful but consumed considerable expert time. Also, numbers cannot show the relative importance of some key datasets in the design of the different models that CR-PRIP developed. Indeed a few of these datasets critical to the flood modeling, particularly a few from MOWRAM and MRC, took a long time to acquire or could not be accessed at all.

1.7.4 Lessons learned and recommendations for future endeavors

The quality, consistency or compatibility of data was found to be sometimes lacking for some important data that the Consultant would have like to use. This is the situation facing several developing countries experiencing multiple initiatives of uncoordinated data gathering through donor projects.

In some instances, the reluctance of some organizations to share their latest project data has also been an issue, because it had not been officially approved by the project owners or was still being adjusted or calibrated. In some cases, like the timber cutting data (land use), significant differences remain between the latest international agencies data and official government data.

Our main recommendations for future data collection exercises can be summarized as follows:

There is an obvious need to establish a dialog mechanism or even procedures within the government to share important sector data particularly pertaining for climate change (or other multi-sector types of) projects since they require datasets covering key information about geography, political boundaries, rainfall, floods or land use. The current multiple uncoordinated data collecting exercises and modeling attempts on a project by project basis can be very unproductive.

1.8 Road Flooding Vulnerability

Road flooding is a result of climatic hazards, namely heavy precipitation or high water levels in waterways. However, not all roads are equally exposed to the flooding risk and one aim of the analysis was to classify all national and provincial roads of Cambodia into risk categories, and analyze the possible impact of climate change on these specific road sections.

It is assumed that changes in the rainfall regime are the most important climate change factors in which can have an impact on physical infrastructure - much more important than, for example, temperature change.

All analysis thus was aimed at characterizing and modeling the existing hydrological and drainage situation of road infrastructure in Cambodia and at investigating how far changes in the rainfall regime, caused be climate change, could affect the existing situation.

The identification of the road vulnerability to climate change is however part of a wider process that aims to strengthen the resilience of these vulnerable roads. The overall flood process is presented in Figure 5.

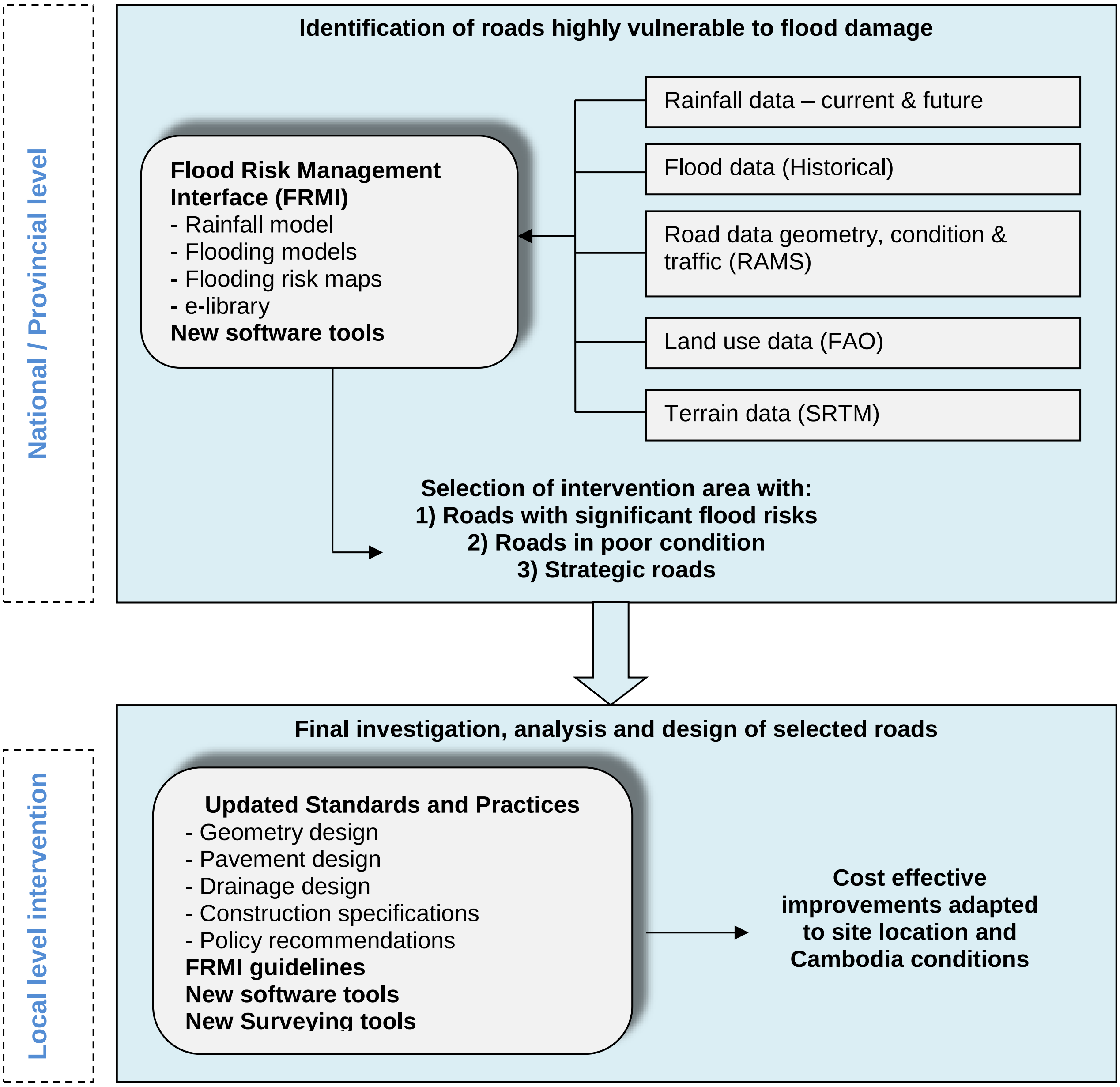

Figure 5 Overall Road Flood proofing Process

It clearly delineates the identification phase from the design phase and shows that the first phase is carried out at the national or provincial levels using a new management tool called Flood risk management interface (FRMI) [1] and the second phase is conducted, only for selected roads at the local level using the updated standards and practices for flood proofing. The Flood risk management interface developed is briefly described in a later section. Improved standards and practices for strengthening roads are provided in a separate report[2].This report therefore focuses on the identification phase.

Finally it is worth noting that all the models developed are probabilistic and not deterministic. The results show the risk levels associated to flood damages to roads but cannot specifically determine when and where these damages will occur at a given time. Similarly, the climate change models and the flood models provide relative risks that a certain event be encountered in the future but cannot predict the exact year that it will occur.

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[1] Full details are available in the Flood Risk Management Interface manual

[2] See the Road Design Standards Changes report

1.9 Socio-economic vulnerability

Socio-economic vulnerability is reflective of broader conditions. At the local level the ability to adapt to climate change can be influenced by such factors as managerial ability, access to financial, technological and information resources, infrastructure, the institutional environment within which adaptations occur, political influence, kinship networks, etc. (Adger et al, 2001, Smit and Pilifosova, 2001, Smit and Wandel 2006). Some determinants of adaptive capacity are mainly local (e.g. the presence of a strong kinship network which will absorb stress) while others reflect more general socio-economic and political systems (e.g. the availability of state- subsidized crop insurance), (Smit and Wandel 2006).

Indices have been developed as a rapid and consistent method for characterizing the relative vulnerability of different areas. Socio-economic Indicators need to be selected carefully, and will vary according to context and the climate (change) hazard(s) with which adaptation is concerned, Balica (2012). The factors that make people vulnerable to one particular hazard (e.g. flood) will not necessarily be the same as those that make them vulnerable to other hazards (e.g. drought) (Brooks et al., 2005).

When addressing vulnerability, we therefore need to be careful to assess the vulnerability of a particular group to a particular type of hazard, with respect to a particular outcome or set of outcomes, (Brooks et al 2011). In terms of socioeconomic vulnerability in the road sector, we need to concentrate on vulnerability to flooding with respect to the populations' ability to evacuate to safe ground, to access to basic services during the flood and also their ability to recover after a flood has retreated.

Socio-economic vulnerability will be influenced by social, economic, political, cultural and environmental factors, and vulnerability indicators will need to capture the key drivers of vulnerability that represent the most important subset of these factors (Brooks et al 2011). Communities are not always homogenous. They are often stratified along class and power structures that are visible, and can also be fractured along gender, age, mobility etc. that are not as visible. Social and economic discriminations based on these differences make some sections of the community more vulnerable to disasters (DDPM and UNISDR 2014). Numerous indices of socioeconomic vulnerability have been presented in the literature. An extensive review of vulnerability mapping in Cambodia has been carried out by MOE (2013).

Based on socio-economic questionnaire responses in the target villages in Kampong Chhnang Province a few simple indicators were chosen to assess vulnerability to flooding. The commune database contains a large range of questions at a national scale that cover many aspects of vulnerability. Commune database questions that reflected the local level indicators were extracted and used to map vulnerability at the national and provincial level. Since the selection of indicators was based partly on questionnaires carried out in Kampong Chhnang Province, it must be noted that they may not be reflective of critical factors that operate in other areas of the country.

1.10 Capacity assessment

The Consultant conducted a series of interviews and introductory training exercises to assess the capacity of MPWT and other key Ministry staff and of communities to account or understand climate related concepts.

The initial assessment is that few MPWT practitioners are familiar with the whole process of assessing the risks of climate change and the design of infrastructures capable to withstand it. However, individual experts were found to be knowledgeable in nearly each sub area of the process. At the community level, people were found to be highly interested to learn about how climate change would affect their livelihoods but were much skeptical if the proposed government interventions would make any change for their family in their lifetime, - perhaps due to the large number of mostly theoretical fact finding technical assistance projects that they have been asked to participate and have failed to deliver any tangible benefits.

A training scheme has therefore been developed by the Consultant on a per topic basis (i.e. per international expert), such as vulnerability analysis, mapping with GIS, modeling flood conditions, etc..., and has progressed at a pace allowing sustainable knowledge transfer and the introduction of new methods developed by the Team as well as new software tools. It has consisted of on-the-job training / mentoring, small group training sessions and larger workshops. Depending on the targeted trainees, the training main objectives are:

- To inform and increase awareness of climate change / flooding impacts
- To create new group of flood proofing practitioners

- To promote inter-department, inter-ministerial and national-local information exchange

The list of training events delivered is given in Appendix 3. Participation and interest in the identification of vulnerable roads has been good. However, challenges remain in identifying groups of practitioners who can master the whole process of flood proofing infrastructures, from the vulnerability assessment to improving their resilience. The idea of creating a climate change unit in the MPWT would provide a good foundation for future learning. More information is also available in the Knowledge Management Report.

2 Climate Change Modeling

The purpose of the climate modeling is to examine the impacts of potential climate changes that may occur in the future and to estimate how this may impact vulnerability. Climate scientists have agreed that the release of Carbon Dioxide (CO2) and other greenhouse gasses into the atmosphere will lead to an increase in the average temperature across the entire earth in the future. It is likely that these higher temperatures across the globe will change rainfall patterns.

The Intergovernmental Panel on Climate Change (IPCC) is a scientific intergovernmental body under the auspices of the United Nations and endorsed by the United Nations General Assembly. Through a series of international assessment reports, the IPCC has kept the global climate change scientists up to date with current state of climate change knowledge.

This chapter is a summary of the climate change investigations conducted during the project. More details are available on each of the following sections in the separate Climate Modeling Report.

2.1 Climate Models

As the science of climate has advanced, climate scientists have gained an understanding of the fundamental physics that control the climate of the earth and the physics of global atmospheric and ocean systems. Using this knowledge, climate research teams have developed computer models that simulate the global climate. These General Circulation Models (GCMs) depict climate using a three dimensional grid over the globe (Figure 6). At each grid cell there are a number of layers (typically 10 – 20) representing the atmosphere.

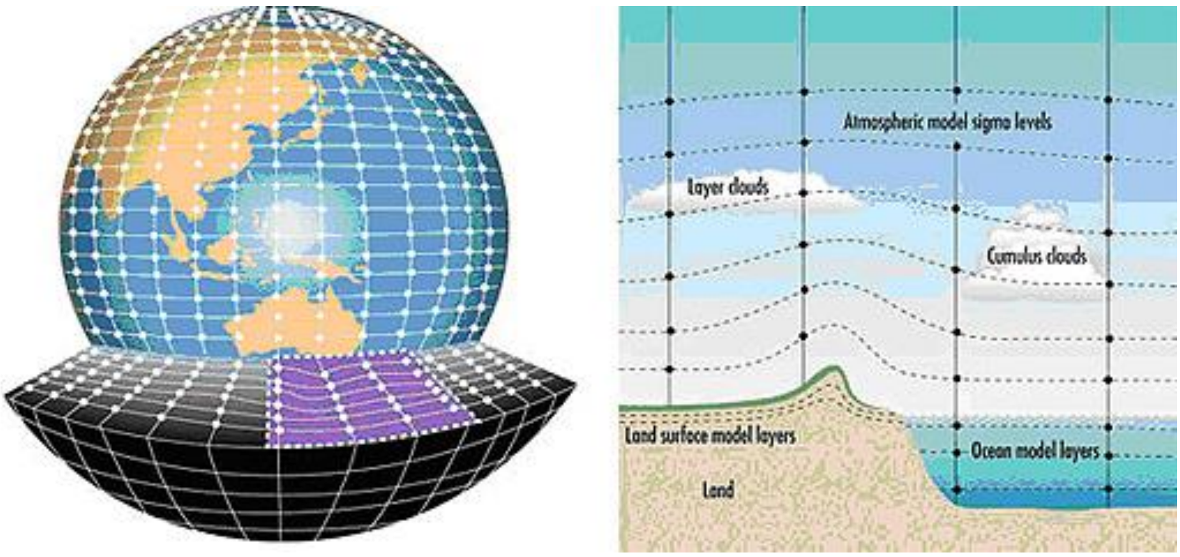

Figure 6 Representation of the horizontal and vertical grid structure used in a GCM (Source: www.dpi.nsw.gov.au)

Within each grid cell of a GCM the physical processes in the atmosphere, ocean and land surface are modeled (Figure 7). Over land the topography, vegetation and surface characteristics are included and the oceans are represented by up to 30 layers. At each grid cell the vertical and horizontal exchange of heat, moisture and energy is calculated. With the development of advanced high speed super computers these models have advanced in sophistication and the size of each cell has become smaller, from approximately 500km in early 1990 to around 100km for the models used in the 2013 IPCC report.

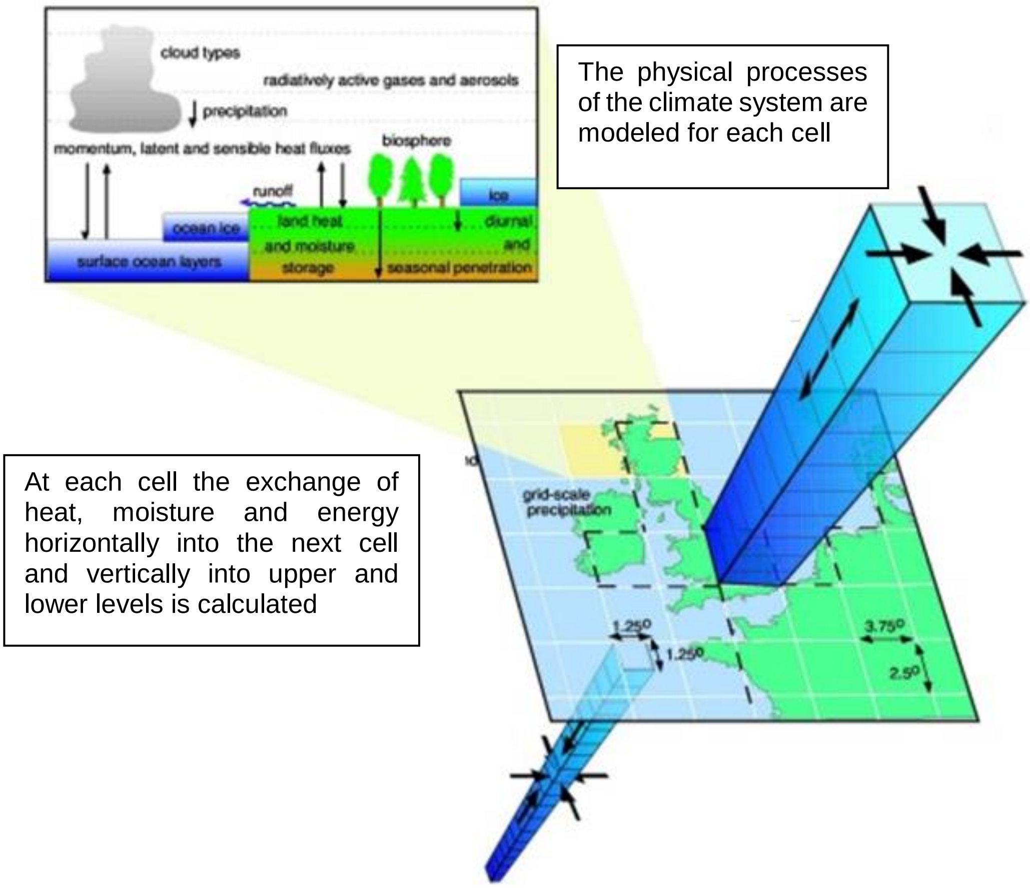

Figure 7 Graphical representation of a GCM. (Source: Dr. David Viner: Climatic Research Unit, University of East Anglia)

However, there are certain physical processes that act at a scale much smaller than the characteristic grid interval of GCMs. As a result GCMs have relatively poor performance on simulating precipitation at a regional or local scale (1 – 20 km) compared to the historical observed data. In addition, different GCMs handle information in different ways and are generally set up to produce results for the country that produced the model. As a result the various GCMs will produce different output data.

The IPCC has led the way on standardizing GCM operation by creating standard future CO2 scenarios and creating standard input climate data such as temperature, rainfall, wind speed etc. The IPCC also provides a list of the most up to date GCMs and funds intercomparison of GCMs. CGMs are constantly being updated and results from each new model is compared to the outputs from all of the others.

2.1.1 Future scenarios

Accurately forecasting the rest of this century's climate is not possible because we are uncertain about a number of factors. The uncertainties that effect climate change modeling are both biophysical and socio-economic. Biophysical uncertainties include a lack of understanding of all of the subtle interactions between the oceans, atmosphere and biosphere. Socio-economic uncertainties include global and national economies, potential technological developments and population and societal change. These uncertainties will also interact, for example if greenhouse gas emissions alter the climate the biosphere may change and human systems will also change in response. As a result GCMs produce a range of modeled future climate.

The major tool used to assess the impacts of future climate is the climate scenario. A scenario is a coherent, internally consistent and plausible description of a possible future state of the world, (Carter and La Rovere, 2001). Various IPCC reports (from 1990 to 2007) have used a range of scenarios called the Special Report on Emissions Scenarios (SRES) that make different assumptions about global changes in future greenhouse gas pollution, land-use and other driving forces. Some scenarios have predicted very high rapid economic growth and associated high CO2 future emissions and others included emission reductions from human influences on climate with proportionally reduced CO2 levels.

The latest IPCC report (5th) uses a new description of scenarios. This scenario description presents "Representative Concentrations Pathway (RCP)". These RCP scenarios are not a complete package of socioeconomic, emissions, and climate projections like the SRES scenarios. They are a set of projections of only the change in the balance between incoming and outgoing radiation to the atmosphere caused primarily by changes in atmospheric composition. The numbers refer to global energy imbalances, measured in watts per square meter, by the year 2100. RCP 3 (PD) refers to a scenario where CO2 emissions peak in the near future and then decline. RCP 8.5 refers to the worst case scenario where emissions continue to rise until 2100 and much more energy is going into the global climate system than is released back into space leading to global temperature increases.

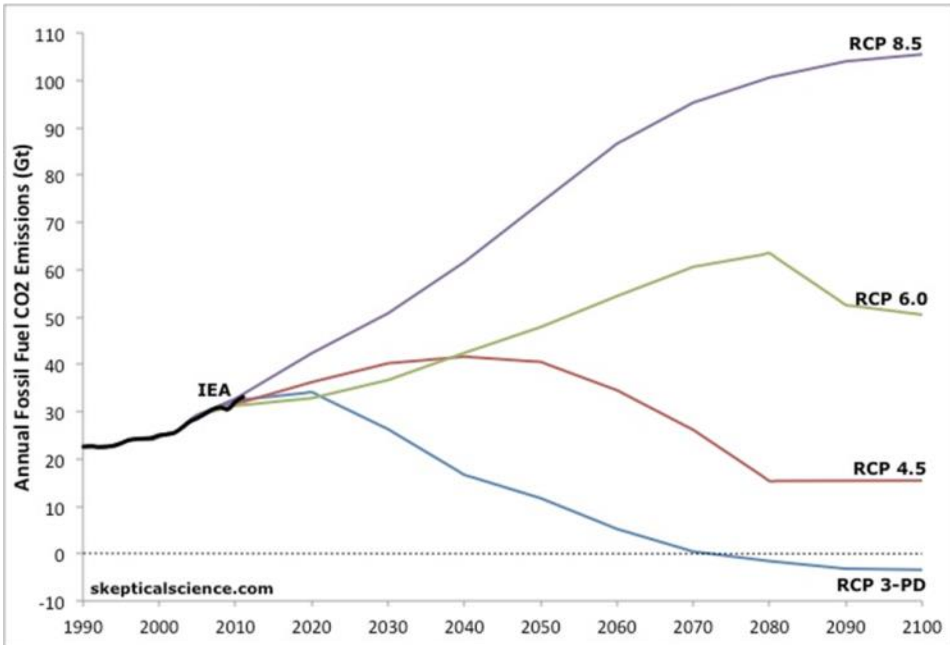

Figure 8 IPCC5 representative concentration pathway scenarios. Source: van Vuuren et al. (2011)

Recent climate change studies in South East Asia have used RCPs of 8.5 for extreme CO2 futures and values of 3.5 or 4.5 to represent low CO2 futures.

2.1.2 GCMs used in the region

More than 20 different GCMs have been used to model climate change in Cambodia. For example, early studies used HadCM3 which was developed by the Hadley Centre at the UK Met Office. Later studies have however used outputs arising from multiple GCMs (up to 15). With more and more detailed GCM data becoming publicly available it is now possible to compare the outputs a large number of GCMs. The suitability of GCMs for use in Cambodia can be assessed by using each model to simulate the current climate conditions and comparing the results to the measured climate conditions. The most important thing that models need to do in South East Asia is to accurately model the summer monsoon rainfall. The models that most accurately predict current monsoon rainfall are therefore considered to be the most suitable.

Comparisons of observed data and model outputs has shown that in South East Asia, while GCMs predict temperature reasonably well the confidence in GCM projected extremes of precipitation is much less. In general, GCM-simulated extreme precipitation intensities are generally much lower than the observed data. The timing of the start and end of the monsoon season are also generally poorly predicted.

A number of studies have made comparisons of GCM outputs against measured data for the South East Asian region with a particular focus on modeling the monsoon. When simulating temperature, the models show good correlations with measured data with errors of from 1 – 3 degrees C. However, for rainfall, models show lower correlations of 0.55 to 0.825. Rainfall errors are generally between 1.5 to 2.5 mm/day. The worst performing model (NASA Godard GISS) model showed rainfall errors of over 4 mm/day. The model that is widely used in climate modeling in South East Asia developed at the Hadley

Centre at the UK Met Office shows temperature errors of 1.5 to 2 degrees C but a good correlation with rainfall with errors of less than 1.5 mm/day.

The CR-PRIP Climate Modeling Report presents the results from eight important inter model comparison studies. From this analysis the best performing GCMs for Cambodia are presented in Table 1.

Table 1 GCMs shown to produce the best match between measured and modelled data for the South East Asia region across 8 scientific studies.

Model	Institute	Ranking across studies
NCAR-CCSM	National Center for Atmospheric Research, USA	1 or 2 in 5 studies (and 5 in a 6th)
NorESM	The Norwegian Earth System Model	1 in 2 studies and 3 in a 3rd
GFDL CM	Geophysical Fluid Dynamics Lab, USA	In top 6 in 4 studies
CanESM2 / CGCM4	Canadian Centre for Climate Modelling and Analysis	In top 6 in 2 studies
BCCR-BCM	Bjerknes Centre for Climate Research, Norway	Ranked 1 in 2 studies
CNRM	Meteo-France, France	In top 6 in 4 studies
MIROC-M	Centre for Climate Research, Japan	In top 6 in 4 studies
ECHAM* / MPI-ESM-LR	Max Planck Institute for meteorology DKRZ, Germany	In top 10 in 5 studies

2.1.3 Downscaling GCM outputs to regional scales

GCM outputs are still the most reliable source of information for future climate scenario projections. However, global models perform best for large spatial scales and have relatively poor performance on simulating precipitation at a regional or local scale. The output from a 100 km resolution GCM over Cambodia produces a grid of approximately 6 by 6 cells. This is much too coarse to determine local scale climate variations and has seriously limited the direct use of GCM precipitation time series in precipitation analysis.

Downscaling climate data is a strategy for generating locally relevant climate data from GCMs. The main goal in downscaling is to obtain regional weather phenomena that are influenced by the local topography, land-sea-contrast, and small-scale atmospheric features (e.g. convection). Downscaling will retain all the large-scale information which can be resolved by the global model and adds regional information that the coarse-resolution global model could not generate.

The important downscaling models used in Cambodia are outlined in the table below.

Table 2 Review of Climate Downscaling Carried for Government Departments in Cambodia

Modeling	Comments
MOE for the 2nd National Communication (draft) *Carried out with assistance from* National Institute of Environmental Studies (NIES), at the Centre for Climate System Research (CCSR) at the University of Tokyo.	The modeling was carried out in 2009-10 Data from 14 GCMs (pixels ~250 km) was downscaled to smaller pixels Using statistical downscaling Final pixel size 20km Older generation IPCC models
MOWRAM *Carried out by* TA 7610 – CAM Supporting Policy and Institutional Reforms and Capacity Development in the Water Sector Project	The modeling was carried out in 2010 Data from 9 GCMs (pixels 125-400 km) was downscaled to smaller pixels (Data from World Bank Web Portal) Using statistical downscaling

Modeling	Comments
	Final pixel size 50 km Older generation IPCC models
Mekong River Commission *Carried out with assistance from* The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and The South East Asia SysTem for Analysis, Research and Training Regional Center (SEA START).	The modeling was carried out in 2012 Data from 1 GCMs - Max Planck Institute for Meteorology's ECHAM4 (pixels ~250 km) was downscaled to smaller pixels Using a Regional Climate Model Final pixel size of 50 km Older generation IPCC models
ADB TA 7459-REG Greater Mekong Subregion Biodiversity Conservation Corridors Project – Pilot Program for Climate Resilience Component – Cambodia *Carried out by* The Commonwealth Scientific and Industrial Research Organisation (CSIRO)	The model was developed and run in 2012. CCAM - This is a regional model that was run specifically for South East Asia. It uses 6 GCMs selected for best performance in South East Asia The model has a pixel size of 10 km It uses the latest IPCC standard set of model simulations

Projected Temperature change

All these models presented show warming occurring over Cambodia in the future, with the early studies generally projecting warming of 0.01 degrees C to 0.03 degrees C per year, and later models projecting warming of 0.03 degrees C to 0.06 degrees C per year. This equates to a warming of 0.35 to 2 degrees C by 2050 and 1 to 5 degrees C by 2100. The results of six of the latest model projections for Kampong Chhnang and Svay Rieng are summarized in Table 3.

The projected change in temperature output by the CSIRO's CCAM model is assumed to be reliable since it is very similar to the one produced by the MOWRAM modeling carried out in 2010 but is slightly higher than that produced by the MOE modeling carried out for the second national communication in 2010.

Table 3 Projected changes in temperature for Cambodia and rainfall for Kampong Chhnang and Svay Rieng by 2050 from six climate change studies in Cambodia for the extreme CO2 scenario.

Study	Annual Temperature change (degrees C)	Wet Season Rainfall change Kampong Chhnang %	Wet Season Rainfall change Svay Rieng %	Seasonal Timing Changes
MOE 1st Nat Com 2002	0.7 - 1	8 – 12 (all of Cambodia)		
MRC 2009	0.8 - 1.6	1 - 5	0 - 1	
MOE 2nd Com 2010	0.5 to 1.5	0	-17	Shorter wet season
MOWRAM 2010	2.2	1.5 - 3.5	1.5 - 3.5	
MekongARCC 2014	2.5 - 3	7 - 9		
CSIRO 2013	1.71 - 2	-8 to -12	0 to -8	Earlier and wetter onset of wet season

Projected Rainfall Change

Climate in Cambodia is traditionally described with reference to two seasons, the wet season, when rain bearing monsoon winds from the southwest predominate and the dry season, when dry northeast monsoon occur. Climate change could result in changes in the total amount of rain in each season and a change in the onset or end of the wet season.

Early climate change studies projected a shorter wet season in the future with a later start and a longer drier dry season. The projections for rainfall change from six recent climate modeling studies for Kampong Chhnang and Svay Rieng are presented in Table 3. The results of these recent studies for rainfall change are much more varied than those for temperature. Many models project no or small changes in annual rainfall and some studies project a decrease in rainfall. For both provinces a change in 1% represents about 17mm so the maximum projected change of -17% represents a decrease of approximately 290 mm spread across the wet season. This amount is less than the interannual variability that is found in both provinces.

The recent CSIRO modeling presents downscaling information at the highest resolution and while it projects a decrease in rainfall during the wet season, it does project an increase in rainfall at the start of the wet season. The CSIRO modeling also projects an increase in the amount of rain that falls in extreme events.

Rainfall Intensity

It is unlikely that projections for sub daily scale rainfall intensity will be available in the near future. All of the recent climate change studies have projected an increase in rainfall intensity during rainy days by 2055. A decrease in the total yearly rainfall that is projected for some locations is a result of a decrease in the number of rainy days not a reduction in intensity. The CSIRO's CCAM model projected an increase of daily rainfall of 10 to 20mm.

While climate models are run at intervals of 1 hour or less the outputs that are generated are at the scale of 1 day. As a result, future predictions of rainfall intensity in terms of mm per hour may be required for high resolution hydrological modeling in the future as the model used could under estimate maximum rainfall intensity in some circumstances.

Model selection

The large number of climate modeling and downscaling efforts that have previously been carried out indicates that there is little need for more climate change modeling and downscaling. The primary requirement is for the outputs of past efforts to be more widely disseminated.

However, many of the recent modeling efforts carried in Cambodia have used unsophisticated statistical downscaled data or freely available software that can be downloaded from the World Wide Web and run on personal computers. These efforts also use the older versions of GCMs that were developed and disseminated for the older IPCC reports.

For example the report presenting the details of the downscaling carried out by the Climate Change Unit in MOE for the Second National Communication has not been officially released. This Modelling was carried out in 2010 using older generation GCMs and was produced using statistical methods. The MRD Rural Roads Improvement Project – Climate Change Adaptation project proposed using this model in order to maintain national consistency. However it is difficult to justify using older modelling outputs particularly considering that they have not been described in any published document and therefore cannot be considered official.

Given the paucity of long term measurement stations in Cambodia it is also unlikely that statistical downscaling based on local station data would produce sufficiently accurate high resolution information. The scant rainfall record and poor topographically coverage of weather stations in Cambodia was reflected in early results at MRD to produce rainfall and projected rainfall change maps based entirely on Cambodian rainfall station data. These maps may not fully reflect the current scientific understanding of the relationship between topography and rainfall distribution and were therefore not used in CR-PRIP.

