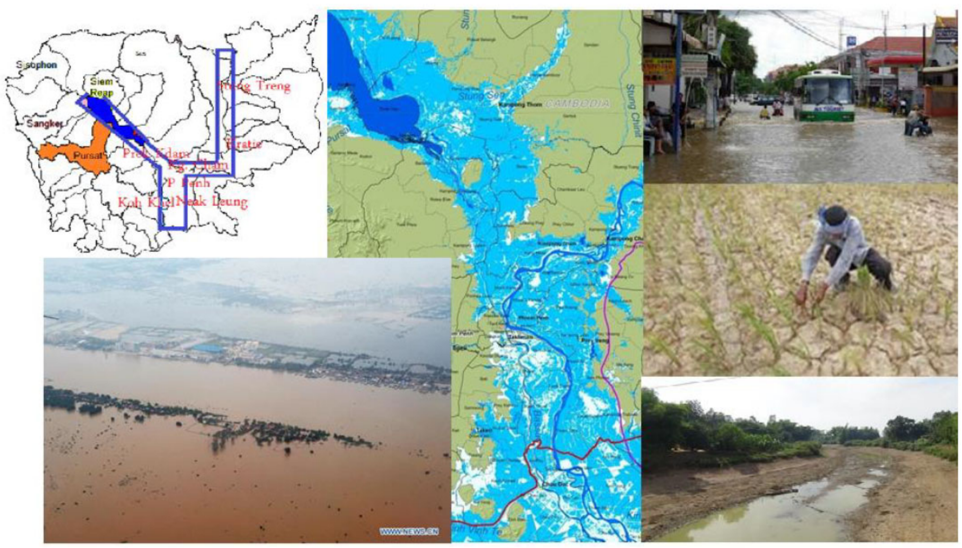
MINISTRY OF WATER RESOURCES AND METEOROLOGY

CLIMATE RESILIENT AND USER MANUAL DESIGN GUIDELINES
FOR
STRUCTURAL FLOOD AND DROUGHT CONTROL MEASURES

Incorporating additional guidance on
Ecosystem-based Adaptation for Climate Resilience in the Water Sector.



GREATER MEKONG SUB-REGION FLOOD AND DROUGHT RISK MANAGEMENT AND MITIGATION PROJECT

Phnom Penh, January 2020

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Supplementary Report (Separate Volume)

User Manual: Design Guidelines for Structural Flood and Drought Control Measures

Foreword

The GMS Flood and Drought Risk Management and Mitigation Project (GMS-FDRMMP) is funded by the Asian Development Bank and the Government of Cambodia. The objective of the Project is to reduce economic losses resulting from floods and drought events. The key components of the Project are:

a. Enhanced regional data, information and knowledge base for the management of floods and droughts;
b. Upgraded Water Management Infrastructure (Damnak Chheukrom Irrigation System Rehabilitation in Pursat Province);
c. Enhanced Capacity for Community-Based Disaster Management.

The Executing Agency (EA) is the Ministry of Water Resources and Meteorology (MOWRAM), and the implementing agencies are the Department of Hydrology and River Works (DHRW) and the Provincial Department of Water Resources and Meteorology of Pursat.

This climate resilient design guidelines for structural flood and drought mitigation measures in Cambodia is prepared by the Ministry of Water Resources and Meteorology (MOWRAM) with support from the Project Consultants, as part of the first component of the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project.

The design guidelines detail a comprehensive approach to flood and drought mitigation for Cambodia and consider current thoughts on climate change and climate variability projections for Cambodia. The significant influence of land use changes due to development in the flood plain and their effect on floods and droughts are highlighted.

The design guidelines for flood control measures outline a process, which uses a range of design flood criteria that considers the critical to non-critical nature of the infrastructure being proposed. The design guidelines consider risk, vulnerability, and climate change aspects with respect to the type of development planned.

The management of drought requires integrative approaches and integrated management, which consider the natural features and socio-economic conditions. A framework for the timely implementation of drought mitigation measures and the adoption of an effective monitoring system for the evaluation of drought risk is proposed.

An additional chapter on the principles of Ecosystem-based Adaptation (EbA) and the existing policies for its application in Cambodia is also included. The chapter is a contribution and result of the Component IV of the Strategic Program for Climate Resilience (SPCR) Phase II coordinated by the Ministry of Environment, namely the ADB TA 8179-CAM: Mainstreaming Climate Resilience into Development Planning. The chapter presents the process for developing and designing ecosystem-based adaptation measures within the context of river basin planning and watershed management. It provides practical examples of both structural and non-structural adaptation measures.

An accompanying user manual is also prepared to guide agencies and individuals in the application of climate resilient design guidelines for structural flood and drought control measures in Cambodia

The design guidelines, and the accompanying user manual, will be useful to the Government Ministries, other non-governmental agencies and private sector to develop polices and regulations within their responsibilities and mandates, and to design climate resilient flood and drought mitigation and adaptation measures in Cambodia.

On behalf of the Ministry of Water Resources and Meteorology, I would like to thank the Asian Development Bank for the financial support to the Project. The Ministry acknowledges the efforts and contributions of H. E. Ponh Sachak, Secretary of State and Project Director, Mr. Bak Bunna, Project Manager, Mr. Yin Savuth, Director of Department of Hydrology and River Works, and the staff of the Central Project Management Unit (CPMU), Ministry of Water Resources and Meteorology (MOWRAM), the Consultant Teams and the stakeholders (participants) in the Concluding Workshop for their inputs, comments and feedbacks during the preparation of the guidelines and the accompanying user manual.

H.E. Lim Kean Hor

Minister of Water Resources and Meteorology

Phnom Penh 2020

Executive Summary

The Royal Government of Cambodia has received financial support from the Asian Development Bank to implement the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project (GMS-FDRMMP), which is comprised of three components. Component 1.0 is to improve the National Flood Forecasting Centre (NFFC) and to propose climate resilient design guidelines for structural flood and drought mitigation.

This report presents climate resilient design guidelines for structural flood and drought control measures in Cambodia. The design guidelines consider the overview of flood and drought protection measures and details a comprehensive approach to flood and drought mitigation for Cambodia present in the Flood Protection and Drought Mitigation Measures Report (NFFC 2017). The role that climate change and land use change due to development and their effect on floods and droughts have been taken in to account during the development of the design guidelines for structural flood and drought control measures. The current thoughts on climate change and climate variability projections for Cambodia have been considered.

Considering the significant influence that land use changes on the flood plain will have, it is not appropriate to simply set a fixed structural standard. Therefore, the design guidelines for flood control measures outline a process, which uses a range of design flood criteria that considers the critical to non-critical nature of the infrastructure being proposed. The design flood event criteria consider risk, vulnerability, and climate change aspects with respect to the type of development planned.

Drought design guidelines are much more difficult to quantify and therefore the response and mitigation of drought impacts requires more of a non-structural approach. The management of drought in a defined area requires integrative approaches and integrated management, based not only on the natural features, but also on socio-economic conditions of the area. A framework for the timely implementation of drought mitigation measures and the adoption of an effective monitoring system for the evaluation of drought risk is proposed. Key to preparing for droughts is the ability to predict the potential for drought in a given season and its severity.

An additional chapter on Ecosystem-based Adaptation (EbA) has been added at the suggestion of HE Ponh Sachak, Director General of Technical Affairs for MOWRAM. The chapter introduces the principles of EbA and the existing policies for its application in Cambodia. As well, the chapter presents the process for developing and designng ecosystem-based adaptation measures within the context of river basin planning and watershed management. It provides practical examples of both structural and non-structural adaptation measures.

The report satisfies the deliverable for WBS 700,

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8.1. COST BENEFIT ANALYSIS 61

List of Acronyms and Abbreviations

ADB	Asian Development Bank
AusAID	Australian Agency for International Development
AWS	Automatic Weather Station
BCA	Benefit Cost Analysis
BDP	Basin Development Plan
CBA	Cost Benefit Analysis
CBDRM	Community Based Disaster Risk Management
CBOs	Community-Based Organization
CNMC	Cambodian National Mekong Committee
CSO	Civil Society Organization
DEM	Digital Elevation Model
DIS	Database and Information System
DHRW	Department of Hydrology and River Works
DOM	Department of Meteorology
DSF	Decision Support Framework of MRC
DTM	Digital Terrain Model
EbA	Ecosystem-based Adaptation
EIA	Environmental Impact Assessment
EWS	Early Warning System
FMMP	Flood Management and Mitigation Programme
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gases
GMS	Greater Mekong Sub-Region
GMS-FDRMMP	Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project
GTZ	German Technical Cooperation
ICT	Information and Communications Technology
IDPs	International Development Partners
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resources Management
M-IWRMP	Mekong Integrated Water Resources Management Project
MOWRAM	Ministry of Water Resources and Meteorology
M&E	Monitoring and Evaluation
MRC	Mekong River Commission
MRC-RFMMC	MRC Regional Flood Management and Mitigation Centre
NCDM	National Committee for Disaster Management

NFFC	National Flood Forecasting Centre
NGO	Non-Governmental organization
O&M	Operation and Maintenance
PEMSEA	The Partnership in Environmental Management for the Seas of East Asia
PIO	Project Implementation Office
RB	River Basin
RBO	River Basin Organization
RBU	River Basin Unit
RCPs	Representative Concentration Pathways
RGoC	Royal Government of Cambodia
SOP	Standard Operating Procedures
SSEPs	Shared Socio-economic Pathways
SRES	Special Report on Emissions Scenarios
TA	Technical Assistance
TSA	Tonle Sap Authority
WB	World Bank
WBS	Work Breakdown Structure
WMO	World Meteorological Organization
WUAs	Water User Associations

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1. Introduction

1. The Royal Government of Cambodia (RGoC) has received financial support from the Asian Development Bank to implement the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project (GMS-FDRMMP). Component 1.0 of the project has two objectives. The first objective is to strengthen the National Flood Forecasting Centre (NFFC) to better forecast floods and droughts and to enhance NFFC's contribution to regional data, information, and knowledge for the improved management of risks associated with floods and droughts. The second objective is to propose climate resilient design guidelines for structural flood and drought control measures in Cambodia. The results of this work will enable the RGoC to reduce the consequences of floods and droughts as well as to undertake measures to better design structural and non-structural measures with the objective of reducing the negative effects that these natural disasters cause.

2. This report focuses on the second objective, which is the development of climate resilient design guidelines for structural flood and drought control measures in Cambodia. The guidelines take into consideration the mechanics of the flood and drought systems in the region as well as projected climate change implications.

3. Natural hazards have drastic effects on Cambodia's population and pose a serious challenge for water resources management and poverty alleviation in the country. Flood and drought vulnerability is one of the most significant factors that must be considered when addressing poverty reduction and economic development in Cambodia. Efforts are being made to devise strategies that aim to decrease this vulnerability through improved natural disaster preparedness and flood and drought proofing coupled with climate adaptation strategies to reduce risks from floods and droughts. Lessening the impact of floods and droughts are key priorities for sustainable development, for ensuring the safety and prosperity of the population, and for maintaining environmental integrity.

4. The Lower Mekong basin has a complex floodplain where floods exhibit many positive benefits as well as have negative consequences. The complexity and role of the floodplain has a significant influence on the extent, duration, and storage of flood water. A comprehensive study conducted by the Mekong River Commission (MRC) under the Flood Management and Mitigation Programme (FMMP) from 2011 to 2015 through the FMMP Initial Studies Project provided valuable insight in to how the flood zones behave with respect to mitigating flood impacts. Accordingly, the findings of the FMMP study are used extensively in the preparation of the guidelines presented in this report related to floods.

5. Climate change projections for Cambodia indicate a wetter rainy season with a greater percentage of the total rain for the rainy season resulting from extreme events, and a dryer dry season with perhaps less rain but higher temperatures. Projected runoff is to be higher and sea level rise will have implications for existing flood prone areas. Cambodia is expected to experience a reduced number of intense cyclones. These climate change projections have implications for floods and droughts in Cambodia.

6. In addition to climate change, future development on the basin's floodplains will affect flood behaviour and flood risk in the Lower Mekong basin. Potential floodplain changes include the development of new infrastructure, increased population, changes to land-use, and a higher standard of living. The critical flood attenuation function of the Cambodian floodplain and the Tonle Sap Lake system is potentially threatened by floodplain development and loss of flood conveyance due to infrastructure. The Cambodian floodplain is currently much less developed than the Mekong delta and this potential for new floodplain development may have a significant effect on future flood risk and vulnerability. The raising of levees and roads, the installation of culverts and bridges, which restrict natural flood flow pathways, and the greater compartmentalization of flood water retention areas all have the potential to increase vulnerability and to affect flood risk.

7. Development and land use changes draw attention to the need for a more encompassing perspective in which structural measures and land use changes in response to social-economic initiatives must be considered. This perspective must not only consider how floods and droughts will affect these developments and initiatives and their need for protection, but more importantly must consider how these developments and initiatives will increase or decrease flood and drought vulnerability. This broader perspective considers both the structural and non-structural measures to reduce vulnerability to floods and droughts.

8. An important consideration with respect to floods in Cambodia is the transboundary nature of the Mekong River basin. Much of the floodwaters in Cambodia are derived from upstream countries, including Viet Nam. Therefore, effective flood and drought management hinges on regional cooperation, information sharing, and the development of region-specific solutions.

9. Given that some provinces in Cambodia may experience floods and droughts within the same season. building capacity and awareness are key components of a flood and drought mitigation and risk reduction strategy.

10. Given this complex setting, the role that climate change and land use change due to development and their effect on floods and droughts must be factored into the design guidelines for structural flood and drought control measures. Therefore, it is not appropriate to merely set a fixed structural standard. What is required is a process driven approach to addressing the design of structural measures to lessen the impact of floods and droughts. This process driven approach for considering flood and drought design requirements is presented in this report.

11. An additional chapter to these guidelines has been prepared on Ecosystem-based Adaptation (EbA), which complements engineering approaches to flood and drought management. This has been prepared by the ADB Strategic Program on Climate Resilience (SPCR) in Cambodia, TA 8179, and included in these guidelines at the suggestion of MOWRAM.

2. Climate Projections and Implications

12. The Intergovernmental Panel on Climate Change (IPCC) notes that in the coming decades, global average temperatures will increase, rainfall patterns will change, extreme weather events will become more severe, sea levels will rise, and numerous other environmental changes will occur (IPCC 2007). However, the degree of change varies because the climate change implications are based on a number of emission and development scenarios. The emission scenarios consider low, moderate, and high emission projections for a range of assumptions related to population growth, technological development, economic growth, and energy sources. This variability among scenarios accounts for the wide margin in predictions. A second layer of variability is due to the uncertainty associated with ecological feedback in the system. Uncertainty increases with the complexity of the system and as predictions move further in time along ecological and social processes.

13. It is important to note that the scenarios used in earlier climate change assessment reports were replaced with Representative Concentration Pathways (RCPs) for IPCC's Fifth Assessment Report (AR5) in 2014. The RCPs supersedes the Special Report on Emissions Scenarios (SRES) projections published in 2000. The RCPs consider four greenhouse gas concentrations, not emissions, trajectories adopted by the IPCC. The RCPs are consistent with a wide range of possible changes in future anthropogenic (human) greenhouse gas (GHG) emissions. RCP2.6 assumes that global annual GHG emissions measured in CO_2-equivalents peak between 2010-2020, with emissions declining substantially thereafter. Emissions in RCP4.5 peak around 2040, then decline. In RCP6.0 emissions peak around 2080, then decline. In RCP8.5 emissions continue to rise throughout the 21st century. The four RCPs have consistent socio-economic assumptions but these may be substituted with the Shared Socio-economic Pathways (SSEPs), which are anticipated to provide flexible descriptions of possible futures within each RCP. The RCPs and SSEPs are used for climate modelling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted and the actions taken to limit these emissions.

14. The average temperature in Cambodia has increased since 1960 by 0.8°C, and with it the frequency of unusually hot days and nights has increased (McSweeney et al. 2008). The climate models project a further 0.3 to 0.6°C increase by 2025 (MOE 2002). Modelled estimates put the expected warming at 0.7 to 2.7°C by the 2060's (McSweeney et al. 2008). The temperature increases are expected to be more severe from December to June.

15. All climate change models agree that rainfall in Cambodia will increase, but the magnitude of change is uncertain. Estimates of the increase vary from as little as 3% to as much as 35% (ICEM 2009). Models predict that the increase in rainfall will occur during the wet season, bringing more flooding, and that precipitation in the dry season will be unchanged or lower (Eastham et al. 2008). Rainfall is expected to increase more in the lowlands than in the highlands, with precipitation and flooding increasing predominantly in the central agricultural plains, which are already vulnerable to flooding and drought.