The use of outdated GCM outputs and the use of relatively unsophisticated downscaling techniques in past downscaling efforts would also reduce the suitability of other previously published results. However a high resolution regional model can overcome the lack of detailed observational data to some extent by incorporating local scale topographic effects within the model.

Therefore the preferred source of downscaled data should be from a recent high resolution regional model. The most recent high resolution modeling/downscaling outputs that cover Cambodia (that are readily available) are the results of the Commonwealth Scientific and Industrial Research Organization (CSIRO) regional model - Conformal Cubic Atmospheric Model (CCAM). These were produced for the High-resolution Climate Projections for Vietnam project, and used for the climate modeling that was part of the Greater Mekong Subregion Biodiversity Conservation Corridors Project – Pilot Program for Climate Resilience Component – Cambodia.

2.2 Comments on Meteorological data availability

In Cambodia meteorological data collection is still poor. Systematic observation involving the recording of hydrological and meteorological data is the responsibility of the Ministry of Water Resources and Meteorology (MOWRAM). From the 1910s until the early 1970s data for hydrological and meteorological stations were recorded daily at 50 hydrological stations on the Mekong, the Tonle Sap and the tributaries. The Department of Meteorology (DoM) of MOWRAM has 38 meteorological stations that record rainfall, 23 that record evaporation, and 14 stations that record wind speed. A number of hydrological and meteorological stations were destroyed during the war and various proposals have been developed for their rehabilitation and modernization but little on ground improvements have been made to date. The MRC maintains 12 stations in Cambodia and these stations are considered to be the only reliable stations. For forecasting purposes, key stations send data (weather forecast) daily to DoM. Rainfall, air temperature, wind speed, wind direction and relative humidity are observed by only two main stations (Pochentong and Sihanoukville).

As a result of the poor coverage of weather station data in Cambodia and the concentration of stations in the central plains and Mekong valley, it is difficult to make accurate comparisons between modeled and measured data for Cambodia. A number of international bodies have developed gridded data sets of rainfall that can be used for comparison but there are inconsistencies between these data sets.

2.3 Climate data provided for Road Risk Analysis

The data used in CR-PRIP was digitized from the CSIRO CCAM model maps available in published reports and consist of:

- Current 1 day extreme rainfall output from the CSIRO CCAM model for the period 1980 - 2000
- Projected 1 day extreme rainfall for the two decade period centered on 2055 for a RCP of 8.5
- Current 5 day extreme rainfall output from the CSIRO CCAM model for the period 1980 - 2000
- Projected 5 day extreme rainfall for the two decade period centered on 2055 for a RCP of 8.5

The detail of the current and projected climate change information that was used in the road risk analysis is presented below.

2.3.1 Current 1 Day Extreme Rainfall

The 1 day extreme rainfall map presents results from the CSIRO CCAM model runs that were used to verify the model against current measurements. The CCAM output was used in preference to other available data sets in order to maintain consistency between current and projected rainfall data sets. 1 day extreme rainfall is an average of the results of six CCAM model runs based on inputs from six different GCMs. It is defined as the maximum total daily rainfall from a 20 year CCAM model run. The current 1 day extreme rainfall represents the maximum rainfall output by the models for a 20 year period centered on 1990.

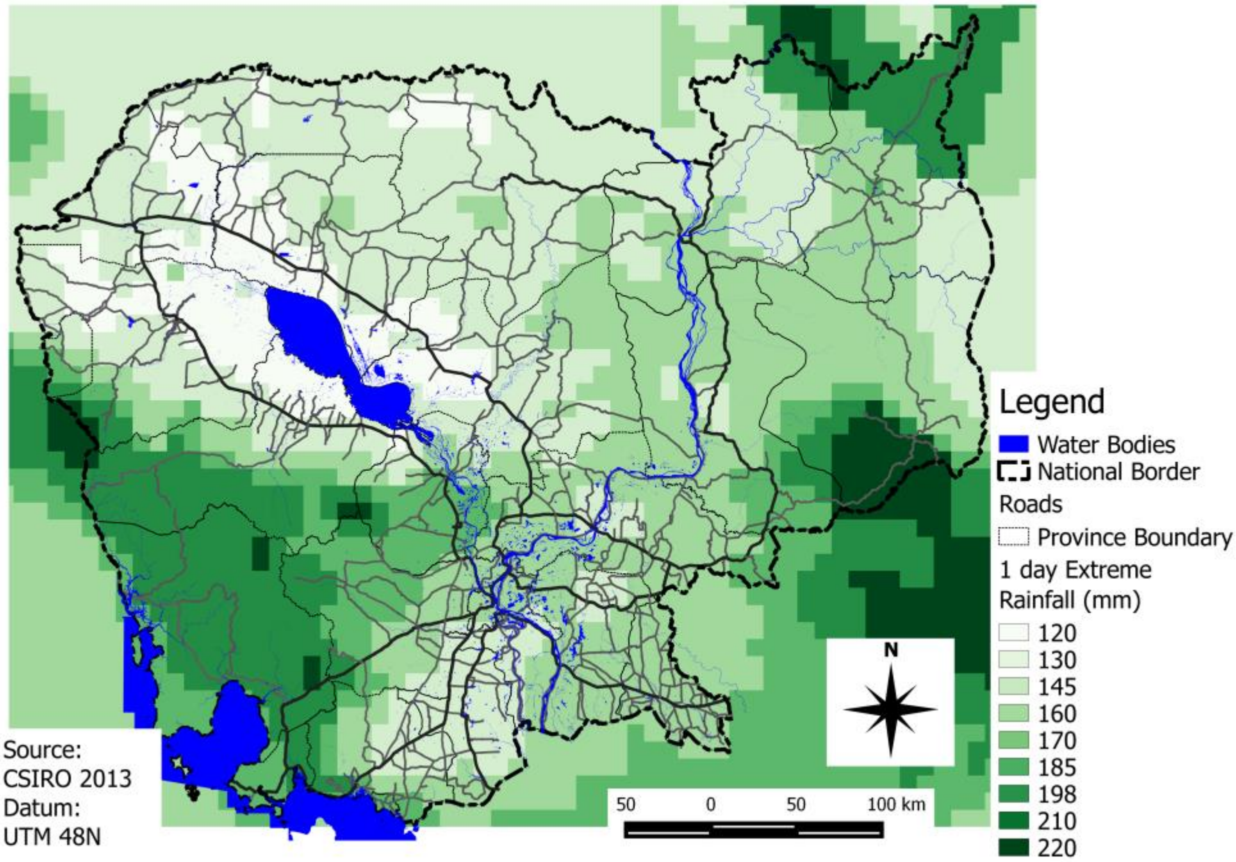

Figure 9 Current 1 day extreme rainfall from the CCAM model.

The distribution of 1 day extreme rainfall shown in Figure 9 reflects the spatial distribution of annual rainfall with high values of around 200mm in the mountainous region near the coast and in Mondul Kiri and in the far north east. Smaller 1 day extreme events of 100 – 145 mm occur in the central flat lands and hilly regions in the north. The model shows the lowest values around Tonle Sap.

2.3.2 Projected 1 day extreme rainfall for 2055 with RCP of 8.5.

The projected 1 day extreme rainfall is the average results from the six CSIRO CCAM model runs for a 20 year period centered on 2055 using an RCP of 8.5. The projected change in 1 day extreme rainfall is the difference between current and projected 2055 values and the map is presented in Figure 10.

The model projects an increase in 1 day extreme rainfall over the coastal mountains and over the hilly regions in the north of the country. There is no change or only a small change projected for the central flat areas, except for a small area north east of Phnom Penh.

2.3.3 Current 5 day Extreme Rainfall

The 5 day extreme rainfall map (Figure 11) presents results from the CSIRO CCAM model runs that were used to verify the model against current measurements. The CCAM output was used in preference to other available data sets in order to maintain consistency between current and projected rainfall data sets. 5 day extreme rainfall is an average of the results of six CCAM model runs based on inputs from six different GCMs. It is defined as the maximum total rainfall recorded over a 5 day period from a 20 year CCAM model run. The current 5 day extreme rainfall represents the average maximum rainfall output by the model for a 20 year period centered on 1990.

The distribution of 1 day extreme rainfall reflects the spatial distribution of annual rainfall with high values of 300mm or more in the mountainous region near the coast and in Mondul Kiri and in the far north east. Smaller 5 day extreme events of 150 – 180 mm occur in the central flat lands and hilly regions in the north. The model shows the lowest values around Tonle Sap.

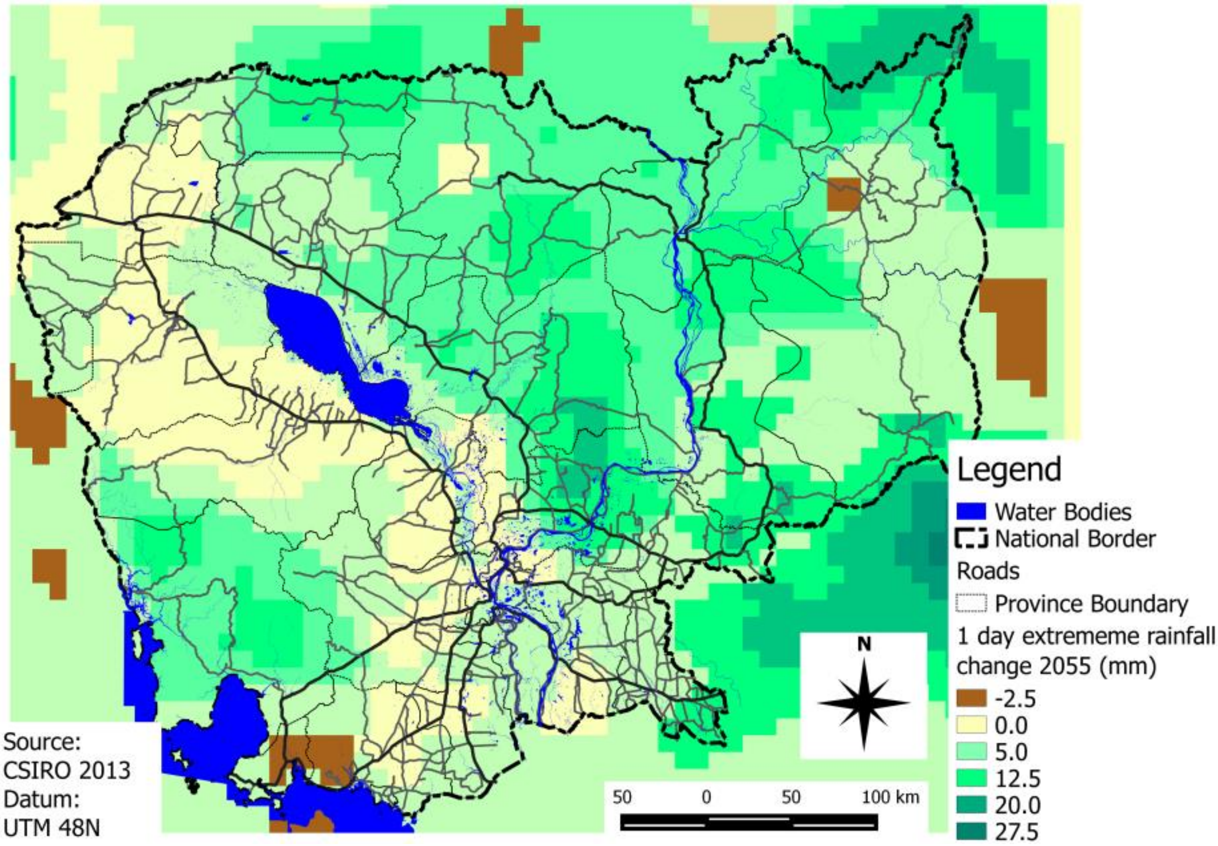

Figure 10 Projected change in 1 day extreme rainfall for 2055 (RCP 8.5 from CCAM)

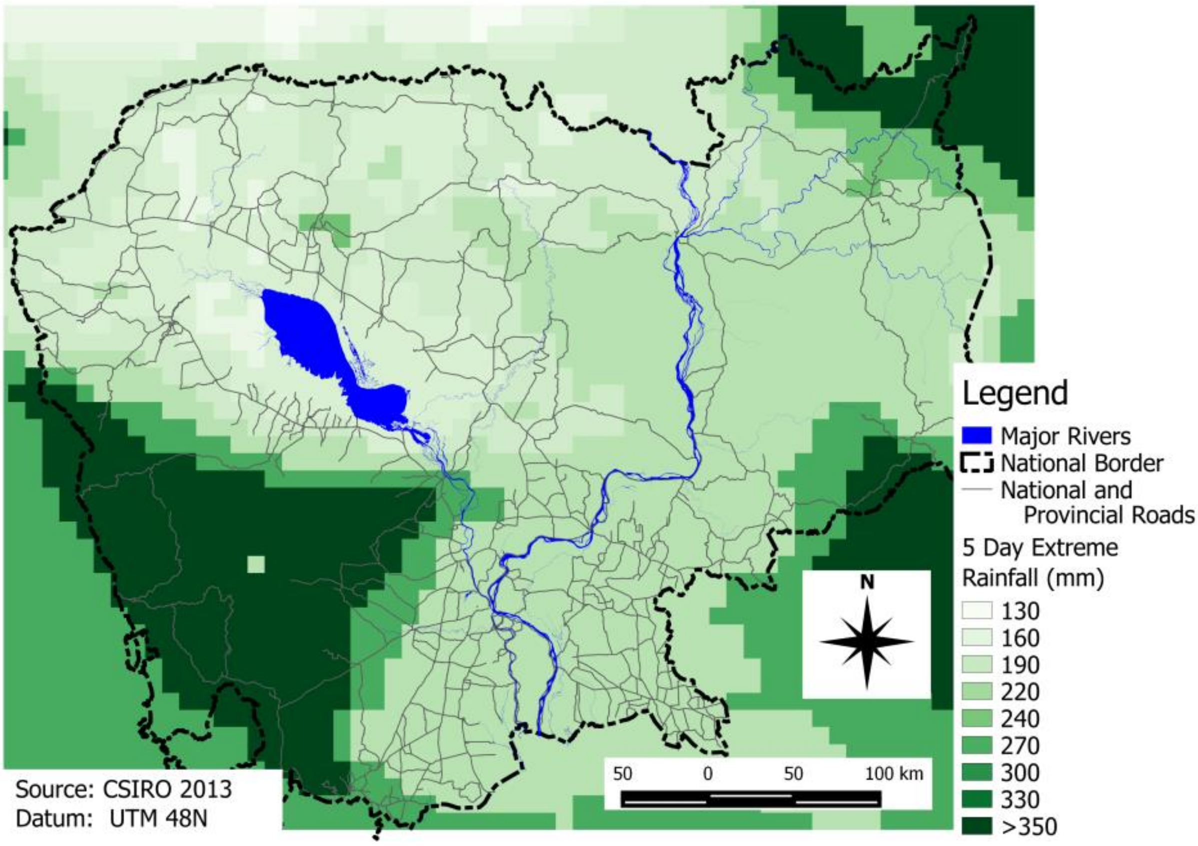

Figure 11 Current 5 day extreme rainfall from CCAM

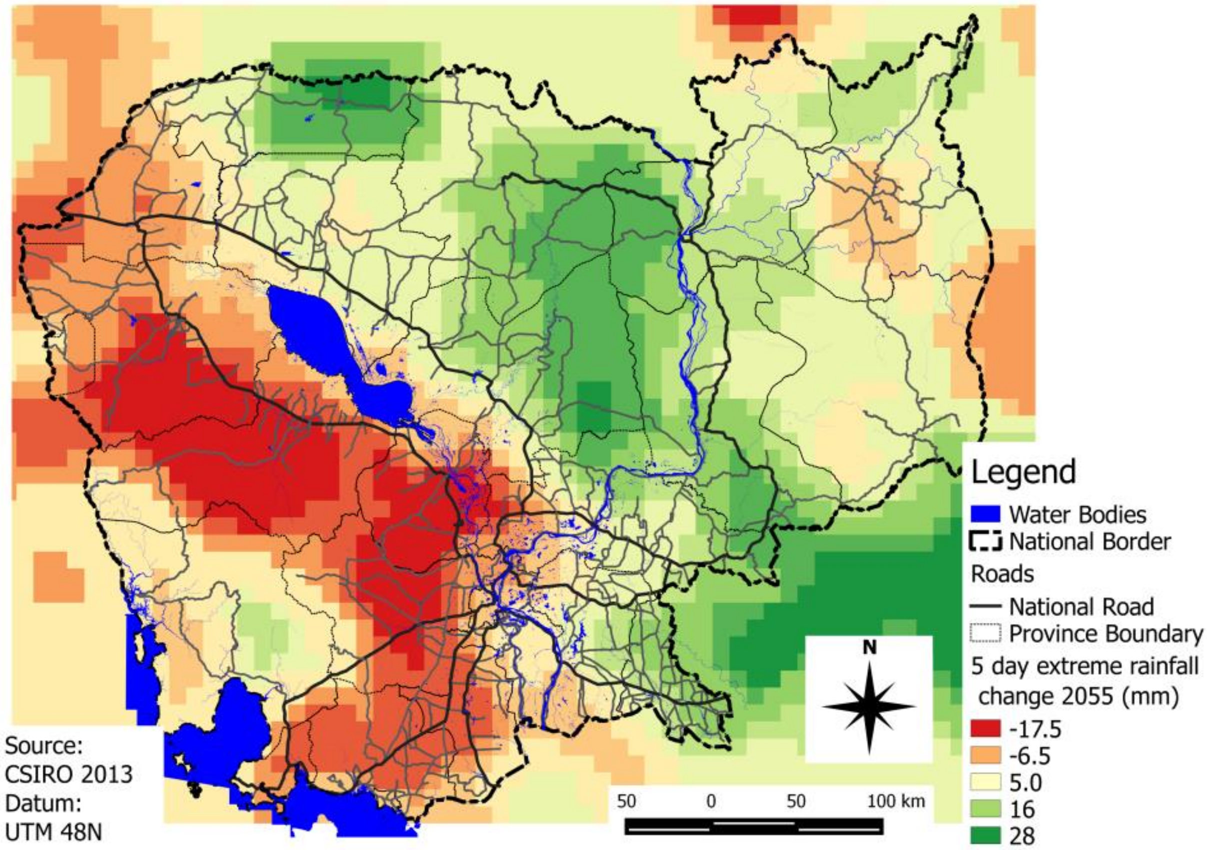

Figure 12 Projected change in 5 day extreme rainfall for 2055 (RCP of 8.5 from CCAM)

2.3.4 Projected 5 day extreme rainfall for 2055 with RCP of 8.5

The projected 5 day extreme rainfall is the average results from the six CSIRO CCAM model runs for a 20 year period centered on 2055 using an RCP of 8.5. The 5 day extreme rainfall represents the maximum output from a 5 day period. The projected change in 5 day extreme rainfall is the difference between current and projected 2055 values and is presented in Figure 12.

The model projects a small increase in 5 day extreme rainfall over the coastal and other high mountains but a more pronounced increase of 16-20 mm per day for the hilly regions to the west of the Mekong in the north of the country. Little change or a slight decrease is projected to occur in the lower hilly areas east of the Mekong. The most pronounced change is a projected decrease of 5 day precipitation of over 17 mm per day for the flat areas south and southwest of Tonle Sap. 5 day extreme rainfall is projected to increase in Svay Rieng.

2.3.5 Limitations of the model

Studies comparing model performance with global climate data have shown that accuracy can be improved if the results are produced as an average of a suit of GCMs that are chosen for good performance in the region. The process of averaging projections from six simulations based on different GCMs may however mask the extreme cases (such as those projecting substantial increases). On the other hand it must be noted that using results from a single extreme model may also be misleading.

With respect to temperature all of the GCMs are projecting increases in temperature for every season across Cambodia. And any differences between models by mid-century (e.g., 2055) are not projected to be large, so that averages are not misleading. The range of minimum and maximum temperature changes during the hot season projected to occur by 2050 are in the order of 0.5 to 1.2 for RCP4.5 and 0.6 to 1.4 for RCP8.5.

With respect to averaging precipitation projections, all of the GCMs simulations agree on the direction and approximate magnitude of change (Katzfey et al 2013), giving good confidence in the results. For example, in Koh Kong, the wettest province, the projected change in rainfall for the six simulations for 2025 for the wettest three months ranges from -5 to -7.5% for an RCP of 8.5 and from -10 to 4 % for an RCP of 4.5. The use of extreme rainfall (the average of the highest values output by each model for a

20 year model run) for vulnerability mapping ensures that a best guess value for the maximum projected rainfall is used. In some other locations, larger changes in rainfall can however be expected but a full country wide comparative analysis was not possible within the scope of this study.

In summary, the effect of extreme cases is partially taken into account by using rainfall intensities from the highest carbon future, in this case RCP8.5 but it is advised that at the detailed design stage, the latest local rainfall data be investigated and appropriate factors be applied if large variations between rainfall predictions models are found.

3 Road Flooding Vulnerability Mapping

3.1 Assumptions and Methodology

Rainfall regime

As stated earlier, it is assumed that changes in the rainfall regime are the most important factors in which climate change can have an impact on physical infrastructure - much more important than, for example, temperature change.

General Methodology

The methodology proposed is specific and has been optimized for Cambodia terrain and conditions, as well as for the availability and quality of data[3].The analysis consists in identifying of road links and parameters based on topographical analysis of road physical parameters and assessing the flooding types that they are exposed to. The topographical analysis is build on Shuttle Radar Topographic Mission[4] (SRTM) data available from public internet sources. Road segments from the National and provincial road network are sourced from MPWT RAMS data and catchment areas and other geographical parameters are then calculated for each road segment. Road resilience is derived from its condition level as provided by the RAMS system. Finally, flood impact or damage risk assessments are carried out for four specific types of flood and mapped.

SRTM accuracy

The accuracy of SRTM is often questioned when used for topographical analysis. As such the official absolute accuracy of the grid ranges from 10 to 20 meters in all directions. That relatively low accuracy results mainly from the data provider obligations to provide worldwide coverage even in cloudy conditions and for all terrain types. For example, the approximate accuracy of a road location and elevation can be obtained from SRTM but that accuracy is in principle limited by the size of the grid utilized. The SRTM data used in the project was retrieved from a 90 m grid or cell[5], and for such a grid size, the elevation of an object can be difficult to determine because of the proximity of other objects such as hills or trees as shown in the following picture.

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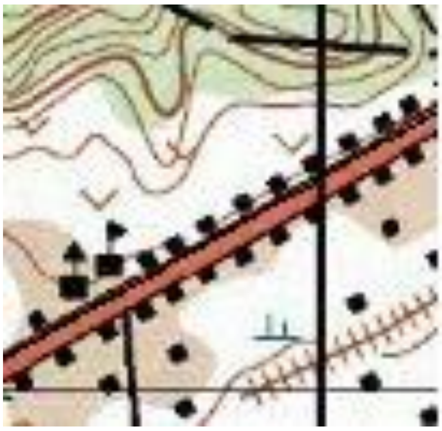
[3] This methodology may differ from example from vulnerability mapping techniques used in a country with significant mountainous terrain such as Timor a different terrain environment

[4] The Shuttle Radar Topographic Mission is an international research effort that obtained digital elevation models on a near-global scale from 56° S to 60° N to generate the most complete high-resolution digital topographic database of Earth prior to the release of the ASTER GDEM in 2009 (from Wikipedia).

[5] New data from a 30 m grid is gradually being published for selected regions in 2015.



90 m

90 m

Figure 13 SRTM grid or cell

However, post analysis can improve significantly the usefulness of any SRTM raw data. The elevation between the measured points can be calculated through linear extrapolation and averaging. This works well for relatively uniform landscapes (like Cambodia) but the distance of 90 m means that break points, steep slopes or vertical drops would not be traced accurately for countries with significant mountainous terrain, as all slopes are interpolated from point measurements.

Having said this it has to be pointed out that despite the shortfalls connected to the SRTM data quality it is usually good for hydrological analysis and low variability terrains like flood plains. In conclusion, for relatively even terrain as in Cambodia, the overall error in elevation is relatively low. Magnitudes of errors of 1 to 2 meters have actually been obtained by comparing SRTM data with measured and benchmarked elevations from the PRIP road, as shown in Appendix 4.

Road catchment area vs. River catchment area method

A road catchment area method has been chosen over a river catchment area method, mainly for effectiveness purpose related to data management and better correlation to road impacts.

Data management aspects

It is possible to calculate every major river catchment area in the whole country and to organize the gained information according to the river flow network. This would come out as River AB - Tributary AB-Sub Tributary CD - etc.. The affected road sections are Road A, B, C, D etc. The type of flood for road A are flash floods from Km 0 to Km 5 and then urban flooding from etc...

Simply from the point of view of data management it would be very difficult to even name the road sections under investigation, as the MPWT data sets are orientated towards the road network, not the river network. From the data management point of view it is much easier to use the existing road section data base as the main analytical unit and attach flooding values to the individual road sections.

Repair packages and budgets can be attached to well established road sections, rather than catchment areas or river sections.

Correlation to road impacts

The road catchment area approach also enables us to describe road sections with multiple flooding risk, for example a low lying road which is susceptible to flash floods if there is a short high intensity rainfall, but will also experience flooding if there is light rain over a number of days. If the road is located in an urban area it might flood with even less rainfall impact, because the drains might not have been maintained properly etc... Therefore, the establishment of 4 indicators for every road section makes it easier to analyse the flooding risk of individual road sections in more detail.

A similar approach for identifying flash flood areas in France has been applied and documented in the publication “Assessment of the susceptibility of roads to flooding based on geographical information – test in a flash flood prone area (the Gard region, France)” by P.-A. Versini, E. Gaume, and H. Andrieu. Of particular interest, the study concludes that “The analysis led to the definition of four susceptibility classes for river crossing road sections. Validation tests confirmed that this classification is robust, at least in the considered area. One major outcome of the analysis is that the susceptibility to flooding is rather linked to the location of the road sections than to the size of the river crossing structure (bridge or culvert)".

Calculation of catchment areas

The calculation of catchment areas, which drain towards a road section is a normal step in the hydrological and hydraulic design of road drainage systems. The GIS - program ESRI ARC Info, provides the catchment calculation function via the 3-D Analyst and the Hydro-Extension. Global Mapper has the catchment analysis function integrated into the normal analysis toolbox. QGIS has a hydro plug-in. The algorithm used usually based on comparing elevation values for neighbouring points to each other to identify the lowest elevation. By the end of this automated process the lowest grid cells in the terrain model are identified and marked as drainage channels to which water flows. The highest points are identified as catchment boundaries. The Rational Formula or another hydrological estimation technique is then used to estimate the design runoff for certain catchment areas.

For analytical purposes it is also possible to analyse a theoretical flow from or to a line segment (road, for example) or a point segment (well or an infiltration point etc.).

However, in these design projects individual catchment areas are calculated and individual structures are designed according to the design runoff. For a normal road section, depending on terrain and road length this can results in hundreds of individual catchment areas and of course the same number of structures. Such degree of detail could was not considered in this project, firstly due to the sheer number of catchments involved and secondly due to the insufficient detail of the terrain model.

Still, in order to obtain a characterization of each road section it is also possible to calculate the combined catchment area, which drains towards a specified road section, not necessarily from one side, but from all sides. This enables an analysis, which can characterize road sections according to their flooding potential: a road, which has very little water running towards it has a low potential of being flooded, for example a ridge road, where all water drains away from the road alignment. This compares to a road parallel to a mountain range, where all surface water has to cross the road alignment in order to drain to lower grounds.

3.2 Classification of road links based on topographical analysis of road physical parameters

The topographical analysis has been carried out as a drainage area analysis, calculating the drainage area and slope of this area towards a specific road link. However, contrary to habitual hydrological practice, emphasis is not focused on the propagation of the flow of water from sub-catchment to larger catchments, but rather upon the issue of a characterization of every road link in view of its drainage characteristics.

In order to characterize the drainage situation of each road link the following parameter were calculated for approximately 550 road links registered in the RAMS (Road Asset Management Project) data base of the MPWT, representing about 11,500 km of roads. The length of the segments varies (i.e. not standardized to 1 km segments) and is based on the MPWT reference road links database, for purpose of compatibility with MPWT other datasets. The results for individual road drainage areas are stored in the Flood risk management database interface (installed in the MPWT mapping department computer) that links the flooding data with the RAMS data.

The following analytical steps were carried out for every road link:

- Definition of the road link as part of the road network.
- Overlaying of the road network layer with the 90 m Shuttle Radar Topographic Mission (SRTM) digital terrain model.
- Definition of the drainage area upstream of the relevant road link.
- Calculation of the relevant geometrical parameter concerning the road link and the drainage area.
- Visual verification of the topographic analysis on the basis of topographic maps, satellite imagery and field observations.
- Storing of the relevant road specific GIS layer for use in a computer application aimed at serving as a tool for improved flooding management and resilience development.

The following parameter were extracted from the SRTM with this method

Table 4 List of geometric road parameters

Road Geometry
• Average road elevation level
• Max. slope of road
• Average slope of road
• Length of road section
Upstream Drainage Area Parameters
• Surface area which drains towards the target road
• Max. slope of drainage area
• Average slope of drainage area
• Average elevation of drainage area
• Perimeter of drainage area
Information on drainage structures, available in the RAMS database
• Type of structures
• Location of structures
• Length and number of spans etc.

The analysis of the drainage areas has been carried out subsequently for all the registered road links. Figure 14 shows the vertical alignment of an example road in the upper part of the diagram and the relevant drainage area upstream of the road in the horizontal view. The area marked in pink indicates water flow towards the target road. Where no pink area appears next to the road the road is located on a ridge, with no water draining towards it.