16. Climate change will bring more extreme weather events such as storms, heat waves, droughts and floods. Damage from intense cyclones has increased significantly in Cambodia in recent decades (Cruz et al. 2007) and may worsen as the intensity and maximum wind speed of tropical cyclones making landfall is

projected to increase significantly for Southeast Asia. However, the total number of cyclones reaching landfall may be significantly reduced. Damages may still rise as the greatest impacts are caused by the most intense storms. Extreme rainfall associated with tropical cyclones is expected to increase by up to a third.

17. The projected sea level rise along the Southeast Asian coastline relative to 1986 to 2005 is expected to exceed 50 cm above current levels by 2060 and approach 100 cm by 2090 (World Bank 2013). It is important to note that the World Bank 2013 report developed its projections on a 4°C increase under a RCP8.5 scenario.

18. In summary, the climate change projections for Cambodia indicate a wetter rainy season with a greater percentage of the total rain for the rainy season resulting from extreme events, and a dryer dry season with perhaps less rain but higher temperatures. Projected runoff is to be higher and sea level rise will have implications for existing flood prone areas. Cambodia is expected to experience a reduced number of intense cyclones.

19. It is apparent that the floodplain system with the current infrastructure cannot absorb the increases in extreme floods that most of the climate scenarios indicate. Considering a 2060 design horizon. which provides a design life of some 40 years for infrastructure currently in the planning stage, sea level rise is expected to approach 0.5 m by 2060, which will increase water levels at Phnom Penh by some 0.2 m. Peak water levels at Phnom Penh for a 1:100 event is expected to approach 0.3 m for a moderate climate change scenario and over 1.2 m for the extreme scenario. The increase in water level for even the moderate scenario is expected to lessen the existing flood protection works to less than a 1:20 year event. The duration of flooding is predicted to be extended by 14 days for a moderate scenario.

3. Basic Principles and Concepts

20. Design guidelines for floods and droughts are incomplete without incorporating the concepts of resiliency, adaptation, and vulnerability. The common definition of these terms are as follows:

- **Resiliency** is the ability to recover from a negative event, such as natural hazards and a changing climate.
- **Adaptation** involves preparations beforehand and strategies for recovery and adjustment. Adaptive capacity refers to a community's capacity to create resilience infrastructure, to develop response systems, and to take action.
- **Vulnerability** is an assessment of adaptive capacity, sensitivity, and exposure. Sensitivity and exposure are both tied to socioeconomic and geographic elements that vary widely in differing communities and geographic regions.

21. Design guidelines must consider structural and non-structural approaches to addressing flood and droughts hazards, where these terms are defined as:

- **Structural measures** aim to reduce flood and droughts risk by controlling the flow of water. Structural measures range from engineered structures, such as flood defences, drainage channels, and storage dams to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers.
- **Non-structural measures** are actions taken to mitigate flood and drought loss and damages through better planning and management of watershed development. Non-structural measures address flood and drought risks by building the capacity of people to cope with floods and droughts. Non-structural measures include activities such as having in place an early warning system, building and zoning codes, supportive policies and strategies, education and awareness initiatives, and institutional capacity.

22. Design guidelines for flood and droughts must consider the design life of structural measures. The longer the design life, the more important are the consequences of climate change and future developments in the floodplain.

23. Design guidelines for floods may be based on a standard design storm or protection level which considers the recurrence period for flood causing events. The level of protection may vary considering the importance of the facilities being protected, which can be designated as critical facilities and non-critical facilities. For example, hospitals, emergency control and response centres, and key transportation corridors and infrastructure are critical and require a higher level of protection. Major industrial and population centres will also require a higher level of protection given the significant economic and potential for loss of life and livelihood associated with these centres. As well, sources of significant toxic contamination from hazardous substance such as oil, pesticides, or fertilisers must be well protected or placed outside the flood zone.

24. Design guidelines are often based on a frequency analysis, which is a standard statistical procedure to assign the likelihood of occurrence to a flood or drought event. However, a basic assumption of the statistical analysis is stationarity. That is, for extreme flood or drought events the statistics do not change in time and past observations can be considered as representative of future observations. With a changing climate the assumption of stationarity may not be applicable and more advanced statistical methods that account for the non-stationarity are required. A number of studies in Europe and North America have shown that there is no linear relationship between precipitation and annual maximum flood scenarios. The studies also revealed that low return period floods are more sensitive to climate change than high return period floods. This is thought to be due to the degree of wetness of the watershed at different flood frequencies. That is, if the watershed is wet, the dynamics that produce higher floods in medium to large watersheds is less affected by changes in precipitation and more governed by the drainage network within the watershed.

25. The **consideration of risk** has also emerged as a key concept for the selection of actions related to disaster management and for the selection of appropriate design criteria. Risk is generally described as the probability of occurrence (Likelihood Level) of an adverse event multiplied by the consequences (Consequence Level) should the selected event occur at the location under consideration. Therefore, the risk that an event may have is a function of the event's likelihood of occurrence and the consequence of the event should it occur for the location selected. The severity or risk level associated with a flood or drought event can be categorised as low, medium, high, or extreme as illustrated by Figure 3.1. Using the severity or risk level an organization can identify areas at high to extreme flood or drought risk, for example, and focus their mitigation measures in these areas. Or, the risk matric can be used to establish the level of protection required from flooding.

Likelihood Level	**Consequence Level**				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	District A			District D	
Likely				District G	
Possible			District B		District E
Unlikely		District F		District C	
Rare					

Low Risk
Medium Risk
High Risk
Exreme Risk

Figure 3.1: Example Risk Matrix considering the likelihood level and consequence level

26. As described above, a risk-based approach to the assessment of natural disasters considers the probability of a natural disaster occurring and the consequences or level of damages that are expected. Furthermore, the risk-based approach considered the concept of inherent risk and residual risk as a dimension of the risk assessment. Inherent and residual risk reflects whether risk controls are in place when

assessing the consequences associate with a natural disaster. For example; for a selected level of flooding if controls are in place to address the flooding at the time of assessment, then the measure of risk is considered to reflect a residual risk. The concept of inherent and residual risk is further demonstrated in Figure 3.2 considering a number of flood mitigation and adaption strategies. The figure shows how the initial risk or inherent risk is reduced through a number of non-structural and structural measures. A similar risk base approach can be applied when considering drought mitigation and adaptation strategies.

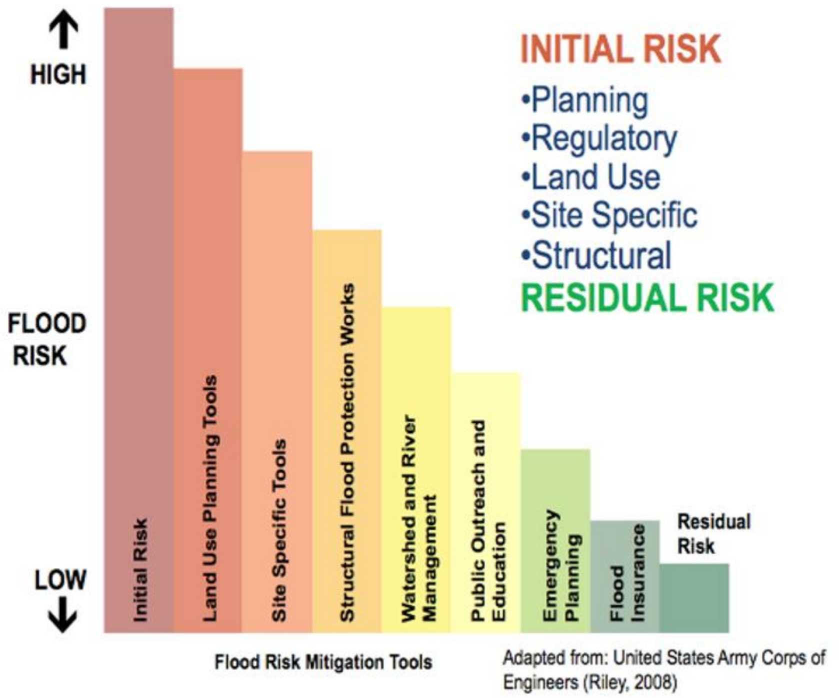

Figure 3.2: Residual risk considering non-structural and structural mitigation and adaptation measures

27. Flood risk assessment refers to the quantitative analysis of the level of flood risk for a river reach or basin as shown by Figure 3.3. The identification and mapping of flood risks requires information on flood hazard such as the extent and duration of flooding and the level of vulnerability in the area affected by flooding. Flood hazard analysis involves an analysis of flood occurrence, which considers meteorological events that may lead to flooding. As well, hydrological information such as peak discharges and volumes, as well as the characteristics of the river channel and floodplain are used to define flood events and flood extent. The flood hazard is defined in terms of inundation area, height of water, water velocity, and duration considering meteorological, hydrological, river channel, and floodplain characteristics. The level of risk is also related to the probability that a flood event of a specific magnitude will occur.

28. Drought risk assessment is generally more difficult to quantify and can vary depending on the type of drought such as:

- Meteorological drought, which is defined by low rainfall over the wet season (May to November)
- Hydrologic drought, which is described by relatively low amounts of water carried by rivers and streams, which can be the result of climatological conditions (low precipitation and high temperatures)

- Agricultural drought, which considers the effect of the reduced availability of soil moisture on crop yields, whether for food or fodder

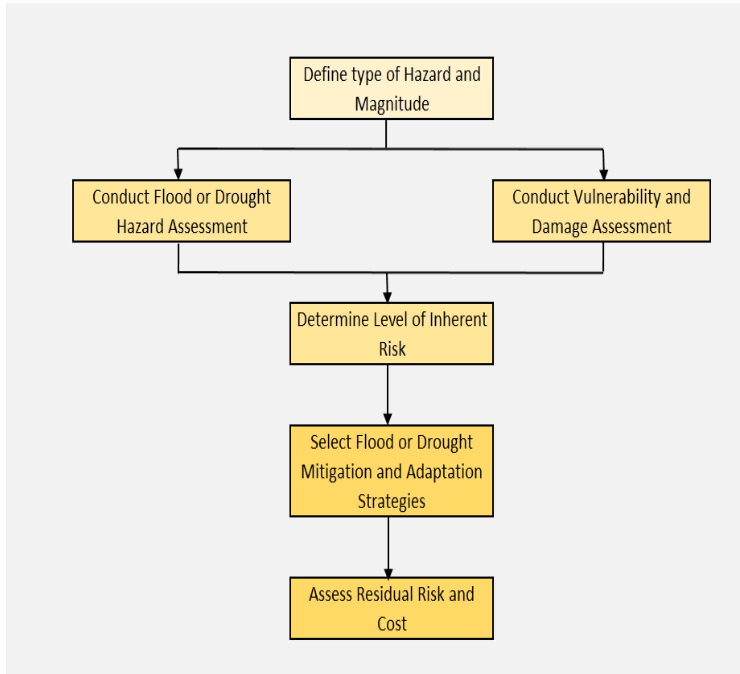

Figure 3.3: Risk assessment process

29. Meteorological, hydrological, and agricultural droughts are typically assessed through the analyses of a time-series of variables such as rainfall, stream flow, groundwater levels, and soil moisture data, on a variety of time scales. Drought is characterized by its intensity, duration, and spatial coverage. Intensity refers to the degree of the precipitation shortfall and the severity of impact associated with the shortfall. It is generally measured by the departure from normal and is closely linked to duration in the determination of impact. Another distinctive feature of drought is its duration. Droughts usually require a minimum of two to three months to become established, but then can continue for months or even years. The magnitude of drought is closely related to the timing of the onset of the precipitation shortage, its intensity, and the duration of the event. Droughts also differ in terms of their spatial characteristics, which can affect different areas from season to season. If the weather pattern persists for a short time over a few weeks or a couple months, the drought is considered short-term. But if the weather pattern becomes entrenched and the precipitation deficits last for several months to several years, the drought is considered to be a long-term drought. Often a drought index is used to display the severity and extent of droughts. Similar to flood risk assessment, drought risk assessment requires and understanding of the potential damages based on socio-economic-environmental data for the drought affected area. This information is used to build a vulnerability/damage model. Risk determination and drought risk mapping involves combining the results of the drought index analysis and the results of the vulnerability/damage assessment. The results can be displayed as risk maps, graphs, or risk numbers. The results provide an expected level of loss with an associated probability or frequency of occurrence.

30. **An adaptive approach** of “living with floods” and “living with droughts” is a strategic direction for flood and drought management in Cambodia. The approach considers the use of structural protection works by flood proofing of settlements and transportation infrastructure and the use and/or development of less vulnerable rice varieties to inundation. Drought adaptation approaches suggest greater use of low intensity irrigation, use of drought tolerant crop varieties, and greater use of water retention schemes and groundwater. Adaptation involves making adjustments in our decisions, activities, and ways of thinking in response to observed or expected changes, with the goal of reducing harm and taking advantage of potential

opportunities. Adaptation involves preparations beforehand and strategies for recovery and adjustment. Adaptation can include behavioural changes, operational modifications, technological interventions, planning changes and revised investment practices, regulations and legislation. Policies, regulations and guidelines are mechanisms that can be used to raise awareness and encourage or require adaptive action. Planned adaptation takes time as it requires research, stakeholder engagement, and adjustments to policies and regulations. Many sectors are starting to use adaptive management approaches to deal with changes in climate and other stressors.

31. The concepts of risk and adaptation to natural hazards are important to understand when developing strategies and measures for flood and drought mitigation. Natural hazards, such as floods, droughts, extreme weather, and rising sea levels cause economic, social, and ecological loss by damaging property, by restricting access to food, by increasing the potential for disease, and by limiting the population's ability to earn a livelihood. Vulnerability is defined as a function of exposure, sensitivity, and adaptive capacity. In the context of vulnerability, exposure is the nature and degree to which a system is exposed to the natural hazard, and sensitivity is the degree to which a system is affected, either adversely or beneficially. Exposure and sensitivity are both tied to socioeconomic and geographic elements that vary widely in differing communities and geographic regions. Adaptive is defined as the ability of a system to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences.

4. Flood and Drought Mitigation Strategies and Measures

4.1. National Strategies

32. The Cambodian government has taken a multi-dimensional approach to flood and drought management. The approach uses both structural and non-structural measures to manage the risk and effects of floods and droughts. A National Early Warning Strategy and a Standard Operating Procedure (SOP) for the Flood Early Warning System was drafted in 2014 for the Cambodian National Committee for Disaster Management by the Asian Disaster Preparedness Centre through funding by the World Bank. The strategy addressed the need to conduct risk assessments and to develop early warning systems and building codes. The SOP for the flood early warning system defined the roles and responsibilities of the various government agencies involved in flood response.

33. The National Early Warning Strategy and SOP have been prepared from the perspective of how to respond to floods and droughts once they occur. Guidance and processes from the perspective of preparedness and adaptation are lacking as well as the development of standardizes building codes and land use zoning is limited. However, the limited availability of the standardized building codes, land zoning, and adaptation polices has not prevented the Cambodia government from undertaking structural measures to provide improved flood protection for larger centres and important transportation routes. Efforts to address drought events have been more difficult. Water retention and storage have been the predominate strategies used to date.

4.2. Structural Protection Measures

34. It is important to note that the Mekong floodplain and the Tonle Sap Great Lake system provides a critical flood attenuation and a drought mitigation function, which must be critically considered when developing flood and drought preparedness and adaptation strategies. Unplanned and uncontrolled development that threatens the storage capacity of the floodplain or the loss of flood conveyance will have long-terms consequences for efforts to reduce damages.

35. The most effective flood protection methods in Cambodia are relocation and elevation. However, when these methods are not feasible, structural flood proofing methods may be an alternative. Flood proofing is defined as any combination of structural and non-structural measures, which reduce or eliminate damages and loss caused by floods and droughts. Structural measures aim to reduce flood risk by controlling the flow of water. Structural measures range from engineered structures, such as flood defences and drainage channels to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers. However, structural measures can be overtopped by events beyond their design capacity and result in significant damage and loss. As well, structural measures transfer flood risk by reducing flood risk in one location only to increase it in another location. Structural solutions have a high upfront investment cost, may induce complacency by their presence, and can result in a significant increase in damages if they fail.

36. Structural measures to address floods and droughts in Cambodia are typical focused on protection measures such as dams, dikes, and levees, and transportation corridor improvements by raising the elevation

of road and rail lines. Building construction in urban areas is most often not flood proofed, whereas in rural areas it is common to have elevated living quarters. Structural measures related to droughts include reservoirs, flood water retention ponds, rainwater harvesting, irrigation, and wetland restoration. A number of flood and drought structural measures are shown in Table 4.1.