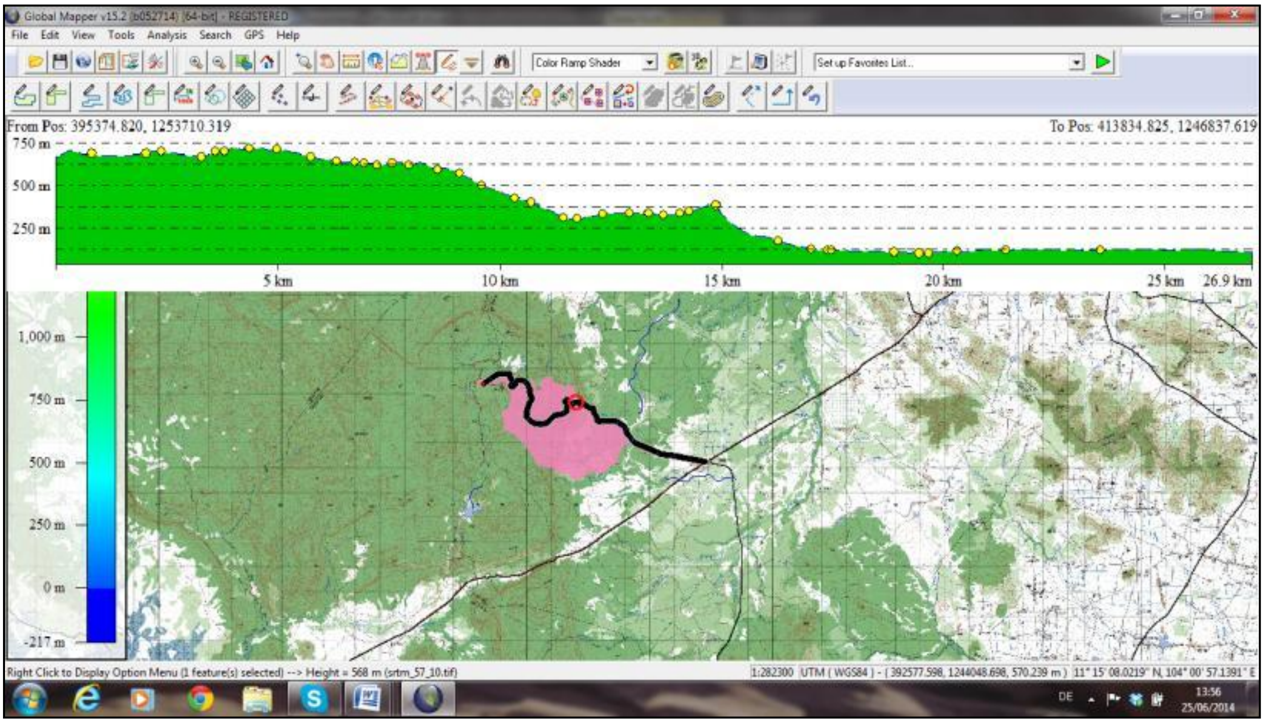


Figure 14 Vertical road alignment and road drainage area

Drainage area maps (also call catchment maps) have been produced for all the road links. The followings aspects have to be considered when discussing the analytical results:

- The analyzed areas cannot be considered as 'catchment areas' in the classical sense. In fact, the resulting areas represent the aggregated area from where water drains towards the relevant road link. This water can flow towards the road from both sides, from one side only, or not at all.
- If the analysis was to be carried out with a more detailed elevation model - such as a LIDAR scan or drone survey- it would be possible to detail the analysis into sub-drainage areas and

designate a specific drainage structure (culvert or bridge) to individual sub-drainage areas. However, such degree of accuracy is only recommended at the design stage of road rehabilitation or of new road construction.

3.3 Definition of flooding types and calculation of risks

In order to define flooding risk - and thus risk from climate change - of individual roads, every registered road link has been analyzed according to the flooding risks outlined in the following.

Four different flooding types have been defined as follows:

- Flash flood
- Large area flooding
- Urban flooding
- Tonle Sap, Mekong and lowland floods

Flood types and the method in which each road section had been checked against the occurrence of each type (the risk) is described below.

3.3.1 Type 1 - Flash Flood

In order to produce a reasonable flood risk analysis it is required to define the term 'Flash Flood`'. The US Weather Service (www.weather.gov) defines a flash flood as:

"A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed, or after a sudden release of water by a debris or ice jam."

The definition[6] indicated that the following conditions are to be fulfilled for the generation of a flash flood.

- High intensity rainfall
- High runoff coefficient i.e. low rate of protecting vegetation cover, especially forest
- Steep overall slope of the drainage area or nearby the target road corridor
- Generally limited catchment area size, as the flood-wave has to keep up over the entire flow Length towards the target road.

Developing a Flash Flood Index for the RAMS Road Network

The development of flash flood indices on the basis of catchment geometry is a fairly established practice. However, it is usually carried out for individual road sections. The systematic analysis of complete road networks is a more recent development.

P.-A. Versini, E. Gaume, and H. Andrieu (2009) have carried out a similar analysis for the Gard Region of France (covering 3,000 km2). Their overall result is that it is possible to define a flash flood risk assessment for specific road sections, even if data concerning the existing drainage structures is limited. It seems that the location, local slopes, elevation and other physical road parameters can be used to broadly generate a flash flood index, if the method is adjusted to local conditions.

As mentioned above, slope, land use, rainfall intensity and catchment geometrics are the most relevant parameters in the analysis. In classical hydrological analysis these considerations were used for the development of the Rational Method for the estimation of peak flow from a specific catchment area. However, these parameters can also be found in most other hydrological methods for peak flood estimation, such as the ORSTOM[7] (Rodier and Auvray, 1965) method or Unit hydrograph methods (see for example Linsley 1958).

Land use and catchment surface cover are critical parameters when assessing flash floods.

National Mapping Organizations (NMO) have produced a Global Land Cover (GLC) dataset. The data is a 1km (30 arc seconds) grid with 20 land cover items. The data were created by using MODIS data

[6] The definition also indicates that flash floods caused by non-natural events, such as the release of flood waters from reservoirs and the case of dam failures have to be taken into consideration. This is a situation occurring in Banteay Manchey due to release of water from Thailand dams. However, since it is localized and not climate related, it has not been incorporated in the model.

[7] Office de la recherche scientifique et technique outre-mer

observed in 2003 (TERRA Satellite) with the cooperation of NMOs of the world in providing training data and validation. The classification is based on the Land Use System developed by the United Nations Food and Agriculture Organization (http://www.fao.org/climatechange/54270/en/). The GLC dataset of NMOs was used to derive runoff coefficients for Cambodia. The following land uses were converted to a land use factor for each drainage area:

Table 5 Land use Factor

Land Use	Factor (LU)
Urban	1
Agriculture / grassland	0.5
Forest	0.2

The average runoff coefficient was extracted for each road link catchment. For further analysis these factors can be extended or fine-tuned, or in the case of future analysis, updated to recent satellite imagery.

Total Rainfall Depth and Rainfall Intensities

High quality data on rainfall intensity for short term events (6 hrs or less) are difficult to obtain for the entire country area of Cambodia. However, it can be expected that change in rainfall intensity is reflected in 24 hour rainfall records and projections. For this reason the 1 day extreme rainfall dataset from the climate data from the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) Conformal Cubic Atmospheric Model (CCAM) regional climate model was used for the analysis of the flash flood risk.

The spatial resolution of the climatic data consists of cells of 20 x 20 km. Extreme 1 day and 5 day high resolution precipitation data for the entire country was used. The data represents the maximum rainfall output by the model for a 20 year period centered on 1990 (current) and 2055. The 1 day extreme rainfall represents the maximum output for a single day and the 5 day extreme rainfall represents the maximum rainfall from any 5 consecutive day totals.

For this analysis normalized rainfall data has been used. The average rainfall component over each catchment was extracted and converted to an integer between 1.0 and 2.2 as outlined below.

Table 6 Rainfall characteristics factors

5 day extreme Rainfall (mm)	Factor (R5)	1 day extreme Rainfall (mm)	Factor (R1)
120	1	120	1
160	1.2	140	1.2
200	1.4	160	1.4
240	1.6	180	1.6
280	1.8	200	1.8
320	2	220	2
360	2.2	240	2.2

The following parameters were therefore used to define the flood risk of a road section due to Flash floods:

Table 7 Flash flood risk parameters and index calculation

Parameter	Justification
Drainage area average Slope ***S*** in %	Steep slopes are required for flash flood development. In order to increase the weight of the drainage-area-slope on the final Flash Flood Indicator, the **square of the average slope** was used in the calculation.
Road Length ***RL*** (m) / Drainage Area Perimeter **DAP** (m)	This indicator aims at describing the overall drainage area shape. A value close to 1 indicates that the drainage area does not extend far from the road alignment. Drainage areas with high values are thus small, with short time of concentration.
Land use factor ***LU***	Satellite imagery used as pointed out above
1 day extreme rainfall factor ***R1***	As pointed out above

Parameter	Justification
Flash Flood Risk = **S**^2 x (**RL**(m) / **DAP**(m)) x **LU** x **R1**	

3.3.2 Type 2 - Large Area Flooding

The parameter is aimed at characterizing large drainage areas, which are drained by medium and large bridges. The key parameter for this index is the drainage area drained by 1 km of road, i.e. Area/Length. The indicator measures the 'hydraulic load' per km of road. If this value is high, bridges are required to provide adequate drainage capacity.

To further focus the analysis on the flooding of large catchment areas a bridge factor is used. The bridge factor quantifies the percentage of the road segment having large drainage structures. The resulting figure is multiplied with the land use coefficient (see above) and a weighted factor for total extreme 5 day rainfall.

Table 8 Large area flooding risk parameters and index calculation

Parameter	Justification
Hydraulic Load ***HL*** = Drainage area (km2) / road length (m)	This indicator aims at describing the overall drainage area shape. A high value indicates a large drainage area to be concentrated on a small section of road.
Bridge Factor ***BF***	Sum of bridge length / road segment length
Land use factor ***LU***	Satellite imagery used as pointed out above
5 days extreme rainfall factor ***R5***	As pointed out above
Large Area Flooding Risk = **HL** x **BF** x **LU** x **R5**	

Note on parameters selected for Large Area flooding

It was pointed out during the technical review that the Bridge factor parameter could be modified to improve the sensitivity of the Large Area flooding index by using (1 – BF) instead than BF. This would result in a variation from 1 to 10% of that risk index. It is however recommended to conduct this adjustment at the time of acquisition of updated data on the pavement and drainage structures of the network whose contribution to the broader flood damage index are also significant (see section 4.3.5) and critical for the performance of the model.

3.3.3 Type 3 - Urban Flooding

Urban drainage systems are designed according to national design standards. Drainage design is usually based upon Intensity Duration Frequency (IDF) curves for various regions, based upon detailed long term measurements of rainfall intensities.

However, the preparation of IDF curves require long term detailed measurements and the measurement network might not be dense enough to pick up climate change processes. A further aspect which makes built up areas susceptible to flooding is the dynamic of the urban areas. Private investment into individual housing and businesses is usually faster than the provision of road drainage structures, provided by public intervention. Planning and construction processes are slow and the construction of urban drainage usually runs behind the construction of houses, especially along transport links.

Urban areas are thus per se vulnerable to changes in rainfall intensities caused by climate change.

The measure for climate change vulnerability used for this analysis is the percentage of urban road in the entire road segment, multiplied with the 1 day extreme rainfall, obtained from the climate model used.

The analysis has been carried out on the basis of a population map available at the MPWT as part of a former project. Raster detection technology was applied to assess the extent to which every road passes through built - up environment. Values range from 0 % to 100% (e.g. all roads in Phnom Penh). Figure 15 below illustrates the built - up area (in pink shading) around the urban section of Road 313-000.

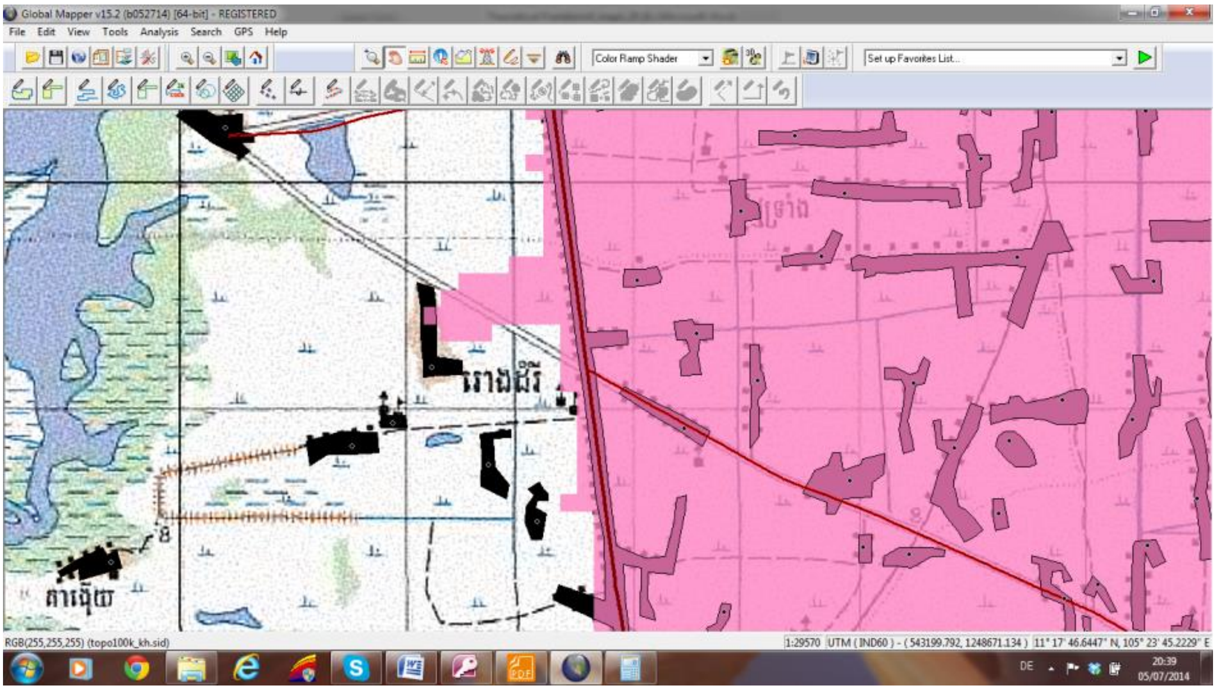


Figure 15 Built up urban area near Road 313-000

It has to be pointed out that this factor is not a land use factor for the drainage area, but an indicator to measure the built-up area directly left and right of the road corridor.

Table 9 Urban flooding risk parameters and index calculation

Parameter	Justification
Urban Ratio ***UR***	Measures the flooding risk in urban area on the basis of urbanization rate per segment of road.
1 day extreme rainfall factor ***R1***	Short term rainfall extreme values are used to simulate correlation with high rainfall intensities
Urban Flooding Risk = **UR** x **R1**	

3.3.4 Type 4 - Tonle Sap and Lowland Flood

The fourth flood risk analyzed is the risk of flooding for low lying areas of Cambodia. This includes not only the areas close to Tonle Sap, but also the flat areas south of Phnom Penh. In order to assess in how far an individual road section can be subject to flooding the inverse of the product of the average road elevation and the average slope of the individual road section was used.

As lowland flooding is susceptible to long and extended rainfall events the five day rainfall data has been used as a further factor in quantifying the flooding risk for low lying roads.

Table 10 Lowland flooding risk parameters and index calculation

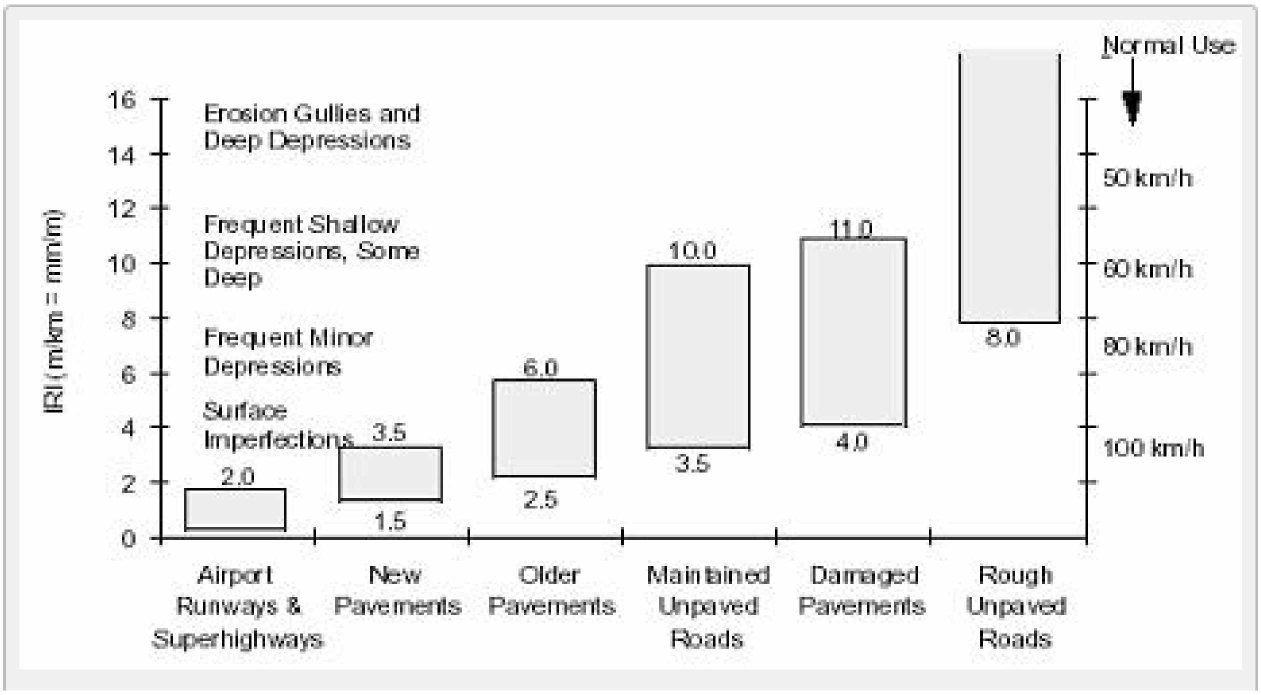
Parameter	Justification
Average road elevation ***HAVG***	Aimed at pointing out roads segments which are completely located in low areas.
Average slope of road ***SAVG***	As above
Total 5 day rainfall ***R5***	Indicator is sensitive to long term rainfall events
Low Land Flooding risk = **R5 / (HAVG** x **SAVG)**	

3.3.5 Road resilience

Vulnerable Cambodian roads are generally recognized as those who are poorly designed – i.e. not account for flood levels, poorly build – with poor material or compaction, and poorly maintained. The actual modeling of flood damage to a road can be rather complex due to the large number of factors and to the difficulty in measuring all these factors.

This is why, in a view to assess the resilience of Cambodian roads, the Consultant has proposed a model based on two key indicators, the road pavement surface condition and the drainage structures condition. From these two parameters, a road planner can obtain a relatively good view of the location of roads whose condition makes them vulnerable to floods, with aim to prioritize rehabilitation interventions.

Pavement condition



The overall road pavement surface condition is assessed using roughness condition (IRI), an indicator used by several donors. International roughness indexes inform on the irregularities of the road surface and can therefore inform on their vulnerability to water infiltrations and to rapid surface flow damage. The range of IRI conditions is represented in the following graph.

Figure 16 IRI roughness index scale (from World Bank)

Next, the pavement type is retrieved from the MPWT RAMS data. To simplify the analysis, the pavement type is grouped as either resilient or non-resilient, in term of vulnerability to floods. Resilient types of pavements include asphalt concrete (AC) and concrete and non-resilient types include double base surface treated (DBST) roads, widely used in Cambodia or gravel roads.

Note: MPWT RAMS data for pavement types presently covers 80% of the network. Non-documented types are assumed as non-resilient.

The risk of flood damage on the road is therefore assessed using empirical curves build using pavement condition (IRI) and pavement type. These curves are however simple approximations of a complex deterioration phenomena and should only be used as indicators in a planning context.

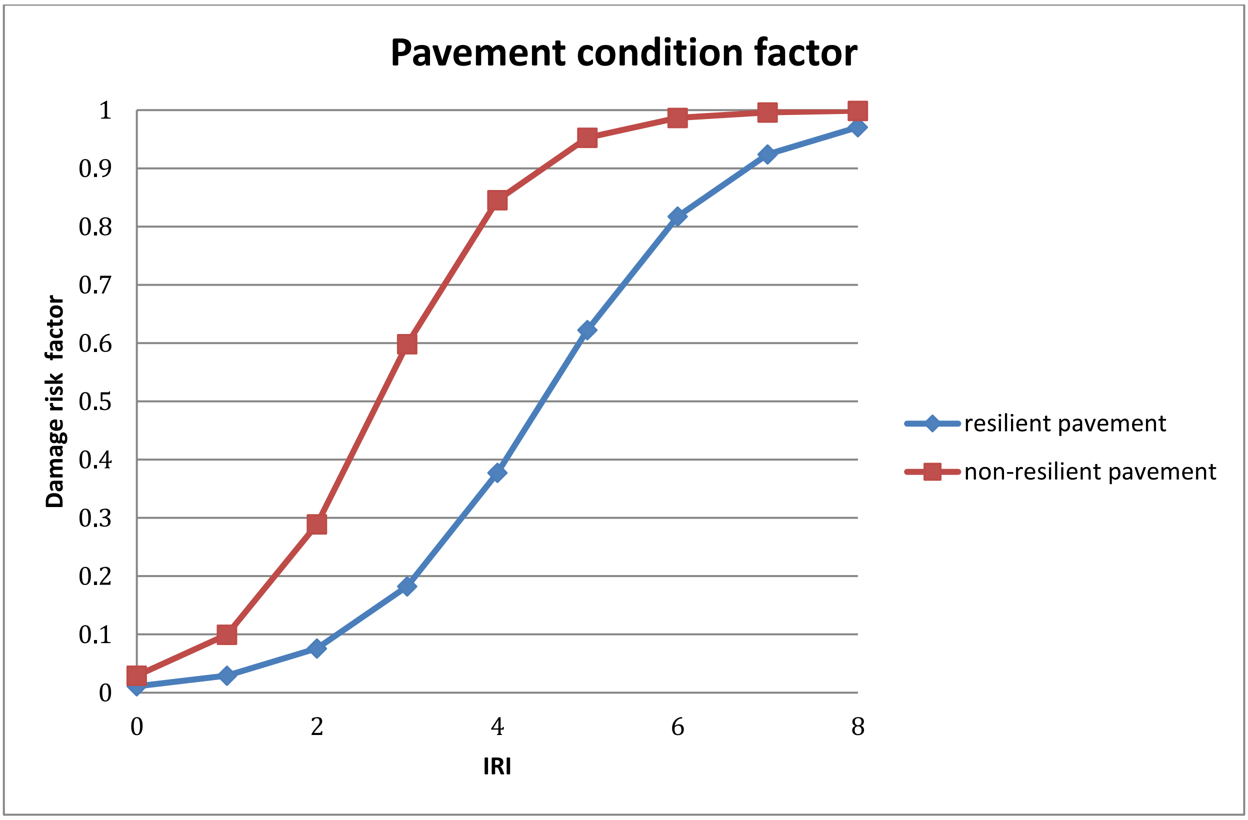


Figure 17 Pavement condition factor curves

The pavement condition factor therefore ranges from 0 for a perfect road to 1 to road sufficiently impaired to offer no resistance to floods.

Table 11 Pavement condition factor

Pavement condition factor	Value
As per graph above	0 (very good resilience to floods) to 1 (no resilience to floods)

Note: MPWT RAMS pavement condition data (IRI) covers presently about 70% of the National and Provincial road networks of the model. Non-documented IRI segments were assumed as 7.

Recently rehabilitated roads

Due to the age of the IRI inventory (one survey in 2011 and one survey in 2014), adjustments are made to account for a reduction in flooding risk following major and recent road construction projects. These recent rehabilitation projects, build under strict supervision arrangements and designed by international teams, are assumed to be build according to latest Cambodian road standards who require hydrological and hydraulic calculations for flooding.

However, due to the variety of design solutions in the projects, the risk of road damage due to flood was accounted for by setting the IRI to 1 for the corresponding road links.

For convenience, all roads under major construction contracts planned by MPWT to be completed within the duration of the Consultant mandate, i.e. 2017, have been recorded as rehabilitated.

Drainage structures condition

The MPWT owns a comprehensive inventory of road drainage structures with associated condition data. A set of factors are proposed to modelize the drainage capacity of a road segment to drain as per its design requirements. First the condition of each drainage structure of the data base, either a bridge or a culvert, is converted in a rating.

Table 12 Drainage structure condition rating

Individual drainage structure condition (as recorded from RAMS)	Rating (0 - good) to 1 - blocked)

Bridge - good	0
Bridge - poor	0.2
Bridge - broken	0.5 or as documented
Culvert - clear	0
Culvert - blocked	1
Culvert - collapsed	1

Then this rating is cumulated for all the drainage structures for the whole length of the road segment and averaged.

Table 13 Drainage condition factor

Drainage condition factor	Value
SUM of (rating * length of drainage structure) / (total length of drainage structures in road segment)	0 (excellent drainage) to 1 (ineffective drainage)

Road resilience

An overall road condition factor is build with a combination of pavement condition effects and drainage condition effects. Each factor is weighable to account for the quality and availability of data and for future calibration purposes.

Table 14 Road condition factor

Road condition factor	Value
PCW * Pavement condition factor + DCW * Drainage condition factor	0 (excellent condition) to 1 (very poor condition)

Where:
PCW = Pavement condition weight
DCW = Drainage condition weight = 1 - PCW

Important note: Given the age of drainage condition data available in the RAMS inventory (data from 2006), DCW was temporarily set to 0 for the flood risk damage maps.

Flood damage risk

The road damage risk is the flood risk reduced by the road resilience factor as shown below. For example, a road having low resilience will be fully exposed to the flood risk assessed for that road. If the flood risks happen to be low for a given type of flood (i.e. small catchment area, low extreme rainfall, etc…), the flood damage risk associated to that road will still be low.

Table 15 Flood damage risk to road

Flood damage risk to road	Value
Flood risk * Road condition factor	0 (No risk) to 3 (High risk)

3.4 Current Road Flooding Damage Risk Maps

In order to assess the flood vulnerability of road links, four types of floods were defined. Each factor is aimed at assessing the flood risk for an existing road from a different point of view. The analysis is based upon physical road parameters such as length, vertical alignment, exposure to natural drainage channels, road condition, etc. as outlined in the previous sections.

The entire process is shown in the diagram below. The first results of the analysis are risk parameters which are then converted into risk scores from 0 (no risk) up to 3 (high risk) for all flood types to make the results mapable. Detailed calculation references, including the main parameters used and the associated data sources are provided in the Flood Risk Management Interface manual.

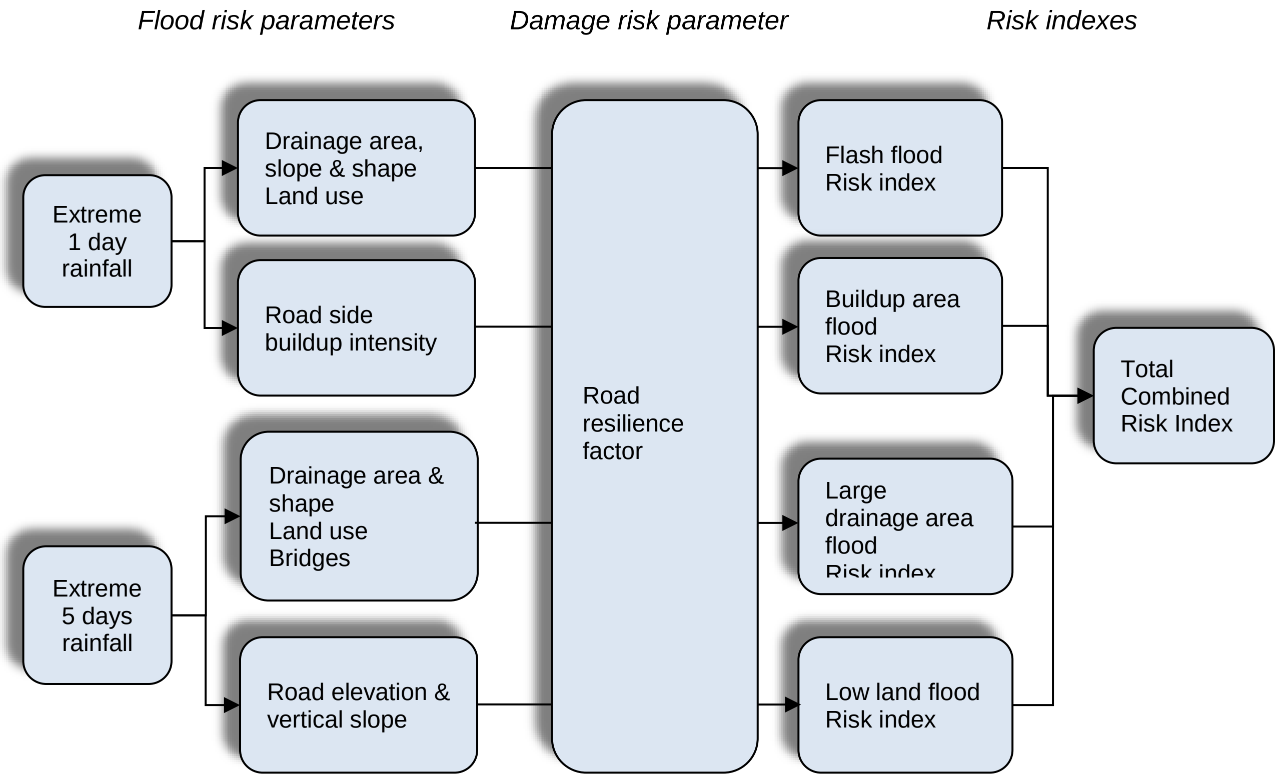


Figure 18 Overview of the risk assessment process

The roads facing high flood risk are shown in red, moderate risk in orange, low risk in yellow and no risk in green.

Maps of the flash flood analysis show that the risks are located in all provinces where there is mountainous terrain. Highest risk areas are in Mondulkiri, Ratanak kiri and Pursat.

Large catchment areas high floods risks are distributed all over the country with no specific patterns as urban flood risk areas and lowland flood risk areas concentrate along the Tonle Sap and the lower Mekong region where is most of the population and happen to be low geographical elevations.

It is interesting to note that the current road damage risks are closely related to the flood risks themselves since there are no patterns of best maintenance practice in any of the Cambodia provinces. The flood risk maps for Cambodia are presented in this report and A3 size versions are provided in Appendix 5. Maps at provincial level are available in a separate document.