Table 4.1: Typical Flood and Drought Structural Measures

Strategy	Options
Reduce Flood Susceptibility	Dams and reservoirs
	Dikes, levees, and flood embankments
	High flow diversions
	Channel improvements
	Flood proofing
	Location of facilities
	Wetland Restoration
Reduce Drought Susceptibility	Dams and reservoirs
	Water retention ponds
	Irrigation
	Groundwater Use
	Wetland Restoration

4.3. Non-Structural Protection Measures

37. Non-structural measures are actions taken to mitigate flood and drought loss and damages through better planning and management of watershed development. Non-structural measures address flood and drought risks by building the capacity of people to cope with floods and droughts. As such, building capacity and awareness are key components of a non-structural flood and drought mitigation and risk reduction strategy. Non-structural measures include activities such as having in place an early warning system, building and zoning codes, supportive policies and strategies, education and awareness initiatives, and institutional capacity. Non-structural measures do not usually require large upfront investments, but rely on an improved understanding and awareness of floods and droughts, on an adequate forecast system, and on the affect population taking appropriate actions. Non-structural measures have four main functional elements as shown in Figure 4.1.

38. **Risk Knowledge** – Knowledge of the risk is gained through the conduct of risk assessments. The assessment of risk requires the systematic collection and analysis of data and considers the dynamic nature of flood and drought events and their associate vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation, and climate change. Risk assessments and risk maps help to prioritize flood and drought actions and to guide preparations for prevention, mitigation, and response.

Figure 4.1: Elements of Non-Structural Measures

39. **Monitoring and Warning** - Warning services lie at the core of the flood and drought mitigation system. There must be a sound scientific basis for predicting and forecasting flood and drought events and a reliable forecast and warning system. Continuous monitoring of flood and drought event parameters is essential to generate accurate warnings in a timely fashion. Warning services for flood and drought events must be coordinated and benefit from existing institutional, procedural, and communication networks.

40. **Dissemination and Communication** - Clear messages containing simple and useful information is critical in enabling proper responses from those at risk as well as to agencies responsible for flood and drought response and relief. Regional, national, and community level institutions must be identified and appropriate roles and responsibilities established well before any events occur.

41. **Response Capability** - It is essential that communities understand their risks, respect the warning service, and know how to react. Education and preparedness programs play a key role. It is also essential that flood and drought management plans are in place, well-practiced, and tested. Communities should be well informed on options for safe behaviour, available evacuation routes, and how best to avoid damage and loss to property and life.

42. Non-structural measures in Cambodia are continuing to evolve. Cambodia has a good understanding of the risk dimension and a number of risk assessments have been undertaken for floods, however few have considered droughts. Many of the studies advocate a 'living with the flood' strategy verse a structural approach. Forecasting and warning capacity is continuing to improve as well as the approach to communicate warnings and disaster information continues to improve and evolve to reach the community level much quicker. Mobile communications technologies and services are facilitating this change. The area requiring the greatest attention is awareness and appropriate response at the community level to flood and drought warnings. However, the level of awareness and knowledge of appropriate responses is expected to increase significantly and in a short period of time as communications of the flood and drought conditions

become more timely and comprehensive. A number of flood and drought non-structural measures are shown in Table 4.2.

Table 4.2: Typical Flood and Drought Non-Structural Measures

Strategy	Options
Reduce Flood and Drought Susceptibility	Catchment management
	Flood plain regulation
	Development and redevelopment policies
	Design and location of facilities
	Housing and building codes
	Flood and drought forecasting and warning
	Greater reliance on groundwater
	Drought tolerant crops
	Restoration of wetlands
Mitigate Impacts of Floods and Droughts	Information and education
	Disaster preparedness
	Post flood and drought recovery
	Flood and drought insurance
Preserve the Natural Capacity of Flood Plains	Flood plain zoning and regulations
National Flood and Drought Strategies	Coordination between governments and non-government organizations at national, provincial, and local levels

5. Flood Design Guidelines and Best Practices

5.1. General Considerations

43. Approaches to lessen the negative affect of floods in Cambodia consist of structural and non-structural measures. A number of studies for the region have raised caution with respect to the wide spread use of structural measures given the implications for loss of the natural floodplain function. The MRC Flood Management and Mitigation Programme 2011-2015 conducted a number of studies related to flood challenges and flood management strategies. The relative fragility of the flood control system for cities such as Phnom Penh and secondary towns such as Kampong Cham are highlighted by the results of the FMMP study. The report concluded that changes on the floodplain as well as climate change will have significant implications leading to higher flood water levels, longer duration of flooding, and increased flows.

44. The Cambodian floodplain and the Tonle Sap Lake system provide a critical flood attenuation function that is potentially threatened by floodplain development and loss of flood conveyance due to infrastructure. The raising of levees and roads, the installation of culverts and bridges to restrict natural flood flow pathways, and the greater compartmentalization of flood water retention areas all have the potential to affect flood risk and increase vulnerability. The Cambodian floodplain is currently much less developed than the Mekong delta and this potential for new floodplain development will have a significant effect on flood risk and vulnerability if it is not properly managed.

45. The possible footprint of Phnom Penh and other major towns along the Mekong River and around Tonle Sap Lake will continue to expand as the population increases and there is greater rural to urban migration due to better social-economic opportunities in the urban areas. The growing urban footprint has implications for increasing vulnerability due to the expansion of the densely-populated areas, which may be affected by flood water, as well as may significantly increase the damages that result from flooding due the higher density and higher valued properties and business located in urban areas. Urbanization of the floodplain will restrict the natural flood attenuation and normal flood pathways resulting in higher flood levels and longer periods of flood inundation outside of the urban areas. The mitigation measures for urban centre are often flood protection through the use of protections levels and dikes. While these structural measures are sufficient for less extreme flood events, they significant increase the urban centre's vulnerability to extreme events that exceed the design capacity of these protection measures resulting in catastrophic losses.

46. Therefore, it is important to recognise the role that development and land use changes have on floods and droughts. This recognition draws attention to a more encompassing perspective in which structural measures and land use changes in response to social-economic initiatives must be to consider not only from how floods and droughts will affect these developments and initiatives and the need for protection but, more importantly, how these developments and initiatives will increase or decrease flood and drought vulnerability. This broader perspective considers both the structural and non-structural measures to reduce vulnerability to floods and droughts.

47. The people of Cambodia have adapted to the occurrence of annual floods and are accustom to "living with floods" through adaptation, however rare and extreme flood events still result in significant loss of livelihood and damage.

5.2. Design Policies and Strategies

48. Adaptation is proposed as the core mitigation strategy, combined with selected and cautious use of structural measures.

49. The EU Floods Directive 9 2007/60/EC) requires that flood risks be addressed following a three-stage process. The first involves preliminary flood hazard mapping followed by a second stage requiring detailed flood hazard and flood risk mapping for critical areas identified during the preliminary mapping stage. The final and third stage involves the development of flood management plans.

50. A 'best practices document' for the EU was developed in 2003 as an update of the United Nations and Economic Commission for Europe (UN/ECE) Guidelines on Sustainable flood prevention (2000). The document identified a number of policy assumptions and principles that covered prevention, protection, and mitigation. The document noted the following key principles:

- Flood events are a part of nature. Floods have existed and will continue to exist. Therefore, in the future, human interference into the processes of nature that have implications for flooding should be understood and mitigated, as far as feasible.
- The flood strategy should cover the entire basin and promote the coordinated development and management of actions regarding water, land, and related resources.
- The flood strategy requires a shift from defensive action against floods to the management of the risk associated with floods that support a 'living with floods' adaptation strategy.
- Flood forecasting and warning is a prerequisite for successful mitigation of flood risk. Its effectiveness depends on the level of preparedness and correct response. The responsible authorities must provide timely and reliable flood warning and flood information.
- Human uses of floodplains should be adapted to the flood hazard. Mitigation and non-structural measures are more efficient and over the long term offer a more sustainable solution to reduce the vulnerability of people and goods exposed to flood risk.
- Structural measures (defence structures) remain important elements and should primarily focus on the protection of human health and safety, and valuable goods and property. However, flood protection is never absolute, and may generate a false sense of security. The concept of residual risk, including potential failure or breach, should be taken into consideration.
- Preparedness is a result of awareness, which is based on reliable and appropriate information that supports and enables individuals to plan, prepare, and react to flood events and reduce their risk and lessen flood damage.

51. Flood information and flood hazard maps must be available, widely disseminated, and explained. The information should be disseminated early and actively and be supported by media plans prior to and during a flood event. Flood hazard maps must identify areas at risk, be easily readable, and show the different hazard levels. Flood hazard maps are necessary for the coordination of actions, for planning, and for raising awareness.