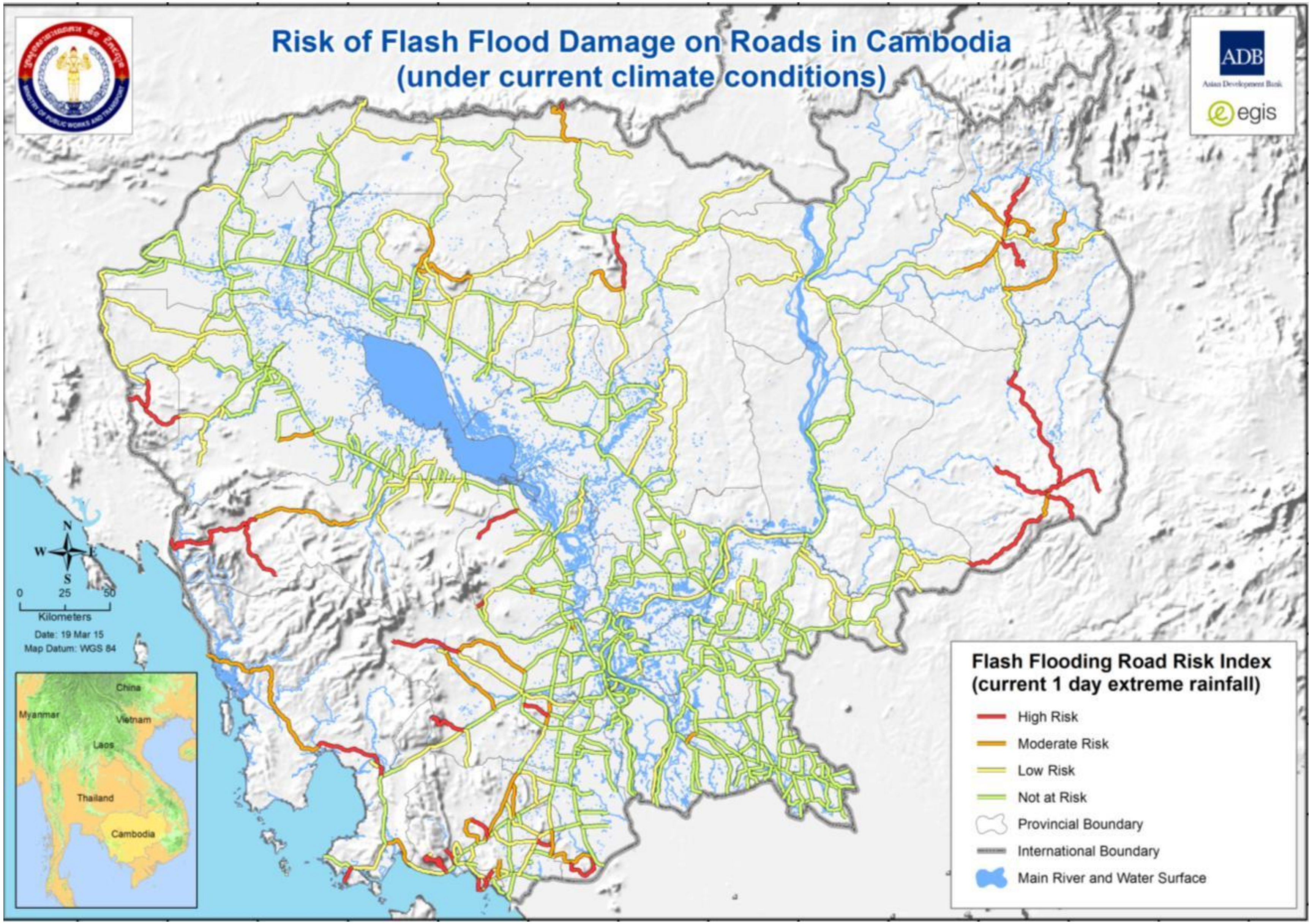


Figure 19 Flash flood Damage Risk Map

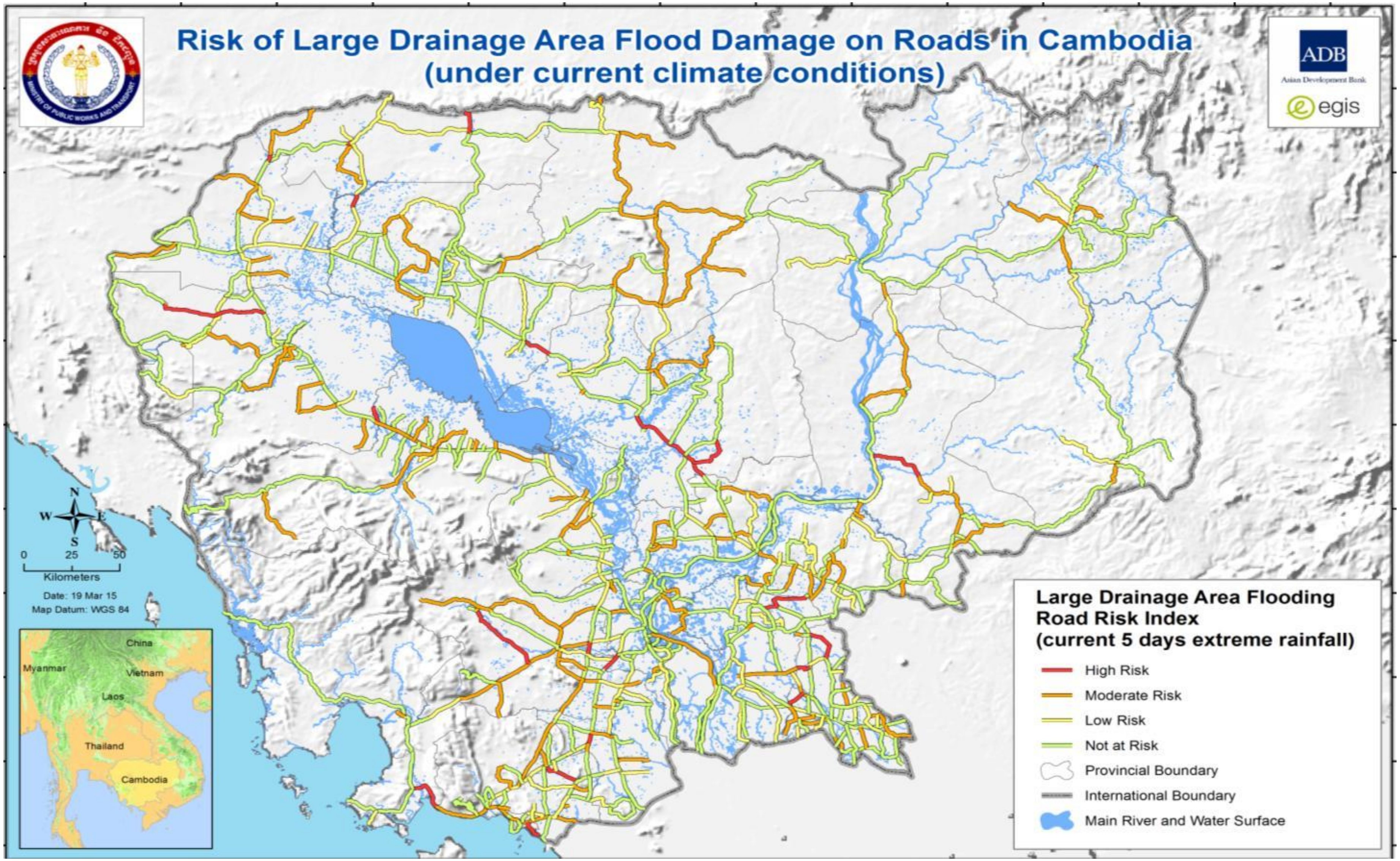


Figure 20 Large Catchment Area Flood Damage Risk Map

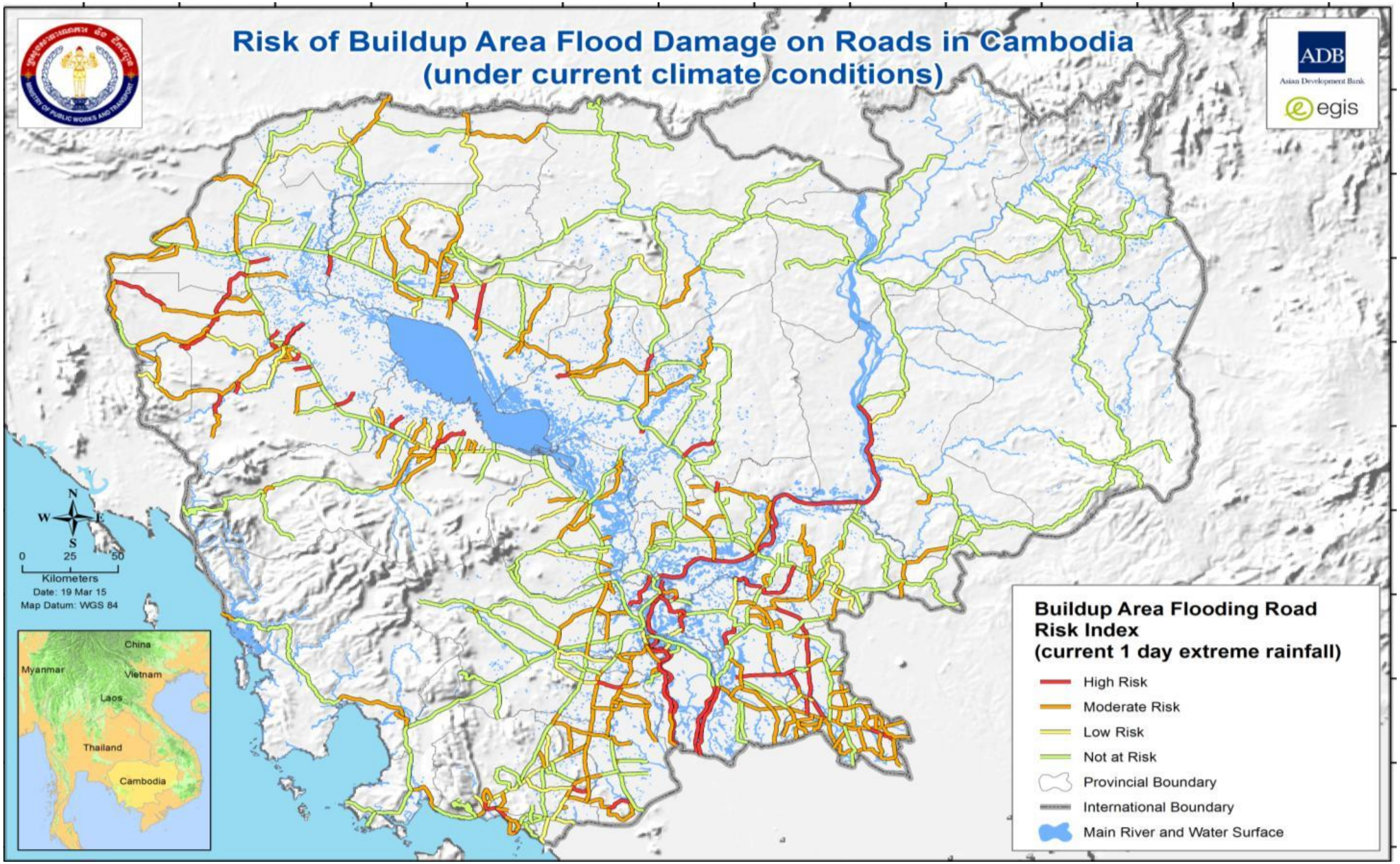


Figure 21 Urban Flood Damage Risk Map

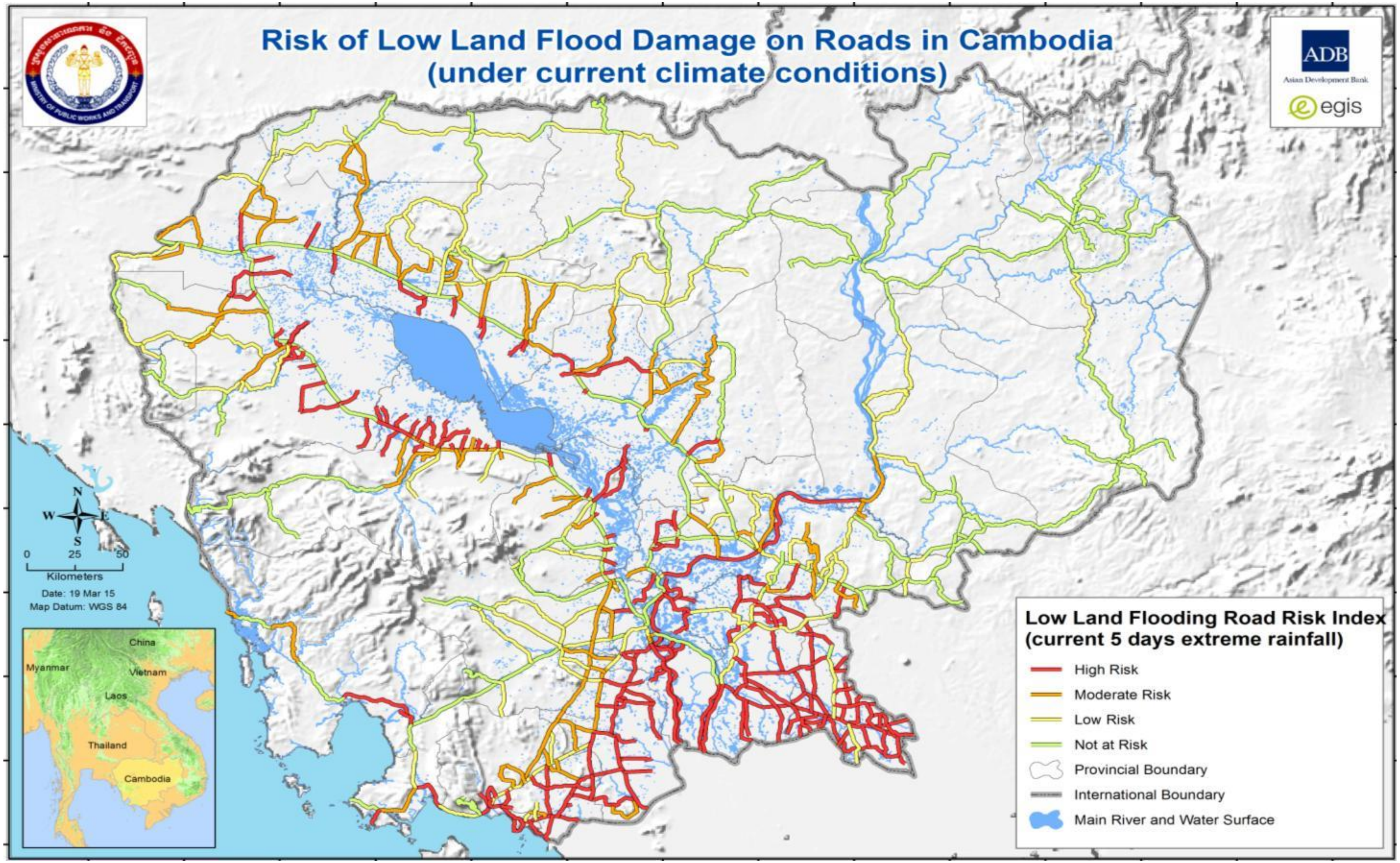


Figure 22 Low Land Flood damage Risk Map

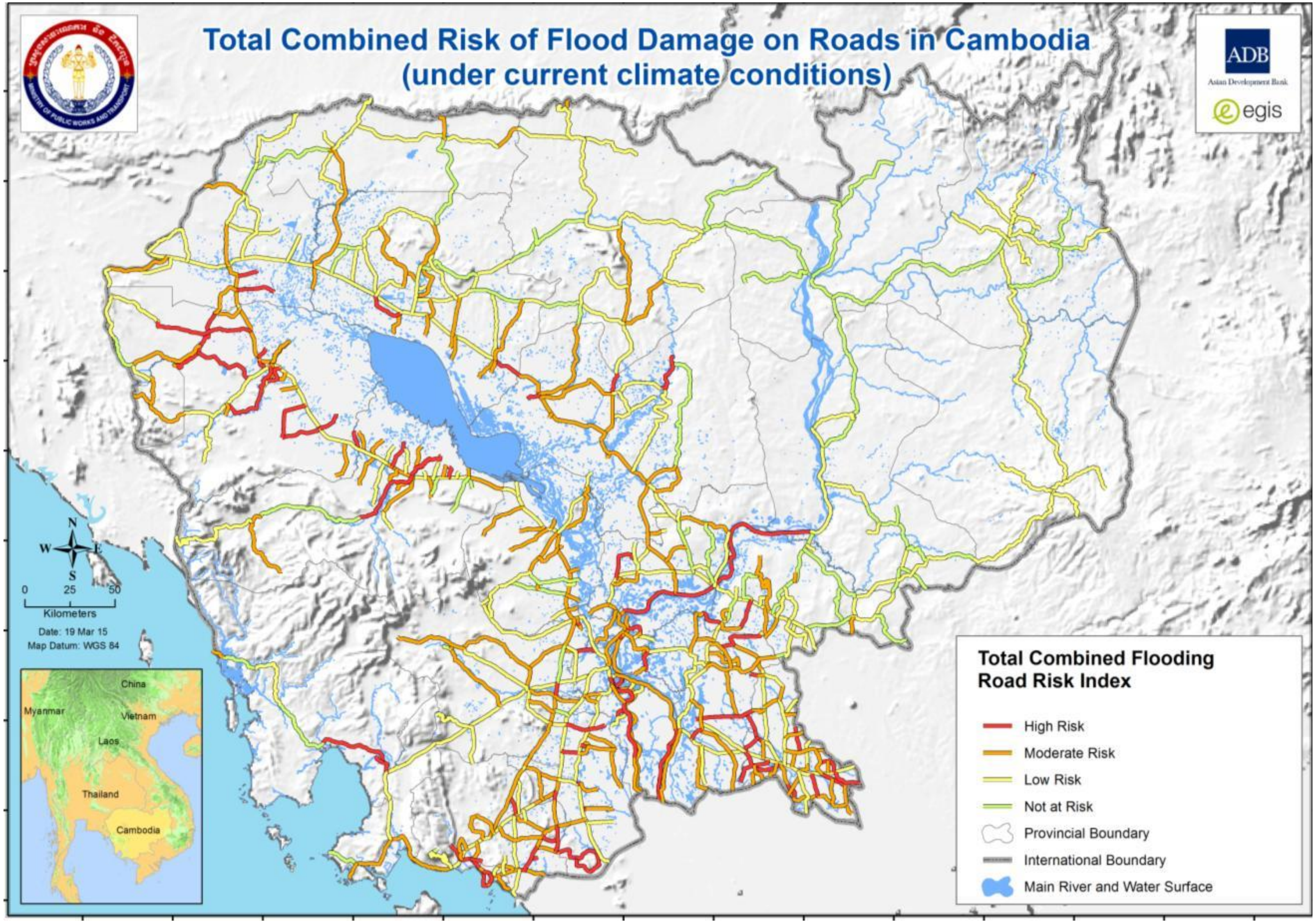


Figure 23 Multiple Flood Damage Risk Map

Multiple Floods

While some of the parameters exclude each other, for example the flash flood index and the large area index, it is interesting to analyze which roads of the national road network are exposed to multiple threats. This can be obtained by adding up the risk scores for all 4 parameters. The resultant total score was then classified into four categories. A first result of this map overlay is presented on Figure 23.

The combined road flooding risk maps indicates high vulnerability in the areas north east of Tonle Sap, but also south of the lake. The road links are essentially the NR 5 west of Kampong Chhnang and onwards to Pursat, Battambang and the NR 6. High total score was also calculated north of Phnom Penh for on some roads links in the eastern low land of the country near Vietnam.

Multiple Flood Vulnerability by Province

Table 16 presents the risk analysis on province basis. For each province the number of kilometers of each road that are classed as being at risk from multiple risk. It must be remembered that the analysis was carried out on the basis of road sections. Therefore the entire length of any section may not be susceptible to each factor and the lengths shown can be an over estimation.

Table 16 Length and percentage of roads by province being at moderate or high risk of a combination of flood types (Current conditions)

PROVINCE	Total (km)	Nb of Km at high risk	% at high risk	Nb of km at moderate risk	% at moderate risk
Banteay Meanchey	425	33	8%	84	20%
Battambang	706	149	21%	131	19%
Kampong Cham /Tbong Khmum	1212	201	17%	232	19%
Kampong Chhnang	462	0	0%	189	41%
Kampong Speu	464	0	0%	204	44%
Kampong Thom	551	31	6%	175	32%
Kampot	497	62	12%	239	48%
Kandal	640	178	28%	233	36%
Kep	74	36	49%	32	43%
Koh Kong	238	54	23%	8	3%
Kratie	460	0	0%	66	14%
Mondul Kiri	218	0	0%	0	0%
Oddar Meanchey	294	0	0%	18	6%
Pailin	145	45	31%	40	28%
Phnom Penh	180	0	0%	86	48%
Preah Sihanouk	99	31	31%	0	0%
Preah Vihear	804	12	1%	105	13%
Prey Veng	643	91	14%	315	49%
Pursat	636	104	16%	228	36%
Ratanak Kiri	456	0	0%	0	0%
Siem Reap	954	37	4%	266	28%
Stung Treng	245	0	0%	0	0%
Svay Rieng	593	139	23%	352	59%
Takeo	450	120	27%	204	45%

The table also shows that Kampong Cham has the largest number of kilometers of roads classed as being at very high damage risk from multiple floods, i.e. 201 km. Then comes Kandal with 178 km and Battambang with 149 km.

3.5 Mapping of Change of Flooding Risk due to Climate Change

A second round of risk mapping has been carried out for the Cambodian Road network. For this assessment the rainfall input figures have been changed according to the projected climate change data. The change in input concerns both, change in extreme one day rainfall and change in total 5 day rainfall. Road condition is unchanged to be able to visualize only the climate change effects. The four different risk parameters are affected to a different degree and in a different way by these climatic changes.

3.5.1 Analysis of road flood risk by Province

The following table summarizes the number of kilometers of roads in each province that are at a high risk of being impacted by each of the four identified types of flooding. The table looks at the current conditions and presents predicted values for 2055 under a high CO_2 scenario climate change (RCP 8.5). Due to its mountainous terrain, Mondul Kiri has over 200km of roads that are at very high risk from flash flooding. Pursat has over 100 km of roads at very high risk from flash flood while Kampot, Ratanak kiri, Kampong Speu, and Kratie have just under 100 km of roads at very high risk. As the flash flood indicator is heavily weighted towards the catchment slope, the smaller input from rainfall means that there is no change projected to occur for this indicator due to climate change.

Table 17 Nb of Km of roads per province rated at high risk of flooding for current climate conditions

Province	Flash Flooding	Large Area Drainage	Urban Flooding	Lowland Flooding
Banteay Meanchey	0	4	11	73
Battambang	0	57	153	226
Kampong Cham / Tbong Khmum	0	0	198	262
Kampong Chhnang	37	0	0	122
Kampong Speu	84	45	0	0
Kampong Thom	0	78	31	101
Kampot	88	20	13	219
Kandal	0	18	207	398
Kep	27	11	14	67
Koh Kong	49	0	0	54
Kratie	61	31	69	0
Mondul Kiri	201	0	0	0
Oddar Meanchey	0	18	0	0
Pailin	56	0	46	0
Phnom Penh	0	11	82	81
Preah Sihanouk	9	22	0	0
Preah Vihear	43	0	12	0
Prey Veng	0	38	131	486
Pursat	119	11	50	196
Rotanak Kiri	69	0	0	0
Siemreap	27	25	52	102
Stung Treng	0	0	0	0
Svay Rieng	0	31	81	521
Takeo	28	7	28	287
Total	898	427	1178	3195

Kampong Thom has around 80km of roads at very high risk from large area catchment flooding, while Kampong Speu and Battambang have around 50 km each at high risk. In Kandal, climate change is projected to result in an increase in the length of roads highly exposed to large area catchments floods from 7 to 18 km.

Most of the high risk urban (buildup area) flooding is located in four provinces, Battambang, Kampong Cham, Kandal and Prey Veng. Climate change is projected to increase the length of roads at very high risk of Urban flooding by 57km in Battambang and 15 Km in Siemreap.

As would be expected the provinces covering the central plains have a large amount of roads that are at risk from low land flooding. Prey Veng and Svay Rieng have around 500 km of roads at high risk each. Climate change is projected to increase the exposure to lowland flooding for two provinces, Pursat and Siem reap.

Table 18 Nb of Km of roads per province at high risk changed by climate conditions

Province	Type of flood	Nb of Km at high risk 2013	Nb of km at high risk 2055	Increase in km
Battambang	Buildup area	153	210	57
Kandal	Large drainage area	7	18	11
Pursat	Low land	196	222	26
Svay Rieng	Buildup area	81	96	15
Siem Reap	Low land	102	163	61

3.5.2 Exposure to multiple flood risk factors

Table 19 shows the number of kilometers and the percentage of the roads of each province that are rated as being at high risk of flooding from a combination of flooding types. Two provinces, Kandal and Kampong Cham have nearly 200 km of roads at high risk of flooding from multiple types of flood each. Three more provinces, Battambang, Pursat, Svay Rieng and Takeo have over 100 km of roads at high risk of flooding from multiple types of flood. Three provinces, Kampot, Koh Kong and Prey Veng have over 50 km at risk from multiple types of flood. The remaining provinces have a small amount of kilometers of roads at risk but the 36 kilometers in Kep that are at risk represents half of the province provincial and national roads. Two provinces, Kampong Chhnang and Svay Rieng, are projected to have new road segments classified as being at high risk by 2055. Takeo risks are projected to decrease slightly.

Table 19 Length of road per province rated at high risk of flooding from a combination of flooding types – Current and future conditions

Province	Baseline Km	2055 Km
Banteay Meanchey	34	34
Battambang	149	234
Kampong Cham / Tbong Khmum	202	202
Kampong Chhnang	0	0
Kampong Speu	0	**17**
Kampong Thom	31	31
Kampot	62	62
Kandal	178	178
Koh Kong	54	54
Kratie	0	0
Kep	36	36
Mondul Kiri	0	0
Oddar Meanchey	0	0
Pailin	45	45
Phnom Penh	0	0
Preah Sihanouk	30	30
Preah Vihear	12	12
Pursat	104	104

Province	Baseline Km	2055 Km
Prey Veng	92	92
Rotanak Kiri	0	0
Siemreap	37	37
Stung Treng	0	0
Svay Rieng	139	**155**
Takeo	119	**110**
Total	**1324**	**1433**

Changes are marked in bold

3.5.3 Summary of effects of climate change

The roads that are assessed as potentially showing a change in the combined road risk index due to climate change are shown in Figure 24. The differences are very limited, as predicted by the rainfall model and the vast majority of the network shows no change in risk level.

Risk increases

Only three sections of road show an increase in the risk of flooding from a combination of flooding types from moderate to high, in Svay Rieng, in Kampot and in Kampong Speu. Five sections of road across the country show an increase in the risk of flooding from a combination of flooding types from low to moderate and nine sections from no risk to low risk.

Risk decreases

Four road sections show a decrease in the risk of flooding from a combination of flooding types. This reflects the climate change projection of a small decrease in extreme rainfall for a few areas around the country.

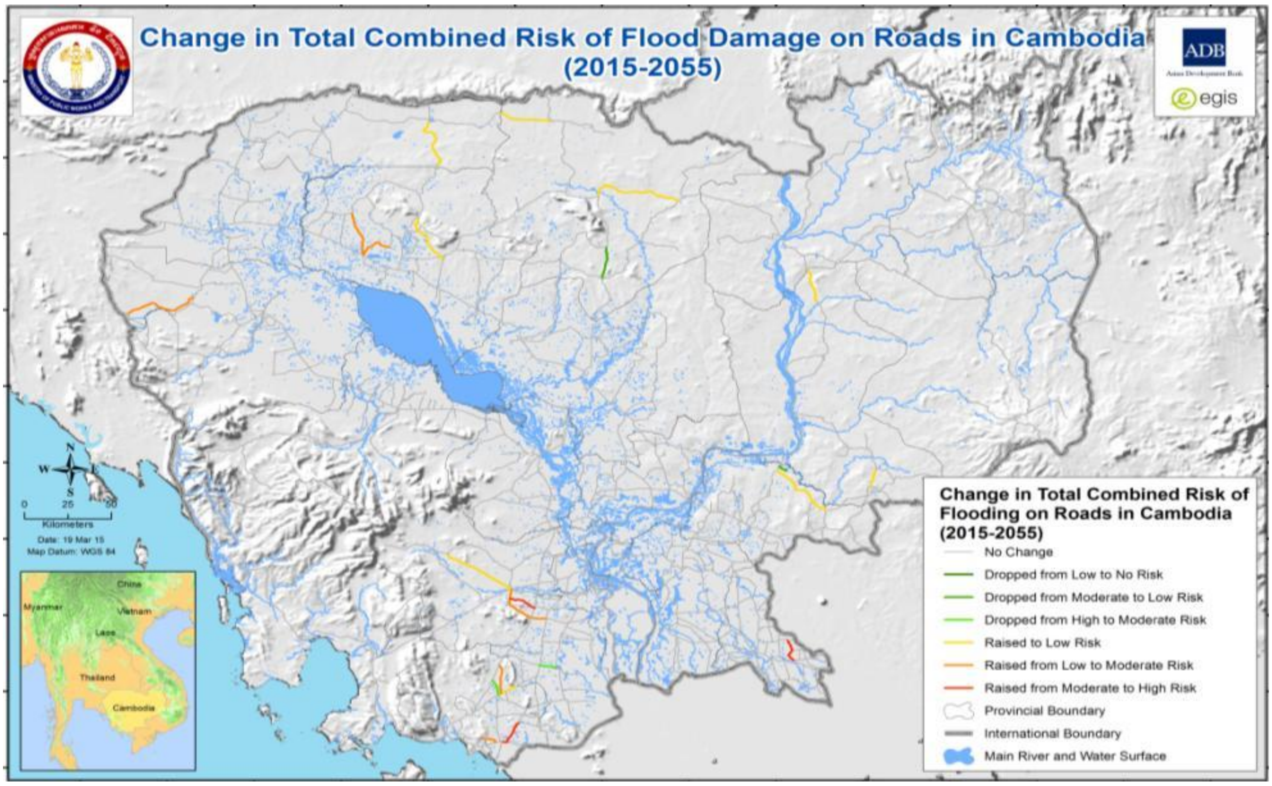


Figure 24 Map of road sectors that are projected to change in combined flood risk category as a result of climate change

3.6 Model limitations

The models developed by the Consultant for flood risk assessment have their limitations, like all models based on climate change data and algorithms, and were devised primarily as a tool for planning (and not for design). In order to adequately assess the scope of changes in future impacts on roads, we must first understand that changes in floods and in flood damage are much more subtle than changes in rainfall.

For example, changes in flood risks are normally lesser than changes in rainfall due to soil moisture absorption effects. Other factors also impact. Future variations in Tonle Sap and Mekong levels will depend on water level manipulations at dams and on future timber cutting of lands and those scenarios were deemed too complex to be analyzed within this study. At the flood damage modeling end, the phenomena that lead to actual damages are complex and still in the research domain. Therefore, several assumptions were made at the modeling phase and results were subsequently calibrated with observed site situations and with local road specialists' site knowledge and experience.

The comparison of flood damage risks to roads under current climate condition and of the same risks under future climate conditions is approximate and therefore carried only to illustrate the magnitude of changes and not for any other purposes.

The range of assumptions made for each modeling exercise lead to known limitations, as shown below.

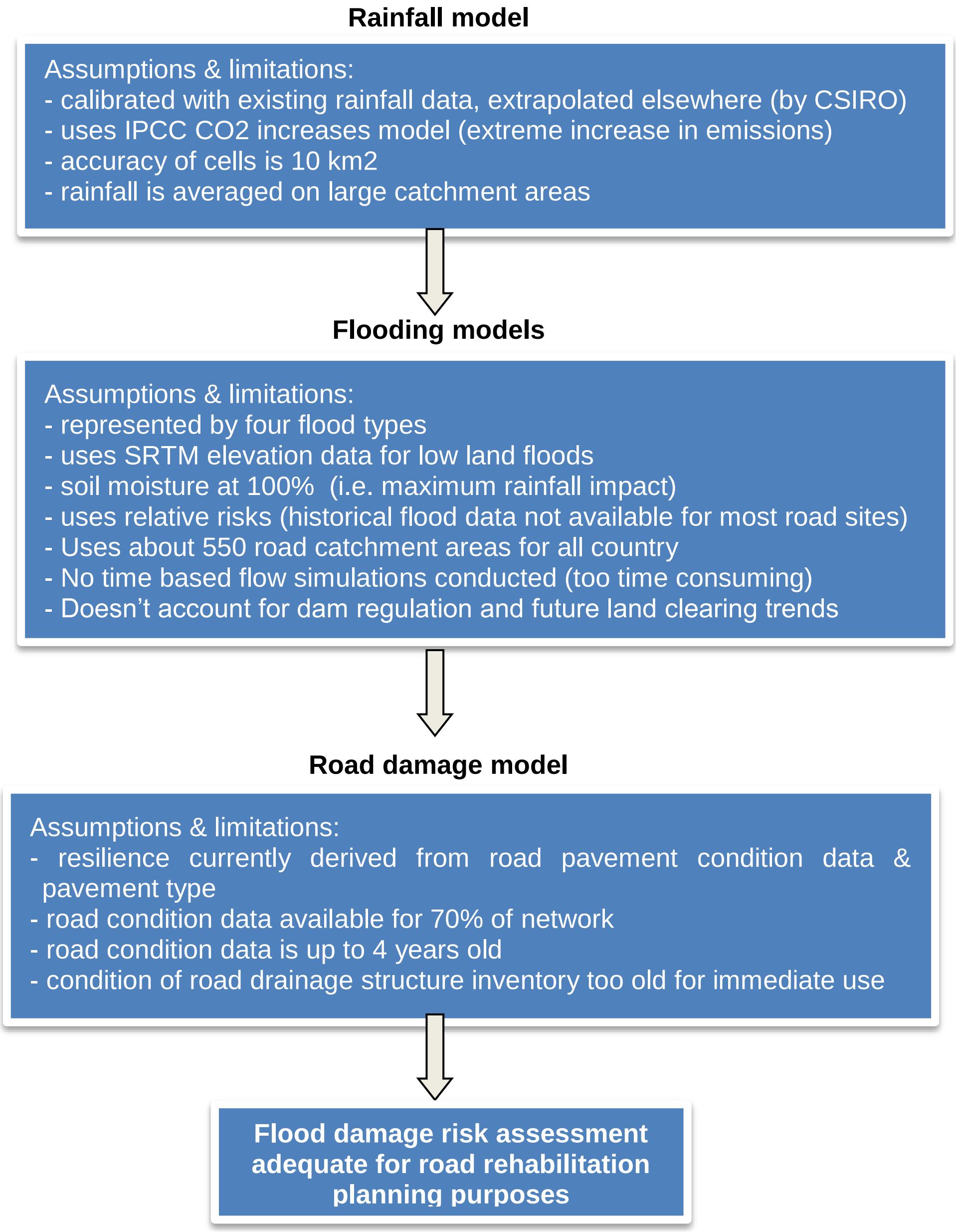


Figure 25 Modeling assumptions and limitations

In summary, due to the limitations of availability of flood data in Cambodia, the method proposed is intended to be part of a larger cost-effective process that starts with the assessment of flood risks using geographical and land use characteristics as well as rainfall data. This first risk assessment helps to prioritize and target the rehabilitation of a number of high risk roads. Once this prioritization is completed, local investigations and traditional hydraulic analysis are then conducted on the selected road segments leading to the final (flood proofed) designs as shown in Figure 5.

3.7 Recommendations and Next Steps

There are several options that can be considered to increase the accuracy of the models. A number of them are suggested hereby to bring some improvements, grouped in order of relevance:

3.7.1 Updating RAMS drainage structure condition data

MPWT should update the condition of its extensive inventory of bridges and culverts. This is one of the best indicators of the vulnerability of roads to flood damages. The latest condition surveys dates from 2006 and was not used for assessing flood risks. The input of drainage condition data has already been built into the flood damage model for future usage. It is also recommended to include into future surveys the condition of the embankment protection near the drainage structures, where the highest flow velocities are normally observed.

3.7.2 Updating RAMS pavement condition data

Another effective improvement of the model is through the actualization of road condition data. Pavement surface condition indexes (IRI) could be refreshed on an annual or bi-annual basis. Optionally, traffic data now available for about 30%[8] of the network, could be updated to develop simple road deterioration models in view of correlating to older pavement condition data.

3.7.3 Reconciliation of MPWT road data sets

This initiative would greatly facilitate any future input of new roads or data in the system and would ensure continuous compatibility with RAMS or other MPWT datasets. The road naming systems (link IDs) of the RAMS database and of the MPWT GIS database are not fully consistent and need to be reconciled in order to benefit from both data sources. There will also be a need to streamline the MPWT Road Infrastructure Department data collection process with the e-datasets of the Ministry. This will require significant investigation of the MPWT road network referencing systems from a knowledgeable local road expert.

3.7.4 Integrating flood damage and flood events data

Although extensive post flood evaluation reports were prepared by the government of Cambodia after the 2011 and 2013 flood events, the collection of damage data has not been harmonized and much information has been lacking, for analysis purposes.

It will be however possible to further calibrate the flood risk model through the incorporating of systematic future flood and road damage data, using a function of the Flood risk management interface which was designed to facilitate this data input. In combination with latest road condition data, this information will make possible a better understanding of the complex relationship between floods and road damages.

4 Socioeconomic Vulnerability Mapping

Village leaders are required to provide a wide range of information to the National Institute for Statistics for the National Commune Database. This includes information on the number people in the village that were affected by flooding. It is proposed that this indicator is used as a measure of exposure. A further measure is the number of people who have housing that is able to withstand the effects of flooding, while the number of people with boats is also considered a measure of their ability to avoid the effects of floods.

Sensitivity is considered to be a measure of the ability of community members to evacuate, and the indicators selected reflect this. Access to a car is considered to decrease sensitivity, while having aged or disabled family members will hinder evacuation. Community members have also stressed that having animals decreases their ability to evacuate.

While exposure and sensitivity determine the potential impact of a climate-induced change, the capacity of the community to adapt will be a major influence on what impact actually eventuates. Local vulnerability is determined by conditions at a range of scales. The capacity of a household to cope with climate hazards depends to some extent on the enabling environment of the community, and the adaptive capacity of the community is influenced by the distribution of the resources and processes of the region, (Smit and Pilifosova 2003, Yohe and Tol 2002). Some influences on adaptive capacity are mainly local (e.g. the presence of a strong kinship network which will absorb stress) while other influences are more general socio-economic and political systems (e.g. the availability of state- subsidized crop insurance), (Smit and Wandel 2006).

At the local level, vulnerability can be influenced by such factors as managerial ability, access to financial, technological and information resources, infrastructure, the institutional environment, political influence, kinship networks, etc., (Adger et al 2001, Smit and Pilifosova 2001, Wisner et al., 2004). However, it needs to be considered that the drivers of vulnerability are not independent of each other. For example, the presence of a strong kinship network will increase adaptive capacity in a number of ways; by allowing greater access to economic resources, increasing managerial ability, providing or offering employment as

[8] According to latest M&E report (June 2014), traffic data is available from RAMS on NR1, 2, 5, 11, 71, 72, 73 and 2714

supplementary labor and buffering psychological stress, (Smit and Wandel 2006). Economic resources will improve the uptake of new technology and ensure that community members have access to training opportunities which will lead to greater political influence. (Smit and Pilifosova 2003, Folke 2006).

Vulnerability[9] can then be estimated by examining indicators that are based on these various components. In order to coordinate national mapping with local mapping efforts, the indicators selected were based on Commune Database questions that best reflected the results of questionnaire carried out in Kampong Chhnang Province.

Table 20 Social vulnerability indicators

Component	Description	Indicator
Exposure (E)		% affected by flood
	Housing security	% HH without sustainable house
		% HH with boat
Sensitivity (S)	Evacuation hindrance	% HH with aged
		% HH with disabled
		% HH with animals
		% >3 km from evacuation center *
	Evacuation Ability	% HH with car or larger
Adaptive Capacity (AC)	Ed & CC Awareness	% PP Education > upper 2ndary
		% in service industry
	Food security	% HH with access to irrigation
		% farm HH with farmland <1 ha

*Not available nationally

4.1 National mapping

The nation socioeconomic vulnerability shows that vulnerability varies spatially across the country with little evidence of patterns. Villages in Takao have low vulnerability. Villages along major water courses also have low vulnerability due to their access to boats.

[9] Vulnerability = (Exposure x Sensitivity) / Adaptive capacity

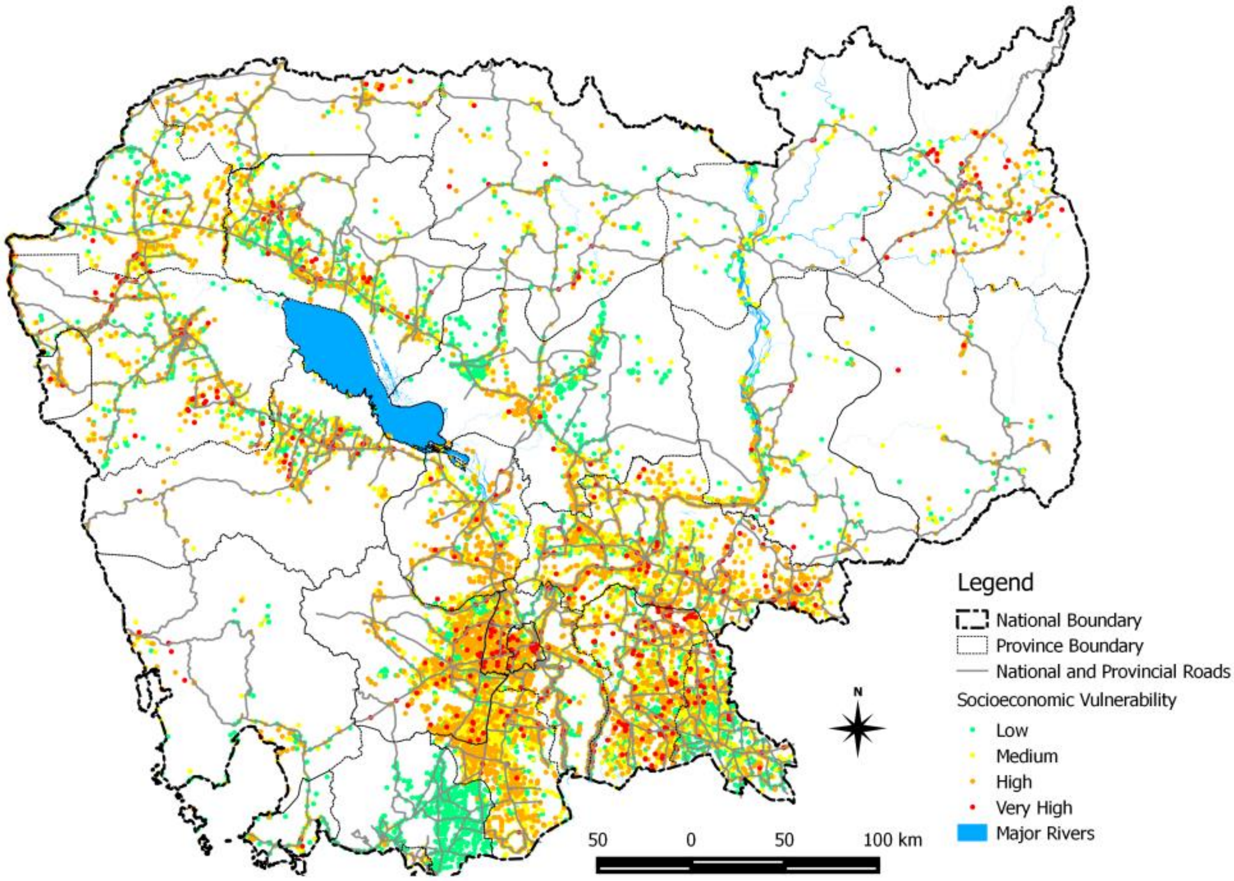


Figure 26 National socio-economic vulnerability to flooding by village (source Commune Database)

4.2 Provincial level mapping

The socio-economic vulnerability map for Kampong Chhnang Province also shows that vulnerability varies spatially across the province with little evidence of patterns. Some villages near the Tonle Sap River also have low vulnerability due to their access to boats. Villages in Kampong Leaeng district generally have high vulnerability. Two villages side by side have different vulnerabilities, with one having medium vulnerability while the other has very high vulnerability.

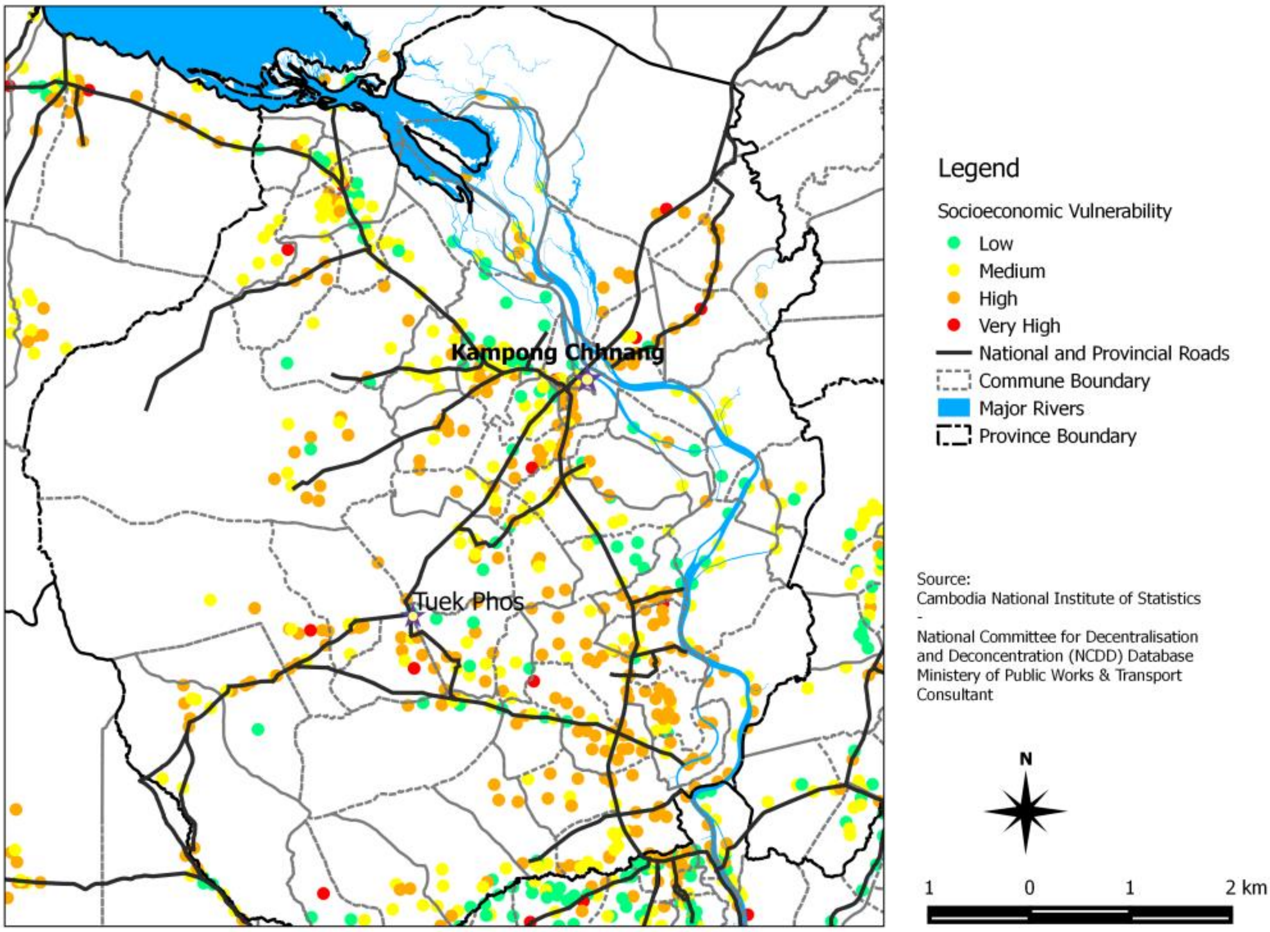


Figure 27 Kampong Chhnang socio-economic vulnerability to flooding by village (Source Commune Database)

4.3 District Level Mapping

Kampong Leaeng District is located in the north east of Kampong Chhnang Province, in central Cambodia. The district capital is Kampong Leaeng district located around 4 kilometers east of the provincial capital of Kampong Chhnang in a direct line. The district shares a border with Kampong Thom province to north and east. Much of the district is low laying floodplain and the Tonle Sap river runs through the district roughly from north to south. In the south of the district are two significant mountains: Phnom Chrak Tunling and Phnom Neang Kangrei both over 1,000 meters in elevation.

The district has very little road infrastructure. There is one provincial ring road that circles the small mountains in the district's south. This road is accessible from National Highway 6 in Stueng Sen District of Kampong Thom. Settlements are located along this road or along the Tonle Sap river and various smaller tributaries. Kampong Leaeng District is the second largest district in Kampong Chhnang province by land area and only Tuek Phos is larger. However, it has the smallest district population in the province after Chol Kiri due to its flooded landscape and lack of road transport infrastructure.

The district is subdivided into 9 communes (khum) and 44 villages (phum). The communes of Kampong Leaeng district are listed in Table 21. Figure 29 shows the Kampong Leaeng district with safe shelter identified during the community discussions.

The overall idea is to have a district or local level vulnerability map to address the project study area (Kampong Leaeng District) with location of houses, safe shelters, establishments, vulnerable river structures, irrigation structures etc. The map will assist the identification of special groups of vulnerable residents (like people with disabilities). To enable these, a detail field survey was conducted by the project team. A total 20 household questionnaires survey were conducted to identify most vulnerable communities with special needs in view of developing an early flood warning system, safe shelters and evacuation measures. The results have been mapped at the community level and overlay into GIS maps.

Based on the questionnaires, it was found that 55 % of all respondents reacted to early warning when someone dies in the community, 15 % of all respondents react to early warning in case of panic situation only/official put enforcement, 10% of all respondents react to early warning when hazard arrives in the area and 10 % react to early warning too when information is widely spread in community, 5% of all respondent react to early warning when people observe some damage in property and 5% of all respondents react to early warning whenever early warning is heard (Figure 28). These figures strongly indicate that there is lack of understanding on hazards at the community level and series of capacity building need to be conducted at the community level on risk management.

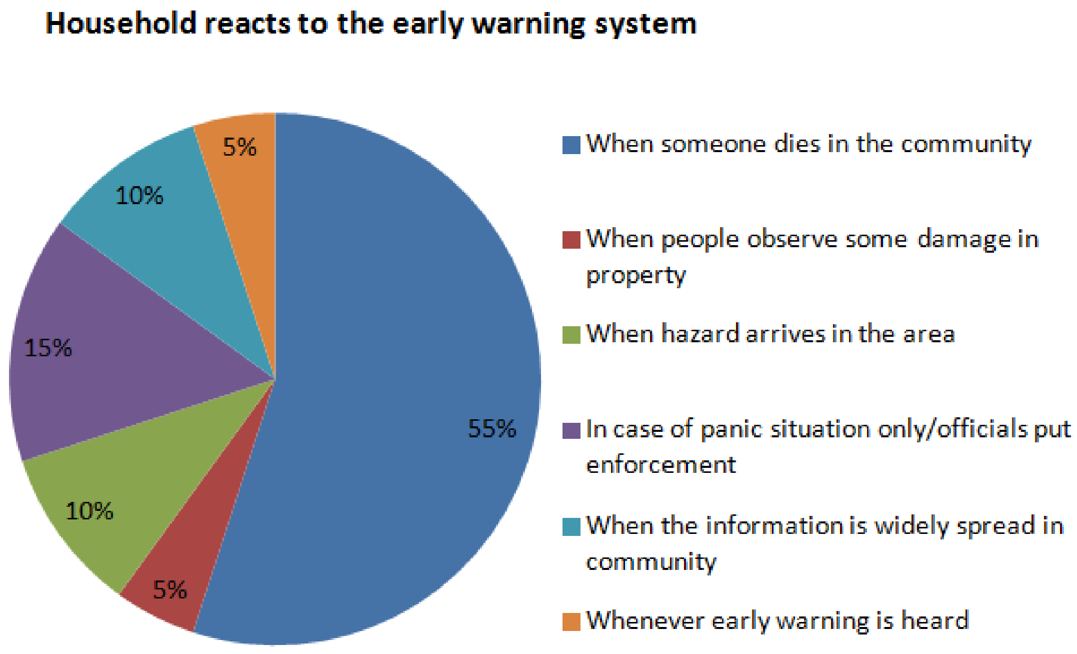


Figure 28 Community reaction to early warning system

Based on the consultation at national-provincial-district-commune, a rehabilitation plan has been developed in the seven communes out of nine total communes. Table 21 shows the community needs and adjusted plan for the safe shelters.

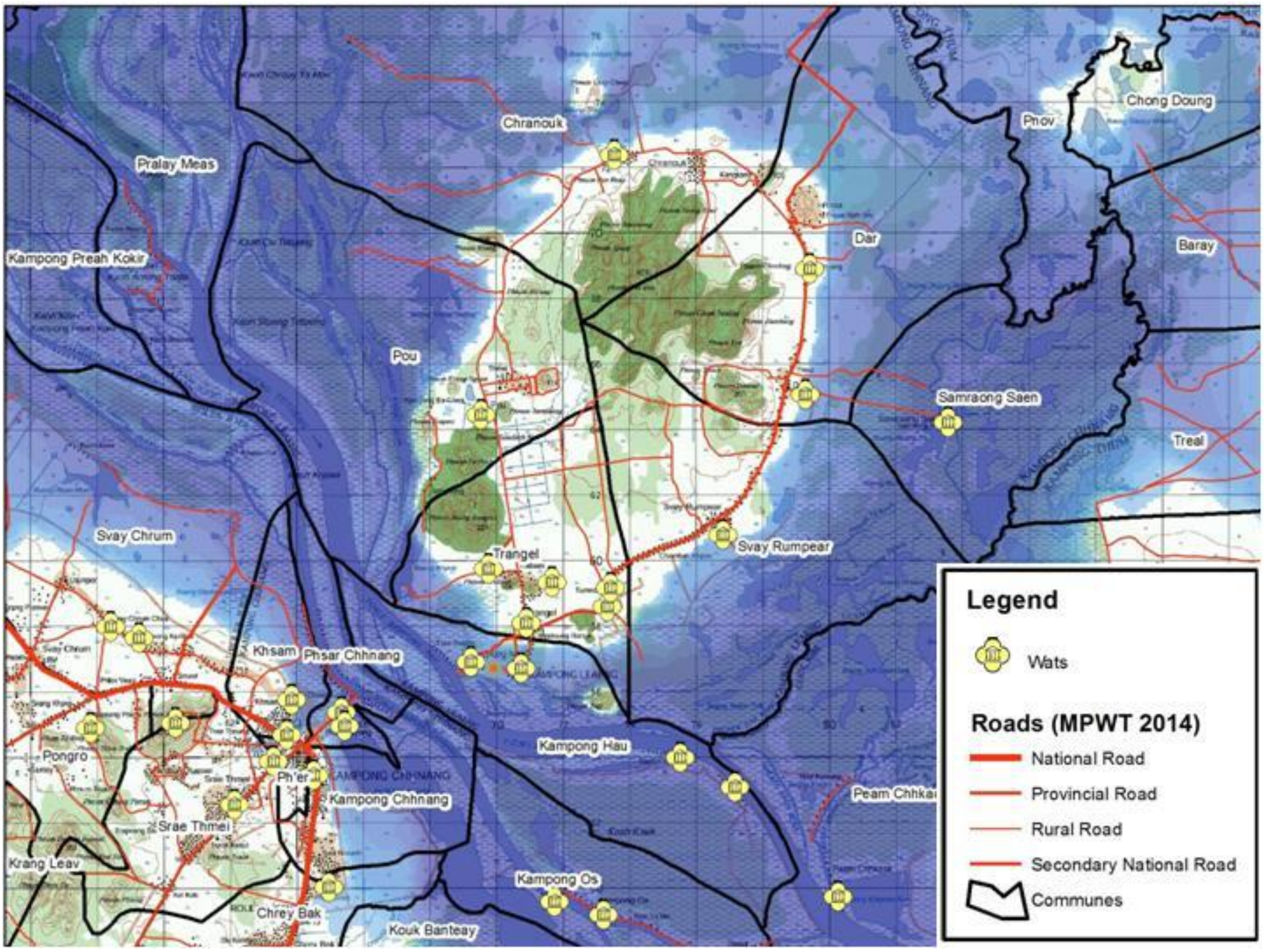


Figure 29 1 in 100 years flood inundation map with safe shelters in pilot area

Table 21 Rehabilitation program under CR-PRIP at commune level

No	Commune name	Safety places	Community Needs Assessment	Rehabilitation Program Under Output
1	Dar	1	Fulfill adding land in Pagoda location, adding three toilets.	1. 700-m3 soil to Dar Pagoda land. 2. Construct three additional toilets
2	Kampong Hau	5	Latrines, Water tanks, Temporary shelter materials	1. Construct additional 5 latrines with 5 canals. 2. Install one water tank that contain 2000 liter of water 3. Support temporary shelter material and food
3	Phlov Tuk	1	Latrines, Purify cans. Shelter material	1. Construct 3 latrines. 2. Provide the temporary shelter material and food.
4	Pou	2	Boreholes, toilets	1. 2 boreholes 2. Construct additional 2 toilets
5	Samraong Saen	1	Adding land. 0.5 m^2 retaining wall, Shelter materials.	1. 3825 m^2 of land 2. Three latrines with 5 canals. 3. Install one water tank of 2000 liter. 4. 0.5 meter of the retaining pagoda wall. 5. Provide the temporary shelter material.

6	Svay Rumpear	1	Opening well, toilets fulfill adding land and temporary shelter material.	1. 2 opening wells and 3 toilets. 2. 2 toilets and 1 borehole. 3. Fill land 50 meter x 40 meter x 0.6 meter). 4. Provide temporary shelter.
7	Trangel	1	Toilets. Boreholes, purify water and material and food	1. Construct 5 toilets, 2. Dig 4 boreholes, 3. Provide purify water cans. 4. Provide emergency food and temporary shelter material.

Figure 30 illustrates the high social vulnerability due to lack of a reliable water supply system in K Leaeng district of K Chhnang province. The Project will address this issue and introduce a water supply system for 10,000 people

Figure 31 identifies the need to improved irrigation systems in K Leaeng, This need is being addressed by one of the project civil works packages designed to rehabilitate 3 reservoirs to make water available year round.

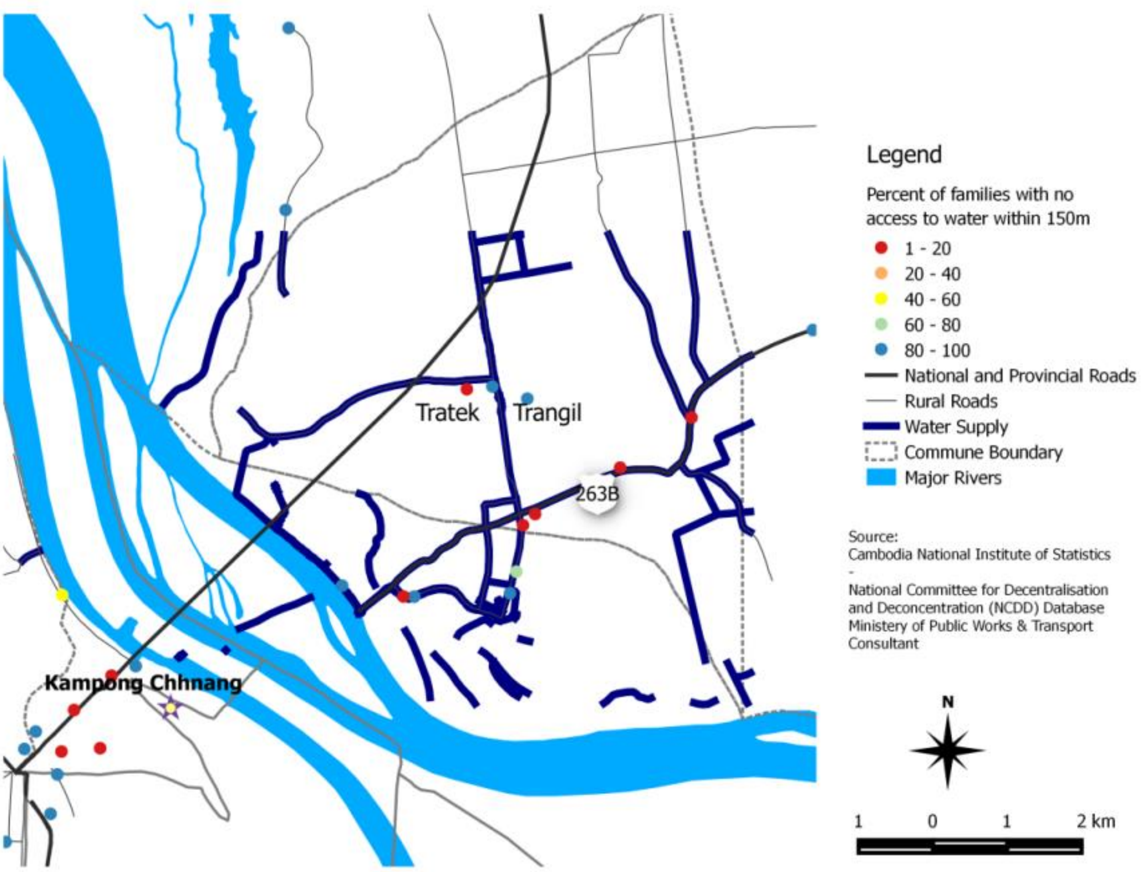


Figure 30 Kampong Leaeng access to household water supply

Figure 32 represents the rice yield map of Kampong Leaeng and provides a good indicator of the revenue capacity of the community, which is currently low. The yield is expected to increase significantly following the rehabilitation of the reservoirs.