52. Flood plains should be identified and designated by law to ensure development activities that threaten flood water retention and conveyance are easily known. The purpose is to discourage protective bank construction, embankments, impoundment and undermining, constructions or installations and, in general, any construction or works likely to form an obstacle to the natural flow of floods that cannot be justified by the protection of critical areas.

53. Information and education must be ongoing to ensure flood awareness is ingrained with the public. Flood marks placed in communities remind the public of the danger and are helpful for those not used to reading maps.

54. The most sensitive establishments, such as buildings, facilities, and installations whose operation is fundamental to civil safety, defence, maintaining public order, or whose failure presents a high risk to humans or are of socio-economic importance, must be implemented in no-risk-prone areas or protected and appropriate mitigation measures taken to address the loss of natural flood retention or conveyance capacity.

55. There is a need to implement a flood hazard risk assessment for all polices and developments activities proposed in a watershed. The flood hazard risk assessment will consider flood prevention and reduction measures as well as the provision of compensating flood retention areas.

5.3. Flood Design Process

56. The FMMP study of the Cambodian floodplain and Mekong delta highlighted the role of the floodplain in terms of conveying and attenuating flood flows. Floodplain storage is seen to be critical as a naturally functioning part of the river system that helps to reduce flood levels and downstream affects. Accordingly, changes on the floodplain as well as climate change will have significant implications leading to higher flood water levels, longer duration of flooding, and increased flows.

57. Given that storage and conveyance features of the floodplain have a direct effect on flood levels, extent, duration, and timing of flooding, a zone approached has been proposed that considers flood behaviour based on local natural influences and requirements. The FMMP study divided the floodplain into zones as adopted for WUP studies (WUP-JICA) and was modified slightly to provide a more comprehensive coverage of the full extent of the influence of flooding and flood considerations in Cambodia. The zones are shown in Figure 5.1.

Figure 5.1: Proposed Flood Zones

58. The flood design process follows the following steps:

Step One: Determine Design Flood Requirements

- Identify the Flood Zone and select design flood event criteria considering the planned development type as shown in Table 5.1. It is important to note that the 2000 flood is considered to represent the design flood for the 1:200-year flood event. The design flood event criteria consider risk, vulnerability, and climate change aspects with respect to the type of development planned.

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Table 5.1: Flood Design Criteria considering Flood Zone and Development Type

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
Zone C1 comprises the Great Lake and part of the connecting Tonle Sap River to Prek Kdam	This Zone contains the wet season maximum extent of the Tonle Sap Great Lake and Tonle Sap river floodplain to Prek Kdam and is a key part of the functioning of the natural response of the Mekong to the annual flood pulse. There are a number of significant provincial towns around the periphery of the flood season extent of the Tonle Sap Great Lake that are potentially at risk.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			loss of floodplain storage and flood conveyance and mitigate
Zone C2 lies on the Mekong right bank and Tonle Sap left bank and is bounded by the high ground to the north, Road 6 to the Prek Kdam bridge, and the Mekong to the south	Key features include the Provincial town of Kampong Cham and the Muk Kampul River which flows parallel to the Mekong eventually crossing the Road 6A and flowing back into the Tonle Sap.	All development should be limited in this Zone given the Zones importance for flood conveyance to the Tonle Sap Great Lake for significant flood events	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C3 lies to the south of Phnom Penh and to the west of the Bassac comprises of the region from Ta Khmau to the border with Vietnam, delimited to the east by the RN 21. There are some 90 artificial and natural colmatage canals transferring flood water from the Mekong/Bassac rivers to this zone through the RN 21. The population density is high along the Bassac river banks and the RN 21.	The area includes important wetlands and minor irrigation development. The Prek Thnot enters the Bassac at Ta Khmau, which is becoming part of the City of Phnom Penh as urbanization expands south. The border area is controlled by dike embankment along the right bank of the Vin Te canal in Vietnam and controlled openings to Zone V1 by two rubber dikes.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater and changes occurring in Vietnam that will affect water levels upstream in Cambodia • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigation
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		important for food security as well as schools and historical cultural and touristic areas Proper planning and managements of colmatage canals to prevent excessive rise of water level in the areas.	• Banned ground floor construction to prevent free flow constriction across RN 21 and Bassac river banks. • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Must identify transboundary impacts based on medium to long term development scenarios in Cambodia and in Vietnam
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection. Needs medium to long term planning supported by detail development scenarios integrated with other flood zones (C4, C7 and C8) to provide inputs for transboundary flood management and planning.	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Develop strategy for cropping pattern to reduce risk to flood and droughts taking into consideration of space for flood conveyance, storage and storage for dry season cropping

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
Zone C4 represents the Trans Bassac area is still under developed as compared to Vam Nao polder area in Vietnam but it is one of the least disturbed fishery ecosystem in the Mekong floodplain and under increasing pressure from development.	The area is relatively underdeveloped except for the land along the banks of the Mekong and Bassac and in the vicinity of Road 1 that passes from Phnom Penh to Vietnam. There are four controlled colmatage canals crossing the RN1 between Kien Svay and Neak Leung and during flood season the flood water levels in the northern part of this zone are largely determined by the Bassac River and may be 1m lower than the Mekong side of the road. Roads are progressively being improved and raised and a major ring-road and bridge crossing of the Bassac has been opened defining the next stage of urban development close to Phnom Penh. Further south during flood season large part of flood water spill over the right bank of the Mekong into this zone to the flood zone C3. During the dry season and high tide period when flow from the Tonle Sap River stops, the Bassac River flows into the Lower Mekong River. With no waste water treatment facilities, this flow might similarly impact on water intake facilities on the Tonle Sap, the water intake on the Mekong.	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigation • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Re-establish, rehabilitate existing natural and artificial drainage channels in the areas connecting the Bassac with the back swamp and lakes
Zone C5 lies on the left bank of the Mekong River, is the largest maximum flood storage areas up to 8.6 MCM and during extreme flood receives more than 65% of the Mekong overbank flow.	The area is one of the key conveyors of floodplain flows via the Tonle Toch and associated floodplain areas. These include a number of flow paths including the lake at Prey Veng down to the connection of the Tonle Toch with the Mekong at Banam and Prek Kampong Trabek rivers spreading the Mekong	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events. An inter-sectoral strategy should be developed taking into consideration of its flow conveyance function, wetland ecosystem services, adaptable cropping patterns (early	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
	overbank flow between Neak Leung and Kampong Trabek towns where RN 1 crosses the floodplain. Two important river branches drain this area namely the Stung Slot and the Prek Kampong Trabek.	crop, recession crop and wet season crop) as basis for medium to long term spatial planning.	• Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Strategy for deep and shallow flooded areas development and management.
Zone C6 lies on the left bank of the Mekong River and is an area remote from the main flood areas of Zone C5 with mild maximum flood storage volume.	The area receives flow in time of high flood as water passes through culverts in RN 8 and RN 11 connecting to the West Vaico in Vietnam. It is also an area of localised flooding and source of water for Svay Rieng and other border areas. Large irrigation canals were built connecting with the Mekong flood water and with pumping during the dry season. Important area for ground water recharge for areas downstream, groundwater recharge facilities and management.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance.	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Medium to long term plan scenarios development for transboundary impact assessment
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas.	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		Reforestation and soil conservation improvements are required.	structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Retain deep flooded areas for ecosystem conservation and no protection during high flood and consider full protection for shallow flooded areas
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection and use of green engineering	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C7 lies on the left bank of the Mekong River below Neak Leung south of the RN1 and north of borders with Vietnam	The area is a key spill area on the left bank of the Mekong River. The Zone includes the Stung Slot and Trabek rivers and borders the Plain of Reeds in Vietnam (Dong Thap) and is one of the most important with respect to trans border concerns. Impacted by water management in Vietnam due to dike embankment along the Prek Smao/Soha Kaico along the border. (flooded land and water shortage for recession crops). Is experiencing decreased ecosystem services.	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events. River navigation rather than road for bulk transport, river regulation with rubber dams for flow and tidal impacted water management Elevated or polders for restricted settlement areas	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • There is a concern with development restricting floodplain flow, which lowers important trans border flooding for Vietnam and increases flood levels upstream in Cambodia • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			• Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Develop medium to long term development scenarios to assess trans border impacts with other flood zones C8, C6, C3 and C4
Zone C8 is a trans border area to the east of Zone C7, severely flooded during the 2000 highest flood; acid sulfate soil, large barren land areas.	The area is a trans border area and has significantly less floodplain flow than Zone C7. It is the source of the West Vaico in Vietnam and flooding on the Cambodia side near the border is closely linked to the hydraulic conditions on the Vietnam side.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance, forest regeneration, reforestation, soil conservation, green technology	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Viet Nam that will affect water levels upstream in Cambodia
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Develop medium to long term development scenarios to assess transboundary impacts with other flood zones C7, C6, C3 and C4.
Zone C9 contains the Mekong River from Kratie to the upper end of Zone C2 and C5 at Kampong Cham	The area has a limited floodplain extent on both side of the Mekong River not well connected and increasingly disconnected with the Mekong with road development along both river banks. The Kratie town is the uppermost location of the Mekong Delta, where the downstream water level start to back up once the water level at Kratie has reached the level above 18.0 m. At high stage large amount of flow bypasses the control of the Kampong	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance Flood protection ring dike of the Kampong Cham town should be verified for its design frequencies. The failures of the dike would	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
	Cham hydrological station and rejoints the Mekong at the northern side of the zone C5. During severe floods Kampong Cham town despite its dike embankment along the Mekong river bank will be vulnerable to floods from its western site. Furthermore, the bypass flows across RN 7 between Kampong Cham and Suong town can only pass through Moat Khmung bridge, where land encroachment upstream is intensifying.	have dramatic consequences downstream, including Phnom Penh	• Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate. • Medium to long term development scenarios should be included in the overall Mekong- TLSGL floodplain development and management.
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate