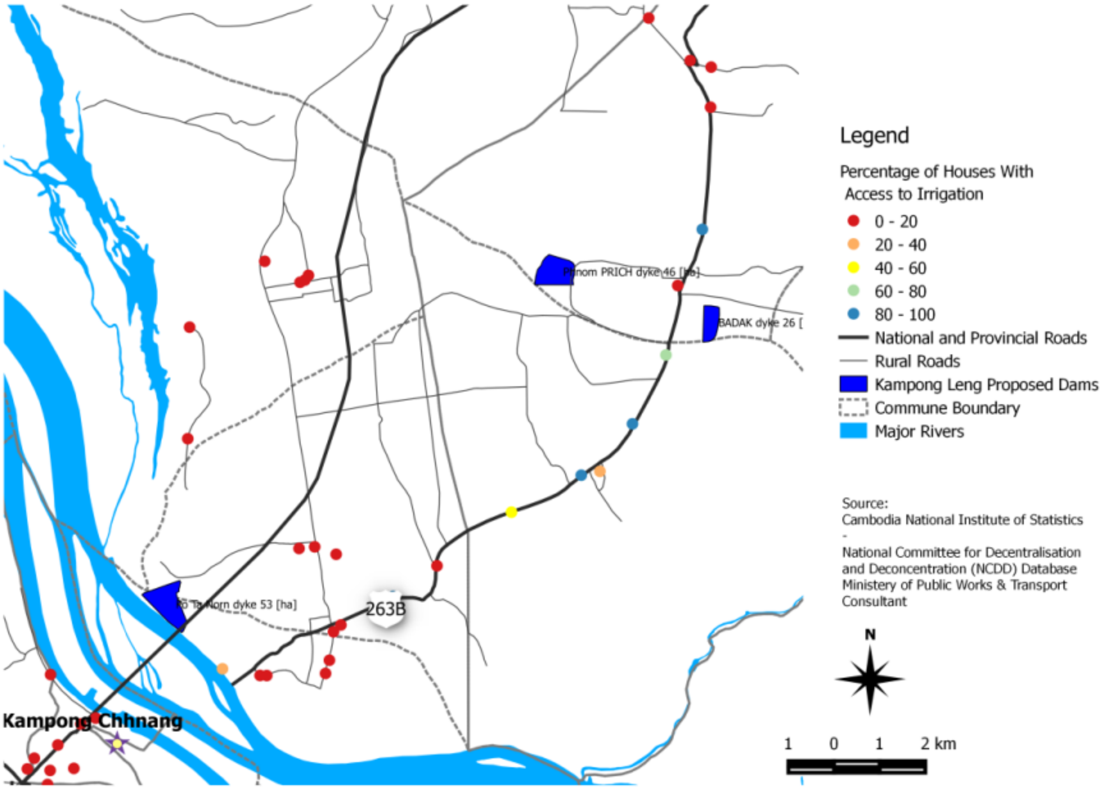


Figure 31 Kampong Leaeng access to irrigation water

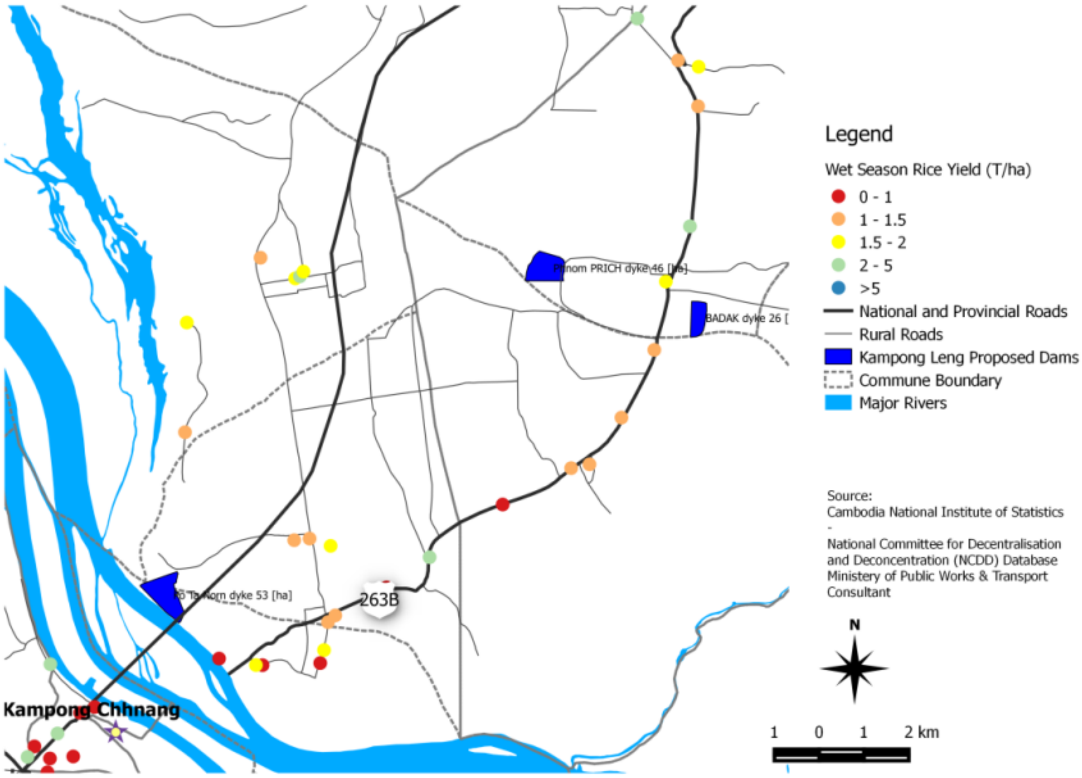


Figure 32 Kampong Leaeng Wet season rice yield

4.4 Recommendations

Socio-economic mapping, in relation to flood proofing roads and rehabilitating earth reservoirs as water storage and capture measures, was found to be most useful at local level, i.e. at the district and commune levels. At these levels, the infrastructures improvements can be designed to target effectively the vulnerable communities, which is not much possible at higher levels due to the high variability of the commune database data, and also makes possible effective local monitoring of the resilience measures.

5 Planning and design tools

In order to ensure sustainability of the processes and methods employed to assess the vulnerability of roads and communities to flooding, a series of tools have been used and training has been delivered to PMU3, to interested MPWT departments and to Ministries such as MRD, MOWRAM and MOE. They are mostly software based and have been selected for their efficiency in solving or visualizing results of flood related analyses, their ease of use and for their low cost.

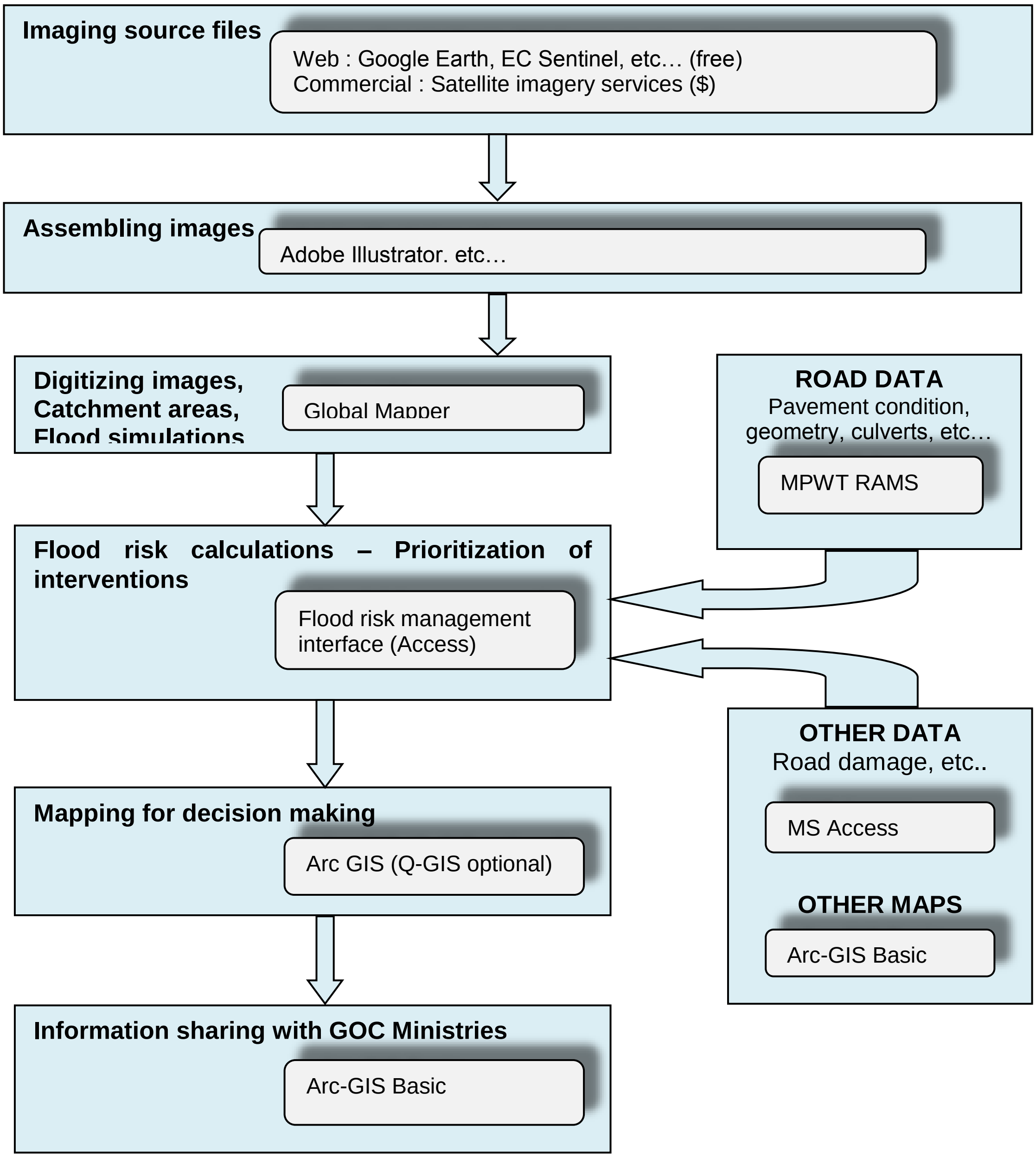


Figure 33 Recommended software tools for road rehabilitation planning with flood data (National and Provincial level)

Their utilization in the two critical phases of flood proofing (see Figure 5) the planning of road rehabilitation and the design of roads and reservoir infrastructures, is described in this section. Most of the software tools are available commercially and one tool, called the flood risk management interface was developed by the Consultant. Training was provided for all the new software introduced.

5.1 Planning of road rehabilitation using flood data

Flood impact is a particularly important factor in Cambodia for prioritizing road rehabilitation and upgrades. Damages by large floods are very costly and the knowledge of high risk areas along the roads allows the planners to upgrade the roads most at risk.

The software tools used in the process for determining the high risk areas at national and provincial level are illustrated in

Figure 33. These tools consist of GIS applications, of analysis software and of drawing and database applications. ARC GIS Basic (ESRI) is a high quality GIS application and is recommended to exchange files with other Ministries. Q-GIS basic (Open Source Geospatial Foundation) is also recommended as an cost effective option, and can be upgraded for disaster management using inaSAFE module. Global mapper basic (Blue Marble) is a powerful mapping software with several analysis capabilities, especially for flood simulations. Culvert Master (Bentley) and HEC RAS (US ACE) are technical applications for the hydraulic design for culverts and bridges.

5.2 Custom interface application

The 'Flood Risk Management Interface' is a software application build on Microsoft Access aimed at integrating road flooding risk in road infrastructure planning & maintenance processes. It serves as a foundation for a knowledge management system for flood proofing and enables the operator to:

- Visualize the risk of flood impacts on the National and Provincial road network of Cambodia, using four specific types of floods
- Visualize these impacts in the future, i.e. 2055
- Access easily information on road sections which are prone to flooding
- Input information about new flood damages and produce reports
- Access easily relevant maps concerning individual roads
- Access recommendations on the strengthening of roads exposed to flooding

Figure 34 Flood Risk Management Interface

Other features are:

- Special GIS knowledge is not required for navigating the application. All basic operations such as requesting information on specific flooding events, road sections or drainage structures is menu based within the data base application
- A second user level, through MS Access, allows any custom queries and searches to the database
- The application is linked to two software, Global Mapper and Arc GIS to expand its capacity
- The application is physically located on a computer of the MPWT mapping department (which has been considered as future climate change Unit of MPWT)
- For research and further calibration purposes, FRMI can generate flood risk maps or flood damage risk maps (pure flood risk maps require pavement condition and drainage structure condition weight factors set to 0; Variable weight values can simulate particular road condition situations)
- Full instructions are provided to update the datasets used by the application, such as land use or MPWT RAMS data, as new data sets become available.

A large number of road sections (about 550) have been analysed in view of their flooding potential and vulnerability of flooding has been established for 4 types of flooding. The interface is fully compatible with the road link references used by MPWT RAMS. A complete description of the functions is available in the Flood Risk Management Interface manual.

5.3 Design of roads and reservoir infrastructures using flood data

The process for designing flood proof roads or reservoir infrastructures, implementable at district or commune level, and the software tools used are illustrated in Figure 35.

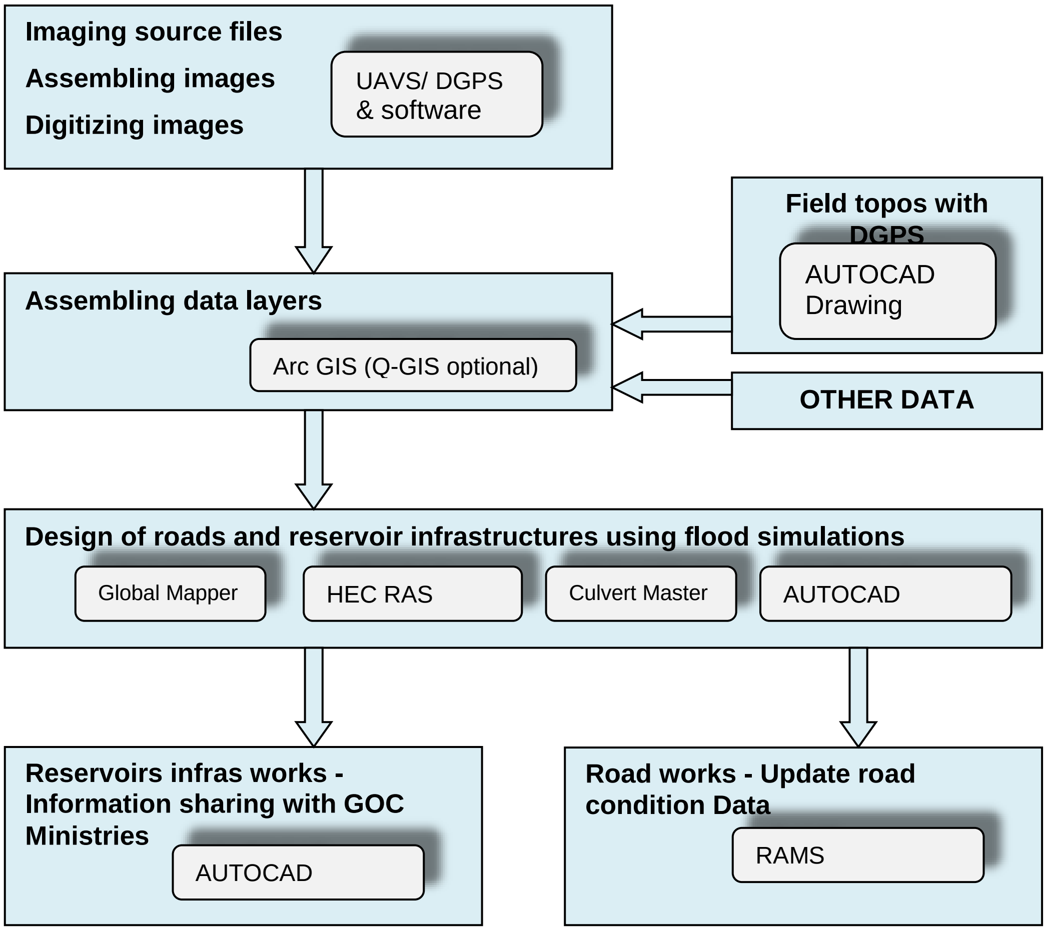


Figure 35 Recommended software tools for the design of roads and reservoir infrastructures with flood data (Local level)

The specific recommendations for improving the process of designing roads facing flooding risks are given in the Road Design Standards Change report.

6 Recommendations and Conclusion

Substantial **data collection** was carried out during this technical assistance mandate, in view of the need to assemble data of flooding, landscape, poverty and socio-economic attributes. As in most developing countries facing multiple initiatives of uncoordinated data gathering through donor projects, the quality, consistency or compatibility of data was found to be sometimes lacking, preventing hence the use of several datasets for the Consultant work. Another issue facing the team has been the reluctance of some organizations to share their latest project data, because it had not been officially approved by the project owners or was still being adjusted or calibrated.

The Consultant has therefore concentrated most of its efforts in gathering and reconciling data available in the MPWT departments, and in linking them to external data sets.

Recent **Climate change prediction** models present varied results. The regional models generally show wetter wet seasons. The adopted CSIRO modeling follows the previous CSIRO-MRC project modeling and presents downscaling information at the highest resolution. While it projects no change to the rainfall during the wet season, it does project an increase in rainfall at the start of the wet season. In terms of intensity, the changes to rainfall were very limited and therefore led to only minor changes in flood risks.

Flood damage risk maps (geo-physical vulnerability) have been prepared at National and Provincial levels using four types of floods. A combined flood vulnerability map has also been prepared to facilitate the prioritization process. Maps covering all Cambodian provinces have been prepared. The risk of flood damage is derived from superposing three layers of modelling, a rainfall model, four flood models and a road resilience model based on the road condition, on 550 road segments totalling 11,500 km of roads.

Using the commune database, the Consultant prepared **socio-economic vulnerability maps** in terms of capacity to access basic services (hospitals, schools and markets) using the transport infrastructure during floods and to access water resources during droughts. Given the high variability of the results at the national and provincial levels, it is recommended to use local maps to plan and devise adaptative measures at the district and commune levels in the future.

New planning tools and processes have been proposed to facilitate both the prioritization of roads at risk of flooding and the road strengthening process. One of these tools is a software interface that the Consultant has developed and that enables officials to easily access flood data and maps in order to take appropriate rehabilitation decisions at national and provincial level.

An assessment of the capacity of MPWT experts revealed that few engineers were familiar with the whole process of risk assessment and design of infrastructures impacted by flood. **New surveying tools** have therefore been introduced and training conducted on these. These tools facilitate the process for strengthening roads as well as the designs of reservoirs such as dikes and their flow control devices.

In **conclusion**, several promising tools and methods have been tested and introduced during this technical assistance to assess the vulnerability of physical infrastructure and of communities to climate change, more specifically with emphasis on flooding impacts. Continuous and further integration of the new flood risk knowledge with the road asset management system of the MPWT is highly recommended.

Appendix 1 Comments on MRC report No 35

This report investigates the issue of constructing roads in floodplains and focuses specifically on the Mekong floodplain of Cambodia and Vietnam. In the first section of the report current practice of road planning, design and construction in the two mentioned countries are analyzed and compared to each other. In the second section international practice and experience into the subject matter is introduced to the discussion. The two fundamental concepts of resistance versus resilience are presented and compared in view of costs, environmental impact and long-term sustainability.

The Mekong basin case studies from road construction projects in Cambodia and Vietnam are presented in the next section of the report. The analysis of the case studies follows the analytical framework set up in the earlier chapters of the report.

The report stresses at many occasions the need for further investigations and studies. For example, the main flood damage mechanisms to roads are said to be changes in change of flow velocities rather than flood level. However, flow velocities are extremely difficult to predict and often simpler indicators have to be used.

In general it has to be pointed out that the authors commence from the starting point that a flood plain is a valuable economic asset. Based on this they propose a much wider scope of analysis for cost /benefit analysis of road construction and rehabilitation projects. Fish migration, for example, which at the moment as no attention at all paid to in current road construction projects in Cambodia, is seen by the authors as an important design aspect for culvert or bridge dimensioning.

The 'Best Practice Guideline' (Section 6.4) is divided into a chapter of general recommendations and recommendations on technical design of road structures.

The general recommendations start by commenting on the current Cambodian and Vietnamese road design manuals.

Recommendation 1

The authors remark that the current Road Design Manuals in Cambodia and Vietnam are based on international guidelines and that they should be adjusted to better reflect regional conditions. This is certainly desirable but two majors impediments encountered in Cambodia are the lack of reliable data and the lack of sharable standards between different Ministries or between technical sectors. For example, knowledge of extreme Mekong or Tonle Sap water level associated with yearly probabilities that can be used for designs is a MRC specialty and not a MPWT or MRD specialty.

In fact a much more important point is that the Cambodian manual - in its current form - only refers to the Rational Method for calculating design flow for hydraulic structures.

By definition the Rational Method excludes the storage of rainfall and catchment runoff within the river network. In addition to that it is only safely applicable to catchment with a surface area of less than 10 km2, or even much less. Complex river networks with irregular flow, which are very common in Cambodia, cannot be analyzed with this method.

Through the introduction of the Generalized Tropical Flood Model (GTFM) the PRIP - CR Project has introduced a method, which can safely be applied to larger catchment areas.

Recommendation 2

A second aspect pointed out by the authors as part of the general recommendations is the fact that the double function of roads as dykes and road embankments is not clearly addressed. It has to mentioned, though, that in practical engineering it is most probable that the right standards will be used for individual projects. Even so, procedures are not formalized.

Recommendation 3

Finally, the general recommendations call for a harmonization of design standards within the different Mekong Basin countries and across national borders. This of course is a high aim which should be high on the MRC's agenda.

However, it also has to be seen clearly that the Mekong River Basin is only a specific part of the entire complex Cambodian and Vietnamese national territory. So national design standards have to be extended by adding flood plain adjusted methods, but they cannot be replaced by them.

Concerning the technical design guidelines recommendations this case is taken up again. The authors point out the lack of an integrated approach for road construction in flood plain, which considers economic, environmental and technical aspects of road design.

Recommendation 4

In the specific recommendations the lack of hydraulic modeling of the impact of road projects is stressed. This point cannot be overstressed. It has to be pointed however, that there is a substantial lack of modeling skills and capacity not only in the public, but also in the private road design sector. PRIP - CR started to address this issue by conducting training activities in this field.

Recommendation 5

The design guidelines continue by proposing a differential analysis for failure mechanism in road damage. This is a useful concept, which also has been taken up by PRIP-CR by analyzing the flooding potential of roads for different flood types for rehabilitation planning purposes.

Recommendation 6

The report also recommends documenting a 'methodology in how to assess the damage potential'. This, of course sounds good, but remains vague. The report mentioned methods used in the Vietnamese Dike Guidelines, but provides no further details.

Recommendations 7 and 8

Recommendations 7 and 8 propose the establishment of safety levels, design thresholds and given hydraulic situations and given damage potential. This is then linked to a cost benefit analysis. All this sounds good, but is in fact nothing more than normal value engineering. Any design carried out under existing international, or even national standard should carry out these steps. There seems to be more of a problem of enforcing the existing standards in current engineering problems than the adjustment of the standards.

Recommendations 9- 13

These recommendations focus on bridge structures, or flow through structures. Overall, they address a fundamental discussion concerning the costs, benefits, environmental impact and sustainability of flow through structures.

The perfect crossing of water and road is not a bridge, but a completely unconnected fly-over. This, of course, is prohibited by costs, so the road engineer has to go for a compromise. With every bridge span costs go up, with every meter of embankment costs go down. An embankment with few culvert openings is cost effective, but environmentally damaging, risky, as it is flood prone and might not be sustainable. The task of the design engineer is now to bring all these aspects into balance. The recommendations of the report call for more costly structures and higher investment. This is only possible if the overall design criteria, are pushed into a more environmentally considered way. Technically speaking these recommendations do not provide new insight into the matter.

Recommendations 14 - 18

Those recommendations focus on embankment level and shape. Measures concerning flow speed limits for flow over embankments are well known and documented in the existing Cambodia design manuals. The use of bio engineering and planting might present a new aspect is being piloted by PRIP – CR and other projects around Cambodia.

Recommendations concerning the actual road level are given as “for example the 100 year flood level, plus 0.5 m for wave action”.

The main issue here is the lack of flood levels expressed as probabilities for use in Cambodia. One would expect that data to be available from MRC along the flood plains. For example, most of the extreme recorded flood levels in Cambodia were recorded in 2000. PRIP - CR analyzed data collected at Prek Kdam and derived a theoretical 100 years level using historical data from the last 35 years. An assessment of multiple stations along the Tonle sap and the Mekong could provide design levels if a sufficient numbers of stations data are made available.

Regarding the embankment cross sections, a slope of 1:3 may be a good idea on paper. But this must be investigated from economic and policy points of view. A 5 meter high embankment of 1:3 as compared to a 1:2 embankment needs 10 m more road corridor and 50 % additional earth works. This represents a huge constraint particularly in densely populated low land areas of Cambodia, and would therefore require stringent resettlement or compensation policies to attract international financing.

So as with the fish passage and the flow through structures we come to the realization that only a shift in the cost / benefit analysis and weighting of arguments have a lasting impact. Technically speaking there is nothing new.

Recommendation 19

The fact that national and provincial roads should better be covered with asphalt, or actually even concrete, has been recommended by CR-PRIP as a new road policy statement for MPWT.

Appendix 2 Datasets collection

Dataset
MRC Flood Risk Maps (2010)
MRC Drought Risk Datasets
MRC Climate Change Related Datasets
Stereo Elevation Model Derived from Aerial Photographs
InSTEDD GeoChat & Associated Systems
Conservation International Data Archive (Large Dataset collection)
Tonle Sap Aerial ortho-photography in colour, 1:25 000 and 1:12 000 DTM Elevation model
Open Development Cambodia (Large collection of datasets)
Mangomap
Historic Climate, Weather & Stream Flow Records
"People in Need" Disaster Warning System currently operational in Pursat province
National Food Security Atlas
SweRoad "Developing Capacity Climate Resilient Road Sector"
Climate Models & Coastal sea level rise vulnerability analysis
Landscan Global Population Dataset
EEPSEA Climate Vulnerability Study
SRTM Space Shuttle Radar Terrain Model
Mekong ARCC
WISDOM project ELVIS online database
NCDM ADPC - World Bank Ketsana Response KERRP
Commune Database
MPWT RAMP Database (Road network, Culverts, Bridges, road condition)
Weather Radar Data
Cambodian Information System on Irrigation Schemes CISIS/PDWRAM database
CSIRO downscale their climate model for Cambodia
New Japanese 5 meter Global DEM
The Global Flood Observatory
InaSAFE
Cambodian Red Cross
Cambodia 2013 POST-FLOOD EARLY RECOVERY NEED ASSESSMENT REPORT
CamDi website supported by UNDP/NCDM
Sentinel-1A Radar Satellite Data "On Demand Access"
Various Online Past Major Flood Extent Maps
Japan Meteorological Agency Downscaled Climate Models
GFZ Flood modelling outputs
Hydrosheds
Various MPWT National Road Datasets and Future Planning Maps
NAPA Provincial Priorities for Flood/Drought
Vulnerability Mapping Workshop
Land Use (Cambodia)
Urbanization rate (Cambodia)
MRC flood stations historical data
Flood damage reports 2011 & 2013
Soil (Cambodia)

Name of Dataset(s):

MRC Flood Risk Maps (2010)

Source(s):

Mekong River Commission - Flood Management and Mitigation Programme (FMMP), Regional Flood Management & Mitigation Center (RFMMC)

Description of Data (Tick all that apply)

- ☑ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☑ Vulnerability/Risk
- ☑ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization

Other: Several meetings and extensive communciations required to obtain the data

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☑ Did consultant draft official request letter for MPWT to send?
- ☑ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☑ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\MRC

Consultant had to conduct an on-site search of MRC computers & network to obtain the data as MRC was unable to locate some datasets.

Name of Dataset(s):

MRC Drought Risk Datasets

Source(s):

Mekong River Commission - Drought Program

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☑ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☐ Past Experience
- ☐ Internet

Other: Previous work done by consultant

- ☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization

Other: Consultant developed this dataset for MRC and was able to provide CR-PRIP

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\MRC

CR-PRIP did not use the national drought data in its climate resilience analysis given its limited effects on road resilience and the fact that location of water capture and storage facilities was found to be better planned at local level with communities

Name of Dataset(s):

MRC Climate Change Related Datasets

Source(s):

Mekong River Commission - Climate Change Program

Description of Data (Tick all that apply)

☐ Hydrological/Flooding related ☐ Drought related ☑ Climate related ☐ Vulnerability/Risk

☐ Road related ☐ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☑ Past Experience ☐ Internet Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☑ Request Email(s) sent by consultant ☑ Consultant had meeting(s) with source organization

Other

☐ Did initial request email(s) and/or meeting(s) result in data access?

☑ Did consultant draft official request letter for MPWT to send?

☑ Did MPWT send the official request letter?

☐ Did the official request letter result in any access to the data?

☑ Did the consultant have to resort to un-official channels to obtain the data?

☐ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

☐ Data was good quality and was useful.

☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.

☐ Data had some quality issues but was still somewhat useful.

☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\Climate

In the end MRC would not release these latest climate models for Cambodia as they were still under review. When the review is finished MRC might be willing to release the data.

Name of Dataset(s):

Stereo Elevation Model Derived from Aerial Photographs

Source(s):

National Geography Department

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☑ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☑ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☐ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location

NGD is in an unique position and has full capability to produce the necessary high-quality/high-resolution elevation data for the CR-PRIP requirements. However MPWT chose not pursue this option.

Name of Dataset(s):

InSTEDD GeoChat & Associated Systems

Source(s):

InSTEDD & "People In Need" http://instedd.org/technologies/geochat/""

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [ ] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data: Disaster Warning System

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization

Other

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [ ] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [ ] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\People in Need

Team leader decided not to pursue collaboration with InSTEDD.

Name of Dataset(s):

Conservation International Data Archive (Large Dataset collection)

Source(s):

Conservation International

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [x] Vulnerability/Risk
- [x] Road related
- [x] Socio-Economic and Census
- [x] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [ ] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization

Other: Obtained at CI organized workshop

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Conservation International

A very useful and relevant data archive containing many different thematic datasets.

Name of Dataset(s):

Tonle Sap Aerial ortho-photography in colour, 1:25 000 and 1:12 000 DTM Elevation model

Source(s):

The Tonle Sap Environmental Management Project (TSEMP) - ADB Project

Description of Data (Tick all that apply)

☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk

☐ Road related ☐ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data: Aerial Photography and Digital Orthophotos

How did consultant became aware of the data? (Tick all that apply)

☑ Past Experience ☐ Internet Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☐ Request Email(s) sent by consultant ☐ Consultant had meeting(s) with source organization

Other Consultant already had dataset and provided to project with no charge.

☐ Did initial request email(s) and/or meeting(s) result in data access?

☐ Did consultant draft official request letter for MPWT to send?

☐ Did MPWT send the official request letter?

☐ Did the official request letter result in any access to the data?

☐ Did the consultant have to resort to un-official channels to obtain the data?

☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

☑ Data was good quality and was useful.

☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.

☑ Data had some quality issues but was still somewhat useful.

☐ Data had serious quality issues and was not used.

Any Additional Comments File Location

Elevation model has some data quality issues and is a useful reference but is not fully useable

Name of Dataset(s):

Open Development Cambodia (Large collection of datasets)

Source(s):

Open Development Cambodia website
http://www.opendevelopmentcambodia.net/maps/downloads/

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [x] Vulnerability/Risk
- [x] Road related
- [x] Socio-Economic and Census
- [x] Base Topographic
- [x] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet

Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [ ] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location

A large collection of very useful national datasets that the consultant helped ODC compile.

Name of Dataset(s):

Mangomap

Source(s):

https://mangomap.com An example CR-PRIP project related map is viewable at http://mgo.ms/s/3u1lkjj

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk
- ☐ Road related ☐ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data: Online map server software that could have benefited the project

How did consultant became aware of the data? (Tick all that apply)

☑ Past Experience ☐ Internet Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☑ Request Email(s) sent by consultant ☑ Consultant had meeting(s) with source organization

Other Arranged for TL to meet with MangoMap

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☐ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments File Location

CR-PRIP Team leader decided not to pursue this option.

Name of Dataset(s):

Historic Climate, Weather & Stream Flow Records

Source(s):

MoWRAM

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [ ] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization

Other

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [x] Did consultant draft official request letter for MPWT to send?
- [x] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [x] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [x] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location

A large and useful data collection but climate modelling data from other sources is preferable

Name of Dataset(s):

"People in Need" Disaster Warning System currently operational in Pursat province

Source(s):

http://www.clovekvtisni.cz/en/humanitary-aid/country/cambodia

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data: Disaster Warning System

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet
- Other:

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization
- Other:

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\People in Need

Team leader decided not to pursue the option of hiring "People In Need" consultants since emergency warning experts were available in CR-PRIP.

Name of Dataset(s):

National Food Security Atlas

Source(s):

WFP VAM various years available / Consolidated Livelihoods Exercise for Analyzing Resilience (CLEAR)

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☑ Vulnerability/Risk
- ☐ Road related
- ☑ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data: Food Security

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization
- Other

- ☑ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Food Security

Name of Dataset(s):

SweRoad "Developing Capacity Climate Resilient Road Sector"

Source(s):

Ministry of Rural Development of Mozambique - http://www.ndf.fi/project/developing-capacity-climate-resilient-road-sector-ndf-c59

Description of Data (Tick all that apply)

- ☑ Hydrological/Flooding related
- ☑ Drought related
- ☑ Climate related
- ☑ Vulnerability/Risk
- ☑ Road related
- ☑ Socio-Economic and Census
- ☑ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☐ Past Experience
- ☐ Internet
- Other: Similar project to CR-PRIP

- ☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization
- Other: Several meetings and extensive efforts were required to obtain this data
- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☑ Did consultant draft official request letter for MPWT to send?
- ☑ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☑ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☑ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location:

The data has many issues and inadequate metadata prevented use by CR-PRIP.