Step Two: Determine Level of Flood Hazard

- Consult the appropriate return period flood hazard map (NFFC 2017) to identify the location of the planned development and determine the expected level of the flood hazard.
- Assess the impact of the planned development's impact on the flood level due to the loss of floodplain storage, flood conveyance, and trans-border flooding considering the flood hazard as defined by the 1:200-year flood event.
- Consider changes to water control structures occurring in Viet Nam that will affect water levels upstream in Cambodia.
- Major works such as roads, levees, irrigation embankments, and water management structures will require the configuration and calibration of a suitable flood hydrodynamic model to assess the effect of the planned development on local flood levels for the required design criteria.
- Propose mitigating measures to ensure there is no net loss of flood storage and flood conveyance.
- Advise National Mekong Committee of any trans-border flooding concerns.

Step Three: Establish Flood Protection Design Level

- Select the design level for flood protection works considering the maximum water level projected to the HATIEN MSL.
- For semi-critical and non-critical works add a freeboard of 0 3m to accommodate for waves, localized influences, and uncertainty in the reference level.
- For critical works add a freeboard of 0.6m to accommodate for waves, localized influences, and uncertainty in the reference level.

5.4. Continuous Improvement

59. Improvements to the Digital Elevation Models (DEM) of the flood zone is of critical importance to the reliability and accuracy of the flood hazard mapping process. The base DEM must have the required precision and must be kept current to reflect changes in the flood zone. Regular investments are required.

60. The use of hydrodynamic models is critical to the effective assessment of the flood hazard as well as the assessment of proposed development will have on floodplain storage, flood conveyance, flood extent, and flood duration. The establishment of a standard approach to hydrodynamic modelling as well as regular improvements is necessary.

61. A timely and reliable flood warning and forecast system, dependent upon consistent near real-time reporting of hydrometeorological data is one of the basic conditions for protection against and response to floods. The basic hydrometeorological data collection system must be well maintained and must provide adequate coverage. The use of satellite and global modelled products, key to the identification of severe and extreme weather conditions as well as to the provision of seasonal outlooks, is critical to a well-functioning flood warning and forecast system. The forecast system must be effective and this

requires regular updates to the modelling platform and the incorporation of new knowledge and science as it becomes available.

62. Information on flood flow distributions within the floodplains are extremely limited and available only for the period between 2001 and 2003 during the MRC's TSLV project. Their usefulness for hydrodynamic model calibration and validation are outdated. Intensive data collection is needed at least every five to ten years to be in line with physical land use and climate changes.

63. Trained and skilled staff are critical to a flood warning and forecast system as well as the flood hazard assessment and flood management activity. Staff must have the correct educational background, be well trained, and motivated to continuous improve their skills and the technical aspects of the flood warning and forecast system.

64. Institutional strengthening requires significant attention. In addition to the establishment of the NFFC for improved flood forecasting, there is an urgent need for strengthening institutional capacity for flood management and mitigation to support medium to long term spatial planning.

5.5. Public Engagement and Awareness

65. An effective flood management framework requires prevention activities prior to the event, response and mitigation activities during the event, and rehabilitation and recovery activities post event. Each of these key activities requires public engagement and awareness.

66. Prevention activities include structural measures such as dams, dikes, levees and diversions as well as non-structural measures such as flood plain zoning, development and management planning (integrated flood risk management, IFRMM or spatial planning), development policies, watershed improvements, and flood preparedness through planning, education, and awareness. During the event, flood response and mitigation activities encompass flood forecasting and the issuing of warnings, emergency relief, and evacuation. Post event rehabilitation and recovery involves financial support, resettlement, reengineering of protection works, and review of flood response plans, flood management systems, and institutional arrangements.

67. It is essential that communities understand their risks, respect the warning service, and know how to react. Education and preparedness programs play a key role. It is also essential that flood management plans are in place, well-practiced, and tested. Communities should be well informed on options for safe behaviour, available evacuation routes, and how best to avoid damage and loss to property and life.

6. Drought Design Guidelines and Best Practices

6.1. General Considerations

68. Drought can result in food and water shortages, loss of income, and higher levels of disease. In Cambodia, the occurrence of relatively moderate drought events has significant impact given the high level of vulnerability and limitations in the ability of rural people to cope with the impact of drought events. Under a normal year, typical rainfall distribution is from May to October with heavy rainfall from August to mid-October. A dry spell of about 2 to 3 weeks in July and August is typical. For reference, droughts may be classified as being a meteorological, agricultural, or hydrological drought as shown in Figure 6.1. In a year when the inter-monsoon dry period is extended longer an agricultural drought can occur. An agricultural drought may also occur as the result of a late start and early end of monsoon season. Droughts are damaging to agriculture, especially rice and domestic water supplies and can result in a total loss of crops, livestock, and fisheries. Given the relatively high frequency of moderate to severe drought in the Lower Mekong basin, the cost of droughts is significantly higher than the cost of flooding. As the climate warms, the cost of droughts is expected to increase and will continue to be greater than those of floods.

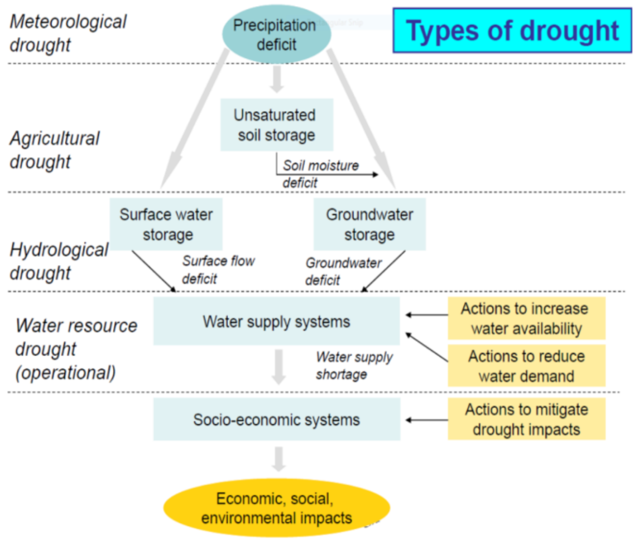


Figure 6.1: Drought Types

69. The implications of development and landscape changes on drought vulnerability are much less direct. Droughts are defined by the limited available of water to satisfy the social-economic and ecological needs of the region. Development may increase the demand for water and hence artificially increase the frequency of water shortages and the regions vulnerability to drought. However, drought is considered more of a naturally driven event, which is directly influenced by the natural climate conditions of the region and changes in rainfall and temperature patterns over the short to long term. The vulnerability of rural communities is increasing with loss of common properties, natural biodiversity, and wetland ecosystem resources that investment in water conservation and management are not able to resolve at this time as compared to decades before when these resources were abundant. Existing traditional mechanisms to cope with drought are becoming less valid today.