Name of Dataset(s):

Climate Models & Coastal sea level rise vulnerability analysis

Source(s):

Ministry of Environment, Climate Unit / UNDP

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization
- Other

- ☑ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Coastal Vulnerability

Not in the end used by CR-PRIP as sea level rise was not considered in the final risk analysis.

Name of Dataset(s):

Landscan Global Population Dataset

Source(s):

US Department of Energy http://bit.ly/1fi4LOc

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☑ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization

Other: Consultant already had data and provided to CR-PRIP with no charge

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location

The best available population density dataset. Not in the end used by CR-PRIP as sea level rise was not considered in the final analysis. Not in the end used by CR-PRIP as population was not considered in the final risk analysis.

Name of Dataset(s):

EEPSEA Climate Vulnerability Study

Source(s):

http://www.eepsea.net/pub/book/Coffee_Book_Final_29Sep10.pdf

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [x] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [ ] Past Experience
- [x] Internet
- Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [ ] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other: Data was re-digitized from the downloaded source document

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [ ] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [x] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location

A useful national overview of climate risk but not at a scale to be useful to specific CR-PRIP requirements

Name of Dataset(s):

SRTM Space Shuttle Radar Terrain Model

Source(s):

USGS

Description of Data (Tick all that apply)

☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk

☐ Road related ☐ Socio-Economic and Census ☑ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☐ Past Experience ☐ Internet Other

☑ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☐ Request Email(s) sent by consultant ☐ Consultant had meeting(s) with source organization

Other

☐ Did initial request email(s) and/or meeting(s) result in data access?

☐ Did consultant draft official request letter for MPWT to send?

☐ Did MPWT send the official request letter?

☐ Did the official request letter result in any access to the data?

☐ Did the consultant have to resort to un-official channels to obtain the data?

☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

☐ Data was good quality and was useful.

☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.

☑ Data had some quality issues but was still somewhat useful.

☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\elevation\SRTM

Not ideal accuracy available but usable for a number of measurements for planning purposes.

Name of Dataset(s):

Mekong ARCC

Source(s):

ICEM / USAID http://www.mekongarcc.net/

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [x] Vulnerability/Risk
- [x] Road related
- [x] Socio-Economic and Census
- [x] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [ ] Past Experience
- [ ] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\Mekong ARCC

A very useful and extensive data archive of climate risk related information with many important related datasets.

Name of Dataset(s):

WISDOM project ELVIS online database

Source(s):

http://wisdom.eoc.dlr.de/Elvis/

Description of Data (Tick all that apply)

- ☑ Hydrological/Flooding related
- ☑ Drought related
- ☑ Climate related
- ☑ Vulnerability/Risk
- ☑ Road related
- ☑ Socio-Economic and Census
- ☑ Base Topographic
- ☑ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

- ☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization
- Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☑ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☑ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☑ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location

Access to these useful datasets was denied by DLR German Space Agency. Consultant eventually found another way to obtain access to the data.

Name of Dataset(s):

NCDM ADPC - World Bank Ketsana Response KERRP

Source(s):

National Committee for Disaster Management - Asian Disaster Preparedness Center

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [x] Vulnerability/Risk
- [x] Road related
- [x] Socio-Economic and Census
- [x] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [ ] Past Experience
- [ ] Internet

Other: Meetings with NCDM

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization

Other

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [x] Did consultant draft official request letter for MPWT to send?
- [x] Did MPWT send the official request letter?
- [x] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [ ] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [x] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\NCDM

A large and interesting collection of climate risk related datasets. It however have some quality issues.

Name of Dataset(s):

Commune Database

Source(s):

National Institute of Statistics / Ministry of Planning

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☑ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization

Other

- ☑ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Commune Database

The best source for national socio-economic data. Unfortunately MoP had not yet updated the necessary administrative boundary files to fully map the 2012 Commune level data

Name of Dataset(s):

MPWT RAMP Database (Road network, Culverts, Bridges, road condition)

Source(s):

MPWT Road Asset Management Office

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk
- ☑ Road related ☐ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☐ Past Experience ☐ Internet Other MPWT Counterparts

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☐ Request Email(s) sent by consultant ☐ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☑ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location D:\FRMI\FRMI-DATABASE.accdb

The reconciliation of this dataset with the road dataset used by mapping department (developed under JICA) took considerable time and left out a number of road segments links due to incompatibilities.

Name of Dataset(s):

Weather Radar Data

Source(s):

MoWRAM
http://www.cambodiameteo.com/slideshow?menu=117&lang=enhttp://www.cambodiameteo.com/slideshow?menu=117&lang=en

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [x] Climate related
- [ ] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [x] Internet
- Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization
- Other
- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [x] Did consultant draft official request letter for MPWT to send?
- [x] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [ ] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [ ] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location

This real-time weather radar data could be integrated into a flash-flood/severe storm warning system. Full access to the data would however still have to be negotiated with MoWRAM.

Name of Dataset(s):

Cambodian Information System on Irrigation Schemes CISIS/PDWRAM database

Source(s):

MoWRAM

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [x] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [x] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization

Other: A lot of effort went into trying to get access without success

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [x] Did consultant draft official request letter for MPWT to send?
- [x] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [ ] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [ ] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location

The CISIS dataset represents the most important data archive on water control infrastructure in Cambodia with significant financial support by donors. MoWRAM is universally blocking any access.

Name of Dataset(s):

CSIRO downscale their climate model for Cambodia

Source(s):

CSIRO

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☑ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☑ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location

CR-PRIP Climate Specialist identified this as the best available climate model dataset. However, MPWT did not agree to purchase that data.

Name of Dataset(s):

New Japanese 5 meter Global DEM

Source(s):

RESTEC / JAXA

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk
- ☐ Road related ☐ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☐ Past Experience ☐ Internet Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☑ Request Email(s) sent by consultant ☐ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☐ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments File Location

Price quote from the Japanese Space Agency was too high ("USD$1 million for whole country coverage")

Name of Dataset(s):

The Global Flood Observatory

Source(s):

http://floodobservatory.colorado.edu

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [x] Internet
- Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization
- Other

  - [x] Did initial request email(s) and/or meeting(s) result in data access?
  - [ ] Did consultant draft official request letter for MPWT to send?
  - [ ] Did MPWT send the official request letter?
  - [ ] Did the official request letter result in any access to the data?
  - [ ] Did the consultant have to resort to un-official channels to obtain the data?
  - [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Floods\Global Flood Observatory

Despite email communications only the data on the Global Flood Observatory website was obtained. This data was mostly in a format that had to be reverse engineered to be useable in a GIS

Name of Dataset(s):

InaSAFE

Source(s):

http/www.inasafe.org

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data: A modelling system for disaster planning integrated into QGIS

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [x] Internet

Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other Technical support requests sent

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [ ] Data was good quality and was useful.
- [x] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\inasafe

InaSAFE was created by Indonesia with support from Australia and the World Bank. The Philippines is currently developing an online version called WebSAFE. Consultant pre-prepared the datasets needed.

Name of Dataset(s):

Cambodian Red Cross

Source(s):

Dr. Uy Sam Ath, Director, Disaster Management Division (DMD)
and Mr. Duch Sam Ang, Head, DMD)

Description of Data (Tick all that apply)

☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk

☐ Road related ☑ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☐ Past Experience ☐ Internet Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☐ Request Email(s) sent by consultant ☑ Consultant had meeting(s) with source organization

Other

☐ Did initial request email(s) and/or meeting(s) result in data access?

☐ Did consultant draft official request letter for MPWT to send?

☐ Did MPWT send the official request letter?

☐ Did the official request letter result in any access to the data?

☐ Did the consultant have to resort to un-official channels to obtain the data?

☐ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

☐ Data was good quality and was useful.

☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.

☐ Data had some quality issues but was still somewhat useful.

☐ Data had serious quality issues and was not used.

Any Additional Comments File Location

Consultant used connections within the Cambodian Red Cross to facilitate meetings to discuss collaboration.

Name of Dataset(s):

Cambodia 2013 POST-FLOOD EARLY RECOVERY NEED ASSESSMENT REPORT

Source(s):

UNDP

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [x] Internet

Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [ ] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- [x] Data was good quality and was useful.
- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Stakeholders\UNDP

A good overview of the effects of the 2013 floods

Name of Dataset(s):

CamDi website supported by UNDP/NCDM

Source(s):

http://camdi.ncdm.gov.kh

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☑ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☑ Internet
- Other

- ☑ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization

Other

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- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\NCDM

A useful online data archive that can be queried to find the effects of past national disasters.

Name of Dataset(s):

Sentinel-1A Radar Satellite Data "On Demand Access"

Source(s):

“Copernicus On-Demand Data User” status https://scihub.esa.int

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☑ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☑ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

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- ☐ Consultant had meeting(s) with source organization

Other

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- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☐ Did the above efforts finally succeed in obtaining the data?

Consultant’s Assessment of Quality / Usability of the Data (Tick all that apply)

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- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location

Consultant on behalf of the Government of Cambodia attempted to gain the special permission required to allow tasking of satellite imagery acquisitions during a disaster. Effort so far not successful.

Name of Dataset(s):

Various Online Past Major Flood Extent Maps

Source(s):

USGS, Global Flood Observatory, JAXA UNOSAT, SAFER, Radarsat etc.

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [x] Internet
- Other

- [x] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [ ] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other

- [ ] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
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- [x] Did the above efforts finally succeed in obtaining the data?

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- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Floods

This collection probably now represents the most comprehensive GIS archive available of historic flood data. The data was mostly in a format that had to be reverse engineered to be useable in GIS.

Name of Dataset(s):

Japan Meteorological Agency Downscaled Climate Models

Source(s):

Dr. Kusunoki & Dr. Taroh Matsuno

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☑ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☑ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☑ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization
- Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☐ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☐ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location

This Japanese climate model was identified as potentially useful but no response to email inquiries.

Name of Dataset(s):

GFZ Flood modelling outputs

Source(s):

JM Delgado martinsd@uni-potsdam.de

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [ ] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [ ] Past Experience
- [x] Internet
- Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization
- Other
  - [ ] Did initial request email(s) and/or meeting(s) result in data access?
  - [ ] Did consultant draft official request letter for MPWT to send?
  - [ ] Did MPWT send the official request letter?
  - [ ] Did the official request letter result in any access to the data?
  - [x] Did the consultant have to resort to un-official channels to obtain the data?
  - [x] Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

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- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Floods\GFZ

A useful "future flooding under climate change" modelling efforts

Name of Dataset(s):

Hydrosheds

Source(s):

USGS/WWF http://hydrosheds.cr.usgs.gov/index.phphttp://hydrosheds.cr.usgs.gov/index.php

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☑ Internet
- Other

☑ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

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- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\Elevation\Hydrosheds

A global dataset with useful hydrological data.

Name of Dataset(s):

Various MPWT National Road Datasets and Future Planning Maps

Source(s):

MPWT

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☑ Road related
- ☐ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☐ Past Experience
- ☐ Internet

Other: MPWT project counterparts

- ☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization

Other

- ☑ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

- ☑ Data was good quality and was useful.
- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: D:\FRMI\FRMI-DATABASE.accdb & E:\GIS_Data\Ro

Various road datasets used by MPWT were very helpful. However, several of these datasets, such as those developed under JICA georeferencing project and RAMP project, show dignificant differences in road links and are now more difficult to link.

Name of Dataset(s):

NAPA Provincial Priorities for Flood/Drought

Source(s):

Ministry of Environment

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☑ Vulnerability/Risk
- ☐ Road related
- ☑ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☑ Past Experience
- ☐ Internet
- Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☑ Consultant had meeting(s) with source organization
- Other

- ☑ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

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- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\Vulnerability mapping\NAPA

National level climate risk analysis

Name of Dataset(s):

Vulnerability Mapping Workshop

Source(s):

CR-PRIP Project organized workshop

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [x] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [ ] Past Experience
- [ ] Internet

Other: From mapping exercise at the workshop

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [ ] Request Email(s) sent by consultant
- [x] Consultant had meeting(s) with source organization

Other

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
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Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

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- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [x] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: D:\FRMI\FRMI-DATABASE.accdb

Many differences were noticed between the flood information (location, length, duration, damage types, etc…) provided by the various provincial authorities making it difficult to harmonize the final results.

Name of Dataset(s):

Land Use (Cambodia)

Source(s):

fao.org

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related
- ☐ Drought related
- ☐ Climate related
- ☐ Vulnerability/Risk
- ☐ Road related
- ☑ Socio-Economic and Census
- ☐ Base Topographic
- ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- ☐ Past Experience
- ☑ Internet
- Other

☑ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- ☐ Request Email(s) sent by consultant
- ☐ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
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- ☐ Did MPWT send the official request letter?
- ☐ Did the official request letter result in any access to the data?
- ☐ Did the consultant have to resort to un-official channels to obtain the data?
- ☑ Did the above efforts finally succeed in obtaining the data?

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- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\MPWT-JICA

Name of Dataset(s):

Urbanization rate (Cambodia)

Source(s):

fao.org

Description of Data (Tick all that apply)

- ☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk
- ☐ Road related ☑ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☐ Past Experience ☐ Internet Other

☑ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☐ Request Email(s) sent by consultant ☐ Consultant had meeting(s) with source organization

Other

- ☐ Did initial request email(s) and/or meeting(s) result in data access?
- ☐ Did consultant draft official request letter for MPWT to send?
- ☐ Did MPWT send the official request letter?
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- ☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- ☐ Data had some quality issues but was still somewhat useful.
- ☐ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\inasafe\landscan2011

Name of Dataset(s):

MRC flood stations historical data

Source(s):

Mekong River Commission

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [ ] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [ ] Past Experience
- [x] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
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- [x] Did the above efforts finally succeed in obtaining the data?

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- [ ] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location: E:\GIS_Data\MRC\Historical Flood Levels

Historical flood levels for abour 7 stations in Cambodia (since 1980)

Name of Dataset(s):

Flood damage reports 2011 & 2013

Source(s):

MPWT - Road infrastructure department

Description of Data (Tick all that apply)

☐ Hydrological/Flooding related ☐ Drought related ☐ Climate related ☐ Vulnerability/Risk

☑ Road related ☐ Socio-Economic and Census ☐ Base Topographic ☐ Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

☑ Past Experience ☐ Internet Other

☐ Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

☐ Request Email(s) sent by consultant ☑ Consultant had meeting(s) with source organization

Other

☑ Did initial request email(s) and/or meeting(s) result in data access?

☐ Did consultant draft official request letter for MPWT to send?

☐ Did MPWT send the official request letter?

☐ Did the official request letter result in any access to the data?

☐ Did the consultant have to resort to un-official channels to obtain the data?

☑ Did the above efforts finally succeed in obtaining the data?

Consultant's Assessment of Quality / Usability of the Data (Tick all that apply)

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☐ Data was acceptable quality but another dataset was found to be more relevant and was used instead.

☐ Data had some quality issues but was still somewhat useful.

☑ Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\Roads\Flood damage

The road infrastructure department of MPWT has valuable data related to flood damage. However, It can hardly be correlated to other datasets in the Ministry because in difference in road links identification and lack of standard in flood damage reporting.

Name of Dataset(s):

Soil (Cambodia)

Source(s):

fao.org

Description of Data (Tick all that apply)

- [x] Hydrological/Flooding related
- [ ] Drought related
- [ ] Climate related
- [ ] Vulnerability/Risk
- [ ] Road related
- [ ] Socio-Economic and Census
- [ ] Base Topographic
- [ ] Satellite imager

Other type of data:

How did consultant became aware of the data? (Tick all that apply)

- [x] Past Experience
- [ ] Internet

Other

- [ ] Was the data obtainable by quick internet download?

Description of steps taken by consultant to request the data (Tick all that apply)

- [x] Request Email(s) sent by consultant
- [ ] Consultant had meeting(s) with source organization

Other

- [x] Did initial request email(s) and/or meeting(s) result in data access?
- [ ] Did consultant draft official request letter for MPWT to send?
- [ ] Did MPWT send the official request letter?
- [ ] Did the official request letter result in any access to the data?
- [ ] Did the consultant have to resort to un-official channels to obtain the data?
- [x] Did the above efforts finally succeed in obtaining the data?

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- [x] Data was acceptable quality but another dataset was found to be more relevant and was used instead.
- [ ] Data had some quality issues but was still somewhat useful.
- [ ] Data had serious quality issues and was not used.

Any Additional Comments

File Location E:\GIS_Data\Soil

Appendix 3 List of training events

No.	Date	Training title	Participants	Trainer
1	Tue. 22 July 2014	Introduction to QGIS	PMU3	Mr. Ian Thomas
2	Thur. 24 July 2014	Design of culverts	1) PMU3 2) MPWT, 3) DPWT	Mr. Juergen Peter
3	Tue. 29 July 2014	Vulnerability Mapping Workshop	1) MPWT 2) MOWRAM 3) MRD 4) MEF 5) MoE 6) ADB 7) Jica 8) NCMD	1) Dr. Michael Russell 2) Mr. Juergen Peter 3) Mr. Ian Thomas 4) Dr. SHM Fakhruddin 5) Mr. Daniel Crickx 6) Mr. Richard Hopkins 7) Mr. Heng Kakada
4	Wed. 30 July 2014	Geo-referencing	1) PMU3 2) MPWT, 3) DPWT	Mr. Ian Thomas
5	Thu. 31 July 2014	-Embankment protection -Borrow pits -Road surface drainage design -Dike design	1) PMU3 2) MPWT 3) DPWT	Mr. Daniel Crickx
6	Fri. 01st August 2014	Advanced QGIS	1) MPWT 2) MRD 3) MoE 4) RID	Mr. Ian Thomas
7	Tue. 28 August 2014	Social Mapping Workshop	1) District Governor 2) MPWT Reps. 3) DPWT Reps. 4) Dist. Officers 5) Com. Reps.	Dr. SMH Fakhruddin
8	Thu. 09 October 2014	Road Flood Proofing Tool Selection	1) MPWT 2) MRD 3) MoE 4) RID 5) MOWRAM	Mr. Juergen Peter
9	Fri. 10 October 2014	Hydrology and Hydraulics Concepts	1) MPWT 2) MRD 3) MoE 4) RID 5) MOWRAM	Mr. Juergen Peter

CR-PRIP international experts

Mr. Gary Spiller / Mr. Michel Dorval	Team Leader
Mr. Juergen Peter	Hydrologist / Impact modeler
Mr. Ian Thomas	GIS Specialist
Dr. SMH Fakhruddin	Emergency Response Specialist
Mr. Richard Hopkins	Road Design Standard Engineer
Mr. Michel Dorval	Procurement specialist
Mr. James Berdach	Ecosystem specialist
Mr. Daniel Crickx	Hydraulic Engineer
Dr. Michael Russell	Climate Change Modeler

CR-PRIP national experts

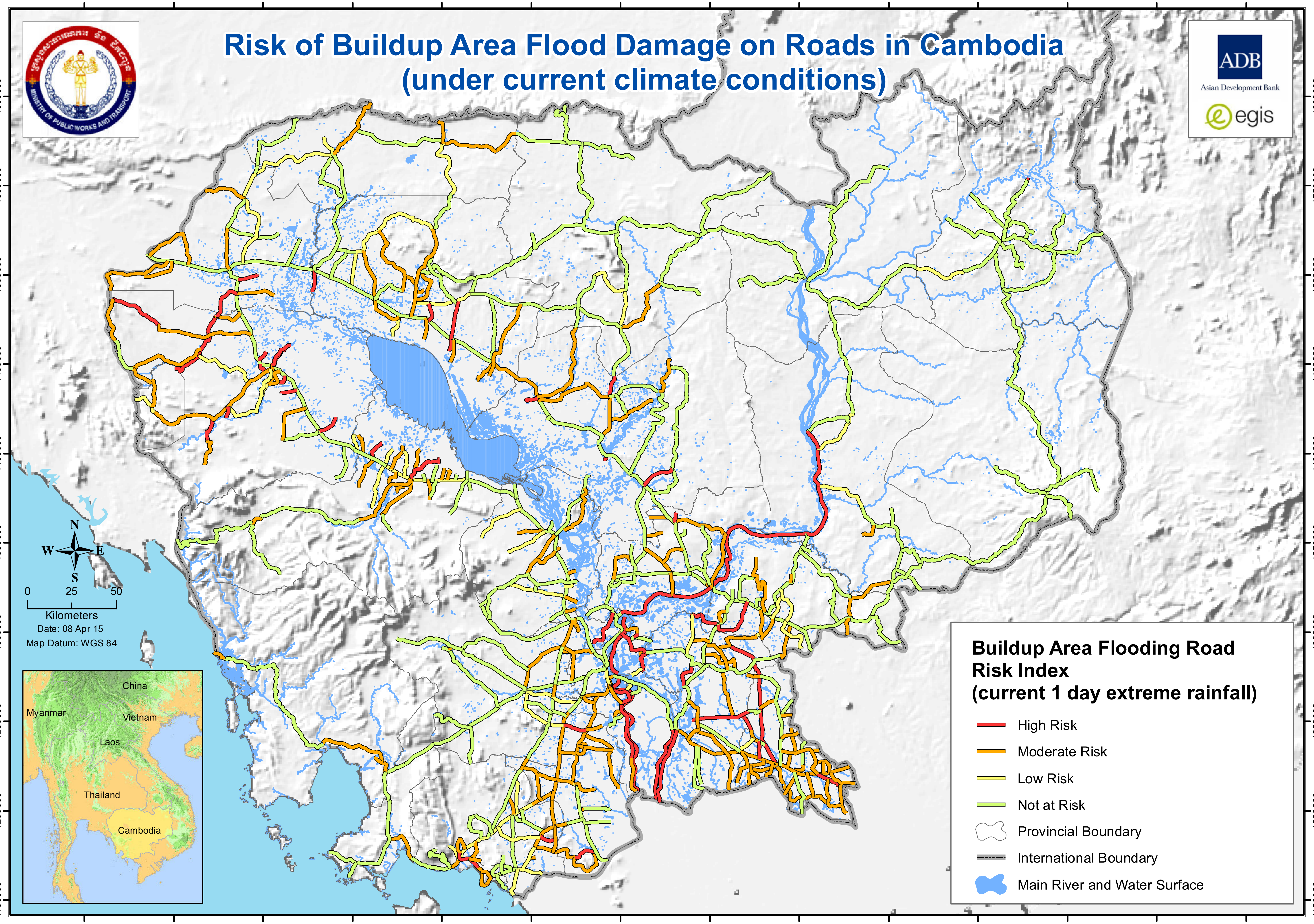
Mr. Roath Kanith/Mr. Soeng Hun	Deputy Team Leader
Mr. Chhit Kimhor	Hydrologist
Mr. Heng Hang	GIS Specialist
Mr. Lorn Trob	Emergency Management Special
Mr. Heng Kackada	Road Design Standard Engineer
Mr. So Sovath	Procurement specialist
Mrs. Sam Savoun	Land Management Specialist
Mr. Mam Sanoun/Mr. Soeng Hun	Hydraulic Engineer
Mr. Pho Sorpheara	Social Specialist

Appendix 4 Correlation of SRTM elevations of PRIP roads

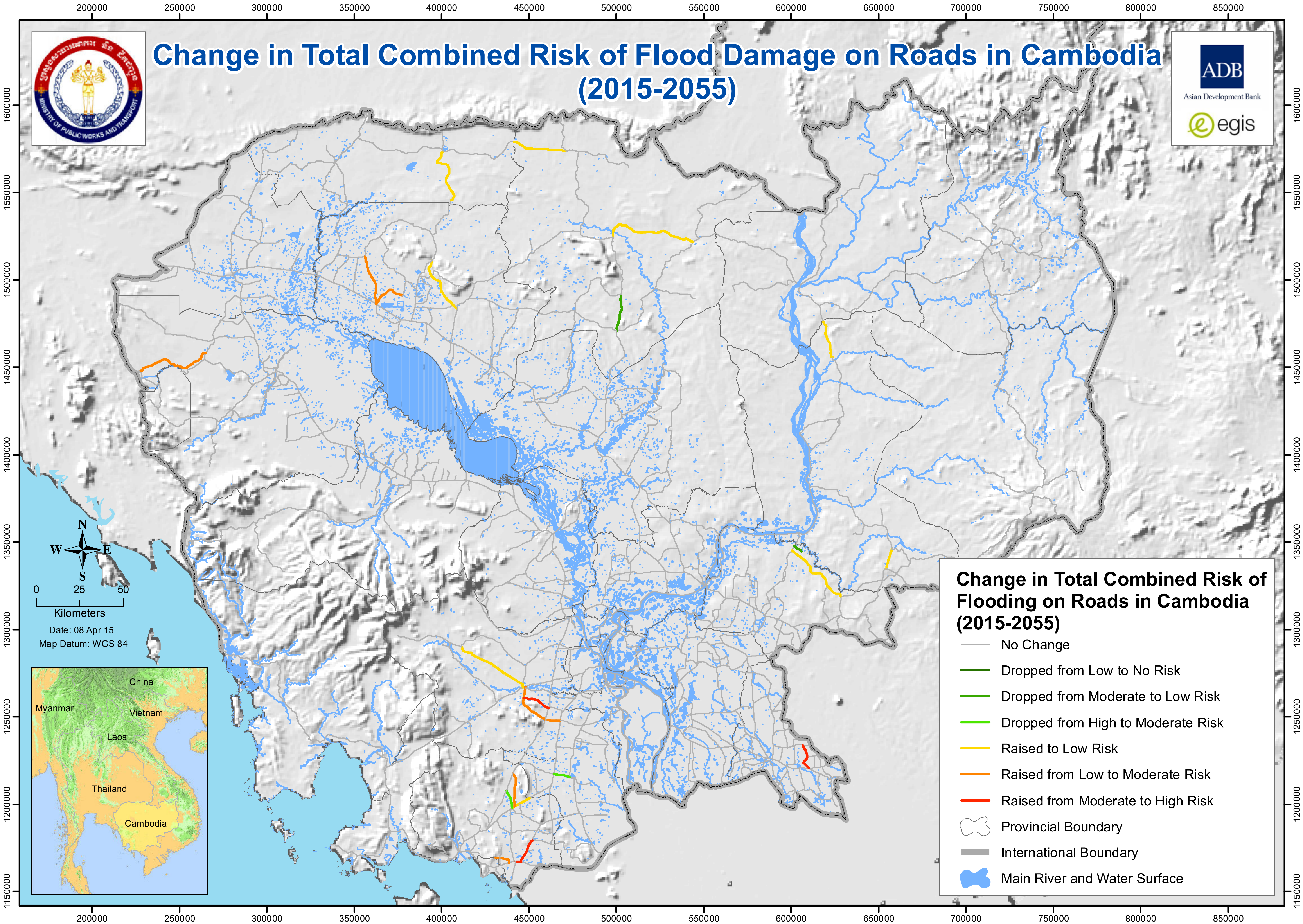
Topos / SRTM elevation comparisons

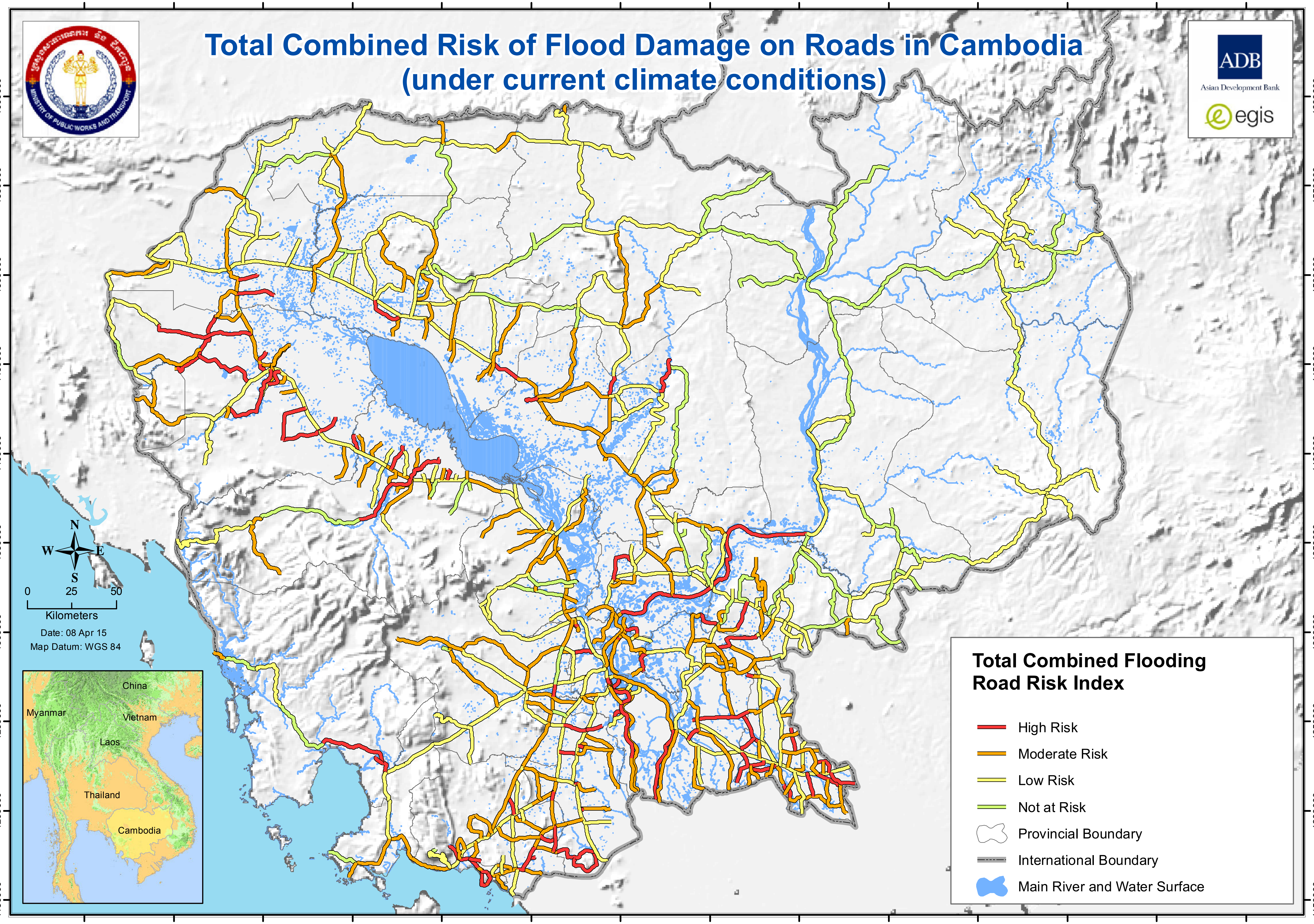
PRIP segment*	Topo elevation range (m)	SRTM average (m)	error (m)
314D	4 to 6	7	+ 2
150B	14 to 18	17	+ 1
150B W	18 to 49	32	- 1
13 - OID 74	3 to 7	7	+ 2
13 - OID 75	5 to 10	10	+ 3
53 - OID 250	60 to 100	84	+ 4
53 - OID 254	50 to 70	62	+ 2
* From RAMS road segments			

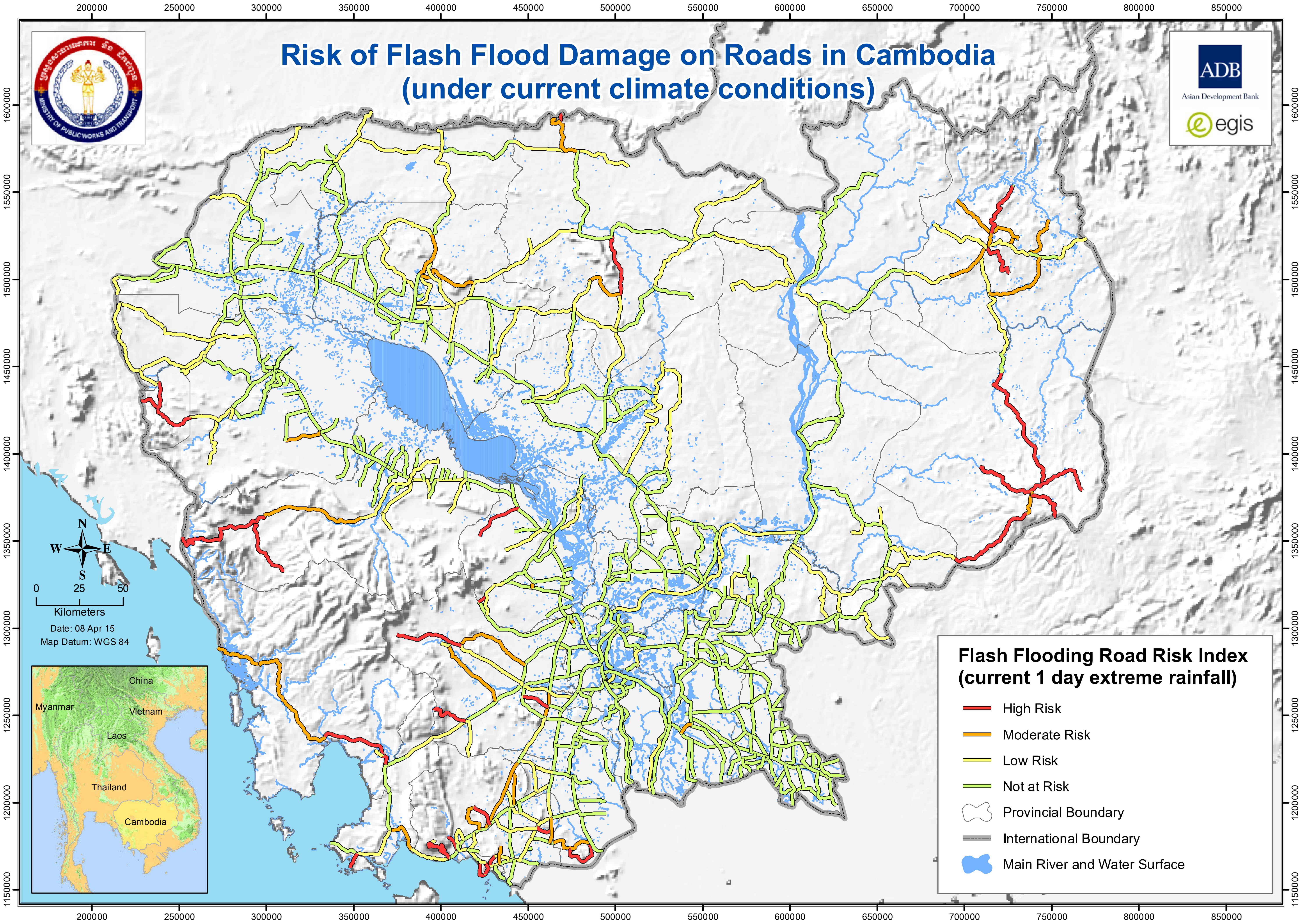
Appendix 5 Flood Risk Maps (A3)

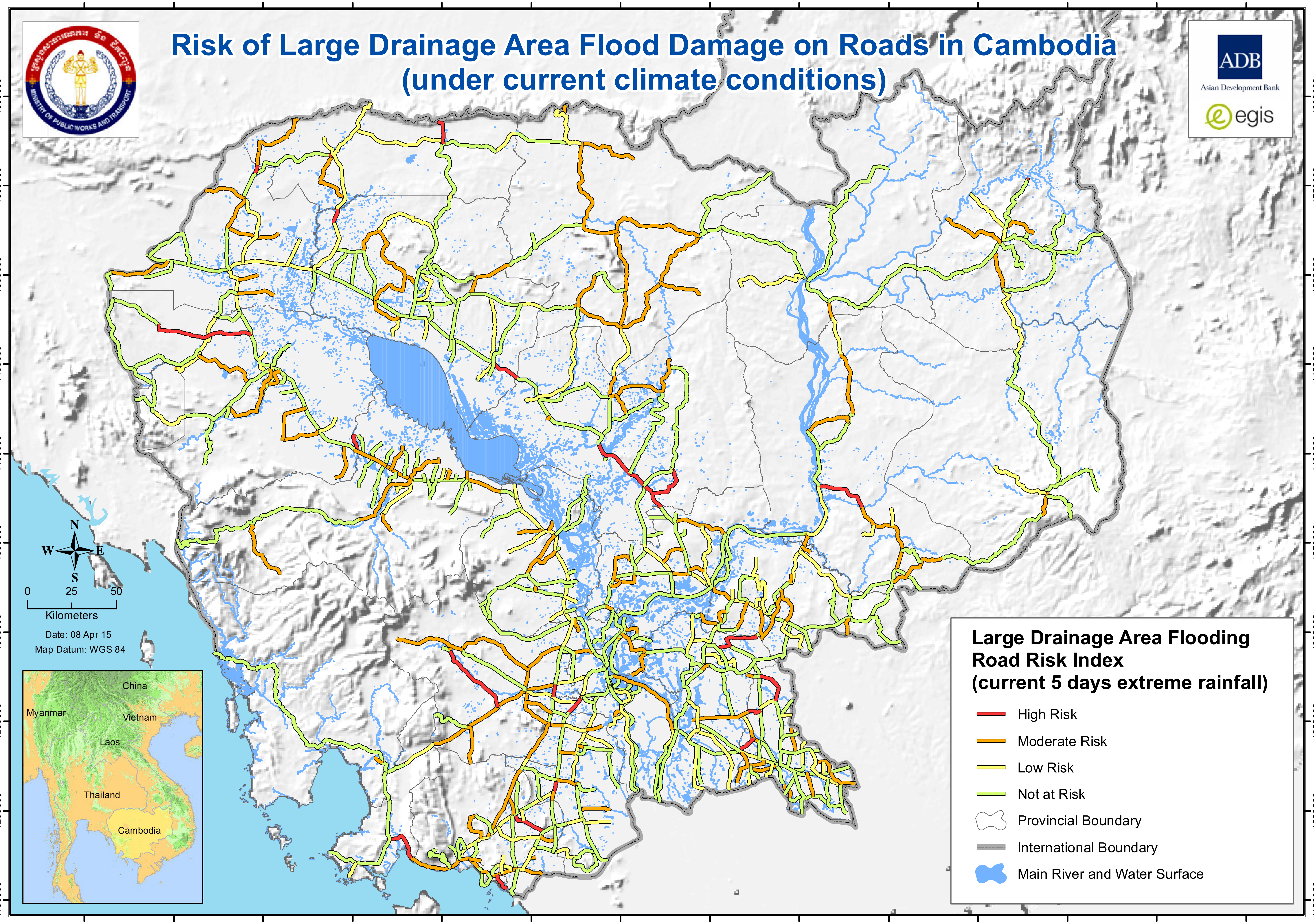

Risk of Buildup Area Flood Damage on Roads in Cambodia
(under current climate conditions)
MINISTRY OF PUBLIC WORKS AND TRANSPORT
ADB
Asian Development Bank
egis
Buildup Area Flooding Road Risk Index
(current 1 day extreme rainfall)
High Risk
Moderate Risk
Low Risk
Not at Risk
Provincial Boundary
International Boundary
Main River and Water Surface
N
S
E
W
0 25 50
Kilometers
Date: 08 Apr 15
Map Datum: WGS 84
China
Myanmar
Vietnam
Laos
Thailand
Cambodia
200000
250000
300000
350000
400000
450000
500000
550000
600000
650000
700000
750000
800000
850000
1150000
1200000
1250000
1300000
1350000
1400000
1450000
1500000
1550000
1600000

Change in Total Combined Risk of Flood Damage on Roads in Cambodia (2015-2055)



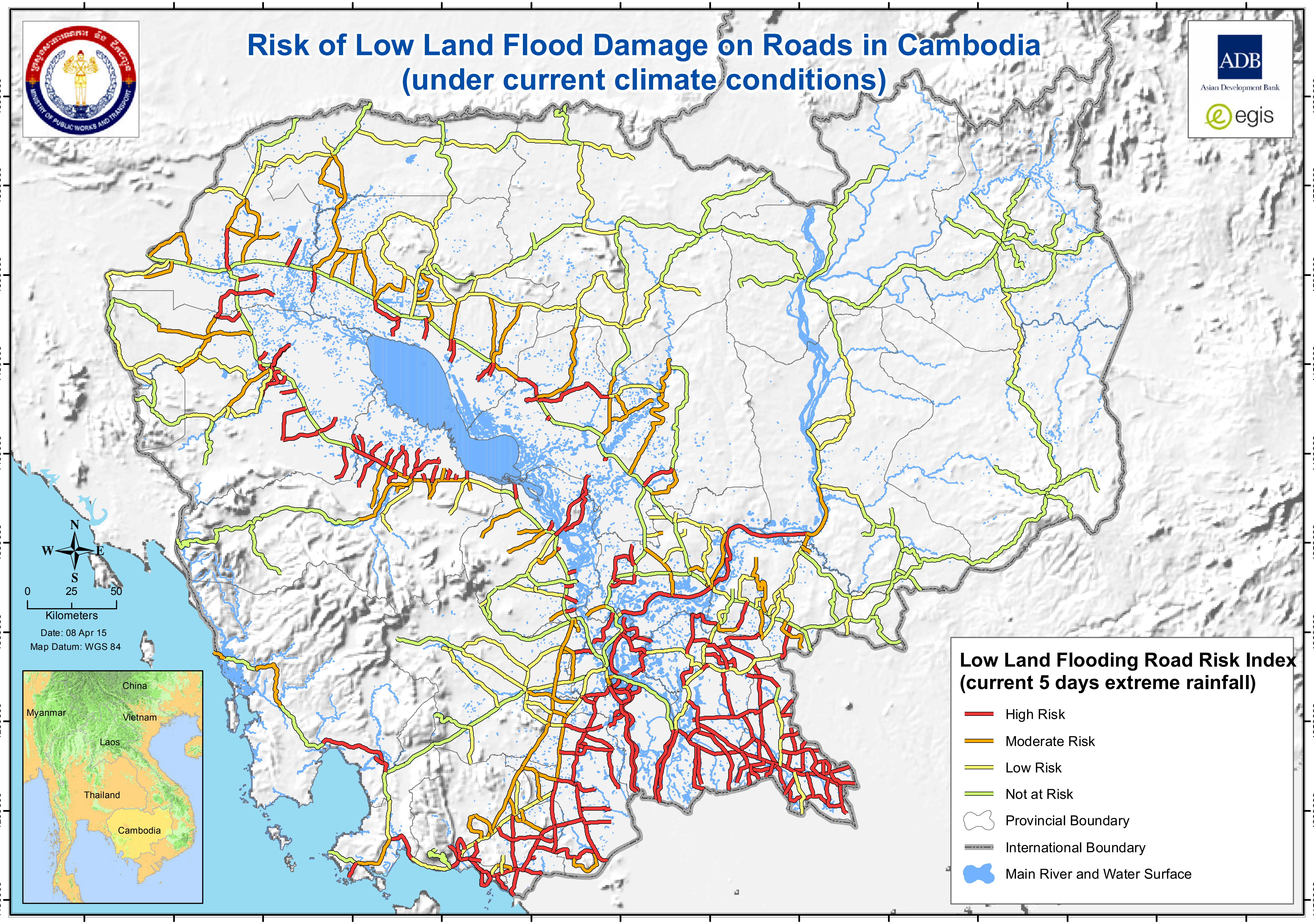

Total Combined Risk of Flood Damage on Roads in Cambodia
(under current climate conditions)
MINISTRY OF PUBLIC WORKS AND TRANSPORT
ADB
Asian Development Bank
egis
N
W
E
S
0
25
50
Kilometers
Date: 08 Apr 15
Map Datum: WGS 84
China
Myanmar
Vietnam
Laos
Thailand
Cambodia
Total Combined Flooding Road Risk Index
High Risk
Moderate Risk
Low Risk
Not at Risk
Provincial Boundary
International Boundary
Main River and Water Surface


Risk of Flash Flood Damage on Roads in Cambodia
(under current climate conditions)
MINISTRY OF PUBLIC WORKS AND TRANSPORT
ADB
Asian Development Bank
egis
N
W
E
S
0
25
50
Kilometers
Date: 08 Apr 15
Map Datum: WGS 84
China
Myanmar
Vietnam
Laos
Thailand
Cambodia
Flash Flooding Road Risk Index
(current 1 day extreme rainfall)
High Risk
Moderate Risk
Low Risk
Not at Risk
Provincial Boundary
International Boundary
Main River and Water Surface



Risk of Large Drainage Area Flood Damage on Roads in Cambodia
(under current climate conditions)
MINISTRY OF PUBLIC WORKS AND TRANSPORT
ADB
Asian Development Bank
egis
Large Drainage Area Flooding
Road Risk Index
(current 5 days extreme rainfall)
High Risk
Moderate Risk
Low Risk
Not at Risk
Provincial Boundary
International Boundary
Main River and Water Surface
N
W
E
S
0
25
50
Kilometers
Date: 08 Apr 15
Map Datum: WGS 84
China
Myanmar
Vietnam
Laos
Thailand
Cambodia
200000
250000
300000
350000
400000
450000
500000
550000
600000
650000
700000
750000
800000
850000
1600000
1550000
1500000
1450000
1400000
1350000
1300000
1250000
1200000
1150000

Risk of Low Land Flood Damage on Roads in Cambodia (under current climate conditions)



Appendix 6 References

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Cinner, JE, McClanahan, TR, Graham, NAJ, Daw, TM, Maina, J, Stead, SM, Wamukota, A, Brown, K and Bodin, Ö, (2012), 'Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries', Global Environmental Change, vol. 22, no. 1, pp. 12–20.

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Appendix 7 ADB technical comments

ADB Comments:

Climate Resilience for Provincial Road Improvement Project; Loan 2839-CAM (SF)/ 8254-CAM and Grant 0278-CAM: Vulnerability Report

The Consultant would like to thank ADB for conducting this technical review and providing valuable comments. All the points raised were investigated and are explained in the text below. Where changes and corrections were necessary, the reports will be updated.

Acknowledged with thanks

Overall: the study and the general methodological approach indicate that the consultants are knowledgeable regarding vulnerability to climate change in the regional and sectoral contexts, inclusive of the underlying climate science. The questions raised here pertain to specific aspects of the methodology that require more or better documentation, or which present problems that can in most cases be remedied. Specific comments and questions follow.

Section 3.1.3 Downscaling GCM outputs to regional scales

Modeling study selected for use: ADB TA 7459-REG Greater Mekong Subregion Biodiversity Conservation Corridors Project – Pilot Program for Climate Resilience Component –Cambodia

Carried out by The Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Description: The model was developed and run in 2012. CCAM - This is a regional model that was run specifically for South East Asia. It uses 6 GCMs selected for best performance in South East Asia The model has a pixel size of 10 km It uses the latest IPCC standard set of model simulations.

Question 1: the approach is based in six GCMs and one regional climate model. In what ways were the variations across parent GCMs represented in the analysis? The text appears to support the interpretation that a single set of down-scaled projections were used to support the analysis. Is this correct?

The characteristics of the performance of the GCMs were investigated early in the project but the variation of the models was however not examined. The value used was the mean of the six regional model runs based on each of the six GCMs.

Acknowledged. This needs to be made clear in the write-up. Averaging over projections with respect to temperature can often be defended since all (or nearly all) GCMs are projecting increases in temperature for almost every region and sub-region of Asia, and any differences between models by mid-century (e.g., 2055) are not likely to be large, so that averages are not misleading. With respect to averaging precipitation projections, caveats clearly apply, since it is often the case that the ensemble of projections will contain both increasing and decreasing cases (annually, seasonally) and when these are averaged, the result appears to indicate very little change in precipitation over time. What this process often masks are the extreme cases (those projecting substantial increases or decreases in precipitation) that are precisely the cases that designers should be concerned with. Since the default assumption is that all GCM results are (in the absence of specific evidence of poor skill within a region) to be considered equally plausible visions of the future, it is improper to dismiss the extreme cases as "unlikely" simply because they are extreme. I would recommend at a minimum including a brief section (one or two paragraphs) that characterizes the range of projected changes in precipitation across the six GCMs so that readers of the report have an understanding of the implied uncertainty regarding future conditions in the project region.

The following paragraphs will be included in the Vulnerability report and the climate change report to inform on the limitations of the models:

Studies comparing model performance with global climate data have shown that accuracy can be improved if the results are produced as an average of a suit of GCMs that are chosen for good performance in the region. The process of averaging projections from six simulations based on different GCMs may however mask the extreme cases (such as those projecting substantial increases). On the other hand it must be noted that using results from a single extreme model may also be misleading.

With respect to temperature all of the GCMs are projecting increases in temperature for every season across Cambodia. And any differences between models by mid-century (e.g., 2055) are not projected to be large, so that averages are not misleading. The range of minimum and maximum temperature changes during the hot season projected to occur by 2050 are in the order of 0.5 to 1.2 for RCP4.5 and 0.6 to 1.4 for RCP8.5.

With respect to averaging precipitation projections, all of the GCMs simulations agree on the direction and approximate magnitude of change (Katzfey et al 2013), giving good confidence in the results. For example, in Koh Kong, the wettest province, the projected change in rainfall for the six simulations for 2025 for the wettest three months ranges from -5 to -7.5% for an RCP of 8.5 and from -10 to 4 % for an RCP of 4.5. The use of extreme rainfall (the average of the highest values output by each model for a 20 year model run) for vulnerability mapping ensures that a best guess value for the maximum projected rainfall is used. In some other locations, larger changes in rainfall can however be expected but a full country wide comparative analysis was not possible within the scope of this study.

In summary, the effect of extreme cases is partially taken into account by using rainfall intensities from the highest carbon future, in this case RCP8.5 but it is advised that at the detailed design stage, the latest local rainfall data be investigated and appropriate factors be applied if large variations between rainfall predictions models are found.

Question 2: is the CSIRO modeling report available?

The CSIRO report has been provided in attachment.

Thanks very much.

Section 3.3 Climate data provided for Road Risk Analysis

There are two issues here:

PP 24-25 and Table 6: In comparing model-simulated extreme 1 day (Figure 9) and 5 day (Figure 11) precipitation patterns, we notice that the 5-day intensities are higher. Both are expressed in mm per day. How is this possible? If the 5-day intensity standardized to mm per day is higher than the 1-day extreme, then it should be used as the 1-day extreme. Please check to see if these are not rather 5-day accumulations rather than standardized to per-day.

This is a mistake in our report. The 5 day extreme values are therefore the 5 day totals (i.e. the accumulations). We are updating the old references and text descriptions in our report.

Acknowledged, thanks

P. 26: “The 5 day extreme rainfall represents the maximum output from events that lasted 5 consecutive days of >1mm rainfall.” Comment – the maximum 5-day precipitation may be missed using this procedure since it is possible for such an event to be an extreme 2-day event bracketed by dry days (< 1.0 mm/day precip). In other words, the annual maximum 5-day rainfall may have occurred over fewer than five days. This is entirely possible due to e.g., the passage of a major tropical storm.

This is also a report mistake. As observed, the rain doesn’t have to be consecutive over five days. Corrections will be made to text in the Vulnerability mapping report p24-26 & 32 and in the Climate modeling report p23, 35-38 & 42.

Acknowledged, thanks

Section 4.2 Classification of road links based on topographical analysis of road physical parameters

The primary problems are found in this section. Specifically P. 32 Table 7, on the definition of the flash flood risk parameter:

The area factor is calculated as: Road Length ***RL*** (m) / Drainage Area Perimeter **DAP** (m)

The table states: “This indicator aims at describing the overall drainage area shape. A value close to 1 indicates that the drainage area does not extend far from the road alignment. Drainage areas with high values are thus small, with short time of concentration.”

Comment: this presents problems of interpretation – see following. Also, flash flood-generating mechanisms are not inversely related to catchment size, except via depth-area-duration relationships. Re-stated, as long as times of concentration are proportional to the duration of high-intensity rainfall it cannot be assumed that smaller catchments produce larger flood peaks even when standardized to area. In addition, the ratio as presented does not serve to characterize "overall drainage area shape" as stated. There is no unique relationship between perimeter length and catchment geometry.

The flash flood risk formula is formula is presented as:

Flash Flood Risk = **S**^2 x (**RL**(m) / **DAP**(m)) x **LU** x **R1**

Comment: the logic of this formulation seems unsound. What it suggests (as presented) is that the time of concentration is all that matters, and the risk implicitly decreases with increases in upstream contributing area. However, the example they use to illustrate the methodology (Figure 14) highlights the problem: for a given reach of road, the risk of damage from flash flooding may be concentrated at a few points where the roadway is not on a ridge or otherwise elevated; and the catchment generating the flood intersects the roadway over a very narrow span with respect to the roadway axis, perhaps at a bridge or culvert crossing. According to the formulation presented, the smaller this lateral catchment's contributing area is, the greater the risk, whereas the opposite is likely the case (greater contributing area; greater flood volume and likely flood peak flow). In addition, Figure 14 illustrates the fallacy of assuming that larger ratios of roadway length to catchment area can be interpreted as shorter times of concentration. There is no escaping the need to consider catchment geometry when evaluating flash flood risks.

Another way to understand the problem is to consider the rational method, a common and widely applied approach to estimating peak discharge from small catchments. The rational formula is:

Q = (F)x(C)x(I)x(A) where:
Q = peak runoff at catchment outlet ($m^3 sec^{-1}$ in SI units)
F = unit conversion factor (0.278 for SI units)
C = runoff coefficient (ratio of runoff to total precipitation)
I = rainfall intensity over critical storm duration (typically equal to time of concentration) (mm/h)
A = catchment area (km^2)

In this approach, peak runoff is directly proportional to catchment area. By contrast, catchments of larger area (perimeter is closely related to area) result in reduced flash flood risk according to the formula presented in the report.

General Approach of the Consultant
A number of points need to be clarified when looking at the hydrological methodology. First of all, the aim of the analysis was ***not to quantify*** *the design flow or the storm water runoff of individual catchments or rivers. This can be done by the Rational Method as pointed by the reviewer or by a number of other methods. However, such a detailed design flow analysis for individual catchments along a road section would be justified only if:*

- *A need for such an analysis is economically driven, i.e. for specific road rehabilitation or post flood analysis etc...*
- *A comprehensive analysis on site (topo survey, hydraulic analysis of existing drainage structures etc..) is carried out to assess the flooding risk of this individual water course at a specified location.*
- *Local rainfall data is available, at best even short term rainfall intensities*

The aim of the analysis was rather to develop a methodology to characterize the flooding risk for nearly all roads within the Cambodia National and Provincial road network in a ***qualitative*** *way. The focus was therefore not* ***how much (in terms of runoff in m3/s)****, but rather* ***is there*** *a flooding risk, how does the risk compare to the risk at other road sections (ranking, not measuring) and what is the most probable cause for this flooding, and also in which way changes (land use, climate change) would impact on this characterization. These risk rankings using 4 different flood indexes were calculated for individual sections of the road network and plotted on hazard maps. The flooding risk maps produced by the project can be regenerated easily to illustrate the impact of change of land use as well as the impact of changing the rainfall input into the equations, caused by climatic change.*

Acknowledged – it would be impractical to conduct detailed design flow analysis for each of 1000's of km of target roadway. See following

Flash floods
Flash Flood Risk = S^2 x (RL(m) / DAP(m)) x LU x R1 seems to be illogical as it implies that smaller catchment areas are likely to produce larger a larger flash flood risk.

That would be correct if the aim of the analysis was to quantify the discharge for an individual catchment at an individual drainage structure. In a same way the reviewer's comment on the high importance of the Time of Concentration (square of slope!) is correct, if a quantitative analysis of an individual water course is aimed at.

The aim of the analysis was rather to characterize the overall topographic setting of the road section. Thus we are not considering 'Catchment areas` in a classical sense, but `Drainage area` upstream of the entire length of a road section. This could well be a single catchment, or a number of small catchments lined up along the road corridor draining towards the road.

We have currently assumed that slope is the most representative indicator (since we squared it - a slope smaller than 1 % would thus decrease the value while a value above 1% slope would significantly increase the index). However, until a more detailed analysis of this specific section is carried out, we are not able to assess whether it is slope or area which actually carries the most weight in the event of a flash flood. Still, one can safely assume that even large drainage areas with a mild slope are less likely (although this is not impossible) to produce flash floods - as defined in the report - than relatively small catchment areas with average to steep slopes.

The volume of flood runoff is proportional to catchment area, while the rate of peak discharge also reflects slope, along with other factors. In the absence of an explicit catchment delineation, how is the slope defined for the purposes of calculating flash flood risk? While acknowledging that as defined in this study, the catchment " … could well be a single catchment, or a number of small catchments lined up along the road corridor draining towards the road", this still leaves unanswered how the slope is calculated, or for that matter interpreted. Can you provide a brief description?

Slopes for drainage areas were calculated in Global Mapper software (by Blue Marble Geographics http://www.bluemarblegeo.com/products/global-mapper.php) using an option to automatically generate the catchment area delineation based on an extended digital elevation model input (which we have for all Cambodia). The software also allows to automatically generate drainage areas towards vectors, or in this case individual road sections. Thus through the application of the software an overall drainage area is calculated which includes standard area statistics, such as surface area, perimeter and average slope of the entire area (the catchment area maps obtained for each of the 550 road links are included in the Flood risk management application).

The calculated slope is thus the overall slope of the drainage area towards the road vector. Combined with the other geometric parameter used in the formula (Road Length/drainage area perimeter) this provides a strong indication of a flash flood risk. The maximum theoretical value for (Road Length/drainage area perimeter) is close to the value of 0.5. This extreme case would mean that the upper end of drainage area delineation is almost parallel to the road vector and the area is very small. If the slope value towards the road is high and the Land use values are also high, this could result in the road being overtopped at a specific place or a number of places by fast flowing water. However, there would be a limited amount of water as the actual drainage area is very small (converging to zero for the extreme case).

Finally, it is pointed out that the slope value used in the calculation is the average slope for the entire drainage area, not for individual catchments. This detailed type of analysis is only possible with more detailed site data and possibly rainfall intensity data.

Please see comment above

To better understand the application of this approach, it would be useful to know the following:

Question 1: at what scale is this methodology applied? Earlier (p. 29) the text describes "approximately 550 road links registered in the RAMP (Road Asset Management Project) data base of the MPWT, representing about 11,500 km of roads" which is equivalent to approximately 20 km per link. Is the above formula, and specifically the road length to drainage perimeter factor, calculated using the total length of road link and associated catchment, or is it standardized to e.g., 1 km segments? If the latter, this should be made clear in the text since the interpretation would be different.

The length of the segments varies (i.e. not standardized to 1 km segments) and is based on the MPWT reference road links database, for purpose of compatibility with MPWT other datasets.

Text will be added in the report in p.29.

Acknowledged, thanks

Question 2: is this approach based on established engineering practice, and if so, what are the key references (e.g., peer reviewed journal articles, design manuals)

The method has been applied on a regional scale (i.e. about 3,000 km2, see "Assessment of the susceptibility of roads to flooding based on geographical information – test in a flash flood prone area: the Gard region, France" by P.-A. Versini, E. Gaume, and H. Andrieu.)

Acknowledged, thanks

Large area floods

P. 32 (large area flooding): "The key parameter for this index is the drainage area drained by 1 km of road." Comment – what is intended is the catchment area draining to 1 km of road.

Comment – this methodology completely inverts the logic of flash flood risk calculation by (correctly) emphasizing the importance of contributing area.

P. 32: the large area flood risk formula is presented as:

Large Area Flooding Risk = ***HL*** *x* ***BF*** *x* ***LU*** *x* ***R5***

Comment: risk is seen to increase as a function of hydraulic load, bridge factor, land use and rainfall intensity. However, as bridge factor is defined as "A large factor indicates a large percentage of bridge length in the road Length" (presumably calculated as meters of bridge per total length of road link) then it should be the case that flood risk decreases as a function of Bridge Factor. Specifically, the greater the combined bridge flow cross-section, the greater the hydraulic conveyance (all other factors equal) and the lower the probability that a given rate of flood discharge results in a road embankment being inundated.

The reviewer correctly points out that the formula for large catchment areas inverts the logic of the flash flood index. In fact, this index is aimed at stressing exactly the opposite parameter, area size, rather than the flash flood parameter (slope).

We agree with the reviewer's comments on the bridge factor and this factor will be recalculated as "1-BF". In this way a theoretical road section which is bridge only (Bridge Length/Road Length =1) will have a Flooding Index of 0. On most sections it will reduce the flooding index by something like 1 to 10 %, depending on the bridge length.

Text will be corrected in the report in p.32 and the model will be rerun on all road segments.

Acknowledged, thanks

Additional comments concerning the use of the 4 Flood Risk indexes:

- *Each risk index is calculated according to a formula aimed at detecting a special flooding risk. The results of the risk indexes calculations are ranked and are only valid within the specific flood type*
- *It is thus not possible to directly compare the numeric values of different risk indexes without any standardization*
- *However, it is possible to compare the influence of the two more flexible input parameters, land use and climate change, on each individual road section.*
- *The four risk indexes should not be looked only in isolation. The sum of the standardized values can inform on the risk at a single location of multiple types of flooding*

Thanks for clarification

*Comment – have any of these techniques been tested against more conventional and rigorous hydrologic modeling techniques? This could easily be done on the basis of the data sets already assembled.

This type of analysis is seldom found in design manuals and engineering literature since it is not intended for designing structures, but rather to identify natural hazard with a non - parametrical statistical method (ranking and sorting as opposed to parameter testing).

The application of this method on a national scale is surely an innovation. A better assessment could be reached by a calibration of the influence of slope and area for the flash flood index and the Large Area Flood Index once more data becomes available. A calibration was attempted during the project period. However, as the documented data on flooding events in Cambodia does often not differentiate between flash floods and slow floods we opted to initiate a new flood data collection system at the MPWT.

We acknowledged the need for future calibration in 4.7.4 and recommended: "It will be however possible to further calibrate the flood risk model through the incorporating of systematic future flood and road damage data, using a function of the Flood risk management interface which was designed to facilitate this data input. In combination with latest road condition data, this information will make possible a better understanding of the complex relationship between floods and road damages. "
To that effect, a database interface was developed (called FRMI) to start collecting systematically flood information and flood damage data and will be used to improve the correlation of the flood risk indexes and eventually lead to recommending cost effective flood proofing characteristics that are most suitable to each flooding case. The risk assessment method itself is not intended for detailed design.

Acknowledged – this will be an extremely important contribution

In summary, due to the limitations of availability of flood data in Cambodia, the method proposed is intended to be part of a larger cost-effective process that starts with the assessment of flood risks using geographical and land use characteristics as well as rainfall data. This first risk assessment helps to prioritize and target the rehabilitation of a number of high risk roads. Once this prioritization is completed, local investigations and traditional hydraulic analysis are then conducted on the selected road segments leading to the final (flood proofed) designs.

Acknowledged, thanks