70. Climate change has a number of consequences for drought management in Cambodia. The consequences of climate change were derived considering the IPCC's Fifth Assessment Report and the investigations conducted under MRC's Flood Management and Mitigation Programme from 2010 to 2015. There is general consensus that Cambodia and the Mekong River basin will experience increased rainfall during the wet season through more intense rain storm events. Rainfall during the dry season is expected to remain unchanged or be slight lower. The estimate for the magnitude of change varieties under the various climate scenarios, however the direction of the change is consistent. Temperatures during the

dry season are expected to increase, which will have significant consequences for the increased potential of prolonged droughts.

6.2. Drought Policies and Strategies

71. While the people of Cambodia have adapted to the occurrence of annual floods and are accustom to "living with floods", they are less prepared for droughts that occur with a frequency of once in every three years.

72. The management of drought in a defined area requires integrative approaches and integrated management, based not only on the natural features, but also on socio-economic conditions of the area. Understanding the national institutional regime is a key factor for establishing effective and integrated drought management plans that incorporate monitoring, public participation, and contingency planning. A clear definition of roles and responsibilities among organizations and institutions are the basis for responsive and effective drought management plans and for improving future actions that mitigate the effect of drought on agriculture, water supply systems and the economy.

73. Considerable progress is being made in drought monitoring and early warning systems. The increased emphasis on improving these systems is largely the result of the mounting impacts of drought, reflecting greater societal vulnerability. Heightened monitoring capability, including the expansion of automated weather station networks and satellites are contributing to such improvements. In addition to improved monitoring, improved access to critical data and information continues with delivery of this information through a wide range of tools or decision support products to users in many sectors. Both the monitoring and availability of drought data has greatly assisted climate and drought assessments.

74. Adaptation is proposed as the core mitigation strategy, combined with selected and cautious use of structural measures.

75. Drought adaptation approaches suggest greater use of low intensity irrigation, use of drought tolerant crop varieties, and, greater use of water retention schemes and groundwater, water soil conservation. Considerations must be given to maintaining sensitive and valuable ecosystems such as forest cover, seasonally-inundated riparian forests; seasonal wetlands including marshes, small pools and pools; and seasonally inundated grasslands, agro-meteorological practices. These ecosystems are important as a habitat for a variety of fish and water birds and for the sustenance of the inland fisheries.

76. The vulnerabilities of drought are complex and have strong linkages between physical, social, economic and environmental conditions. A strategic plan for drought management must consider the Hyogo Framework for Action 2008-2015. According to the Hyogo Framework the strategy should follow five priorities:

- Strengthen institutional and technical capacities for drought risk reduction and climate change in agriculture and enhance coordination mechanisms
- Promote and enhance early warning systems for pro-active drought risk reduction and climate change adaptation
- Enhance knowledge management and innovation in support of drought risk management and climate change adaptation in agriculture
- Reduce vulnerabilities to droughts by improving technical options and implementing Community Based Disaster Risk Management and Climate Change Adaptation measures in agriculture

- Strengthen effective preparedness and response capacities including the integration of drought risk reduction and climate change adaptation into agriculture intervention approaches

77. National guidelines on drought management will reduce risk by developing better awareness and understanding of the drought and the causes of societal vulnerability. The principles of risk management will promote the building of greater institutional capacity through the improvement and application of seasonal and shorter-term forecasts, integrated monitoring and drought early warning systems and connected information delivery systems, developing preparedness plans at all levels of governance, adopting mitigation actions and programmes, and creating a safety net of emergency response programmes that ensure timely and targeted relief.

78. Watershed development programs entails the rational utilization of land and water resources for optimum production while causing minimum trauma to natural and human resources. Watershed management in the broader sense is informed by an undertaking to maintain the equilibrium between elements of the natural eco-system or vegetation, land or water on the one hand and human activities on the other hand. Watershed development provides the best environmental unit for planning a developmental program. The watershed development approach is an important facet of drought management initiatives.

79. Prevention and preparedness activities are designed to increase the level of readiness and improvement of operational and institutional capabilities for responding to a drought. Drought prevention and preparedness involve water supply augmentation and conservation such as rainwater harvesting techniques, expansion of irrigation facilities, effective dealing with drought, and public awareness and education. Transport and communication links are a must to ensure supply of food and other commodities during and just after a drought. Successful drought management requires community awareness on the mitigation strategies, insurance schemes for farmers, crop contingency plans, and economic relief mechanisms.

80. The overall development of the agriculture sector and the intended growth rate in GDP is largely dependent on the judicious use of the available water resources. While irrigation projects (major and medium) have contributed to the development of water resources, the conventional methods of water conveyance and irrigation are inefficient and have led not only to wastage of water but also to ecological problems such as water logging, salinization and soil degradation rendering productive agricultural lands unproductive. It has been recognized that use of modern irrigation methods like drip and sprinkler irrigation must be considered as an alternative for the efficient use of surface as well as ground water resources.

81. Existing local traditional droughts managements systems and related social capital must be reinstated and strengthened as a national model before they are completely disappeared.

6.3. Drought Mitigation Process

82. Drought design guidelines are much more difficult to quantify and therefore requires more of a non-structural approach. Accordingly, droughts in a defined area require an integrative approach and integrated management based not only on the natural features, but also on socio-economic, institutional, and environmental considerations.

83. Long-term actions oriented to reduce vulnerability of water supply systems and short-term actions that are to be implemented during droughts are required. A framework for the timely implementation of

drought mitigation measures and the adoption of an effective monitoring system for the evaluation of drought risk is required. Key to this is the ability to predict the potential for drought in a given season and its severity.

84. Drought management encompasses a number of vital components namely:

i. Plan for droughts events through actions such as:
   - Understanding drought vulnerability and how it varies temporally and spatially to establish comprehensive and integrated drought early warning systems as the result of water shortage and the exposure of the communities to water shortages
   - Developing a drought emergency plan
   - Developing criteria or triggers for drought-related actions
   - Developing a drought communication plan and early warning system to facilitate timely communication of relevant information to officials, decision makers, emergency managers, and the general public
   - Developing agreements for secondary water sources that may be used during drought conditions
   - Establishing an irrigation time/scheduling program or process so that agricultural land and priority crops receive the required amount of water at the required time
   - A definite cropping plan is required considering short duration varieties

ii. Develop drought indicators that identify the types and the severity of drought. The impact of drought has an environmental, economic, and social dimension and the indicator must capture these dimensions. Among the environmental indicators one could include, rainfall, water level in the reservoirs and other surface storage systems, ground water depth, and soil moisture.

iii. Develop drought prevention and preparedness measures that involve water supply augmentation and conservation, expansion of irrigation facilities, and public awareness and education. The use of integrate watershed management plans that encourages reforestation and maintenance of upland forest areas to preserve natural infiltration of rain water necessary to sustain base flow in upland tributaries is essential. Farmers should be encouraged to apportion at least 1% of their land holding for digging farm ponds. This will have a beneficial effect not only on tiding over the periods of drought due to lack of direct water availability but also help in recharging the local ground water table. A definite cropping plan will be designed for late sown crops with short duration varieties.

iv. Emergency response will always be a part of drought management, as it is unlikely that mitigation programs will anticipate, avoid, or reduce all potential impacts. As well, future drought events may exceed the “drought of record” and the capacity of a region to respond. However, it is necessary that there is a shift in public policy from drought relief to drought mitigation measures.

v. Develop community awareness and community leadership. Investments in disaster education, public awareness, and community leadership development must be encouraged. Communities need to be sensitized and to understand the importance of drought preparedness and mitigation.

85. The drought response process has the three stages:

i. **Pre-alert** - The management objective in the pre-alert stage is to prepare for the possibility of a drought. This involves public acceptance of measures to be taken if the drought intensity increases by raising awareness of the possible impacts due to drought. The measures that are taken in the pre-alert situation are generally of indirect nature, are implemented voluntarily, and are usually low-cost. The goal is to prepare for future actions. Responsible government agencies should increase monitoring, activate drought committees, and evaluate potential drought scenarios with special attention to worst case scenarios. With respect to the potentially affected communities, the focus is on communication and awareness. Generally, non-structural measures are taken, aimed to reduce water demand with the purpose of avoiding alert or emergency situations.

ii. **Alert** - The management objective in the alert situation is to overcome the drought by avoiding the emergency situation through the application of water conservation policies and mobilization of additional water supplies. These measures should guarantee water supply at least during the time span necessary to activate and implement emergency measures. The kind of measures that are taken in the alert situation are generally of a direct nature, require compliant by stakeholders, and generally have a low to medium implementation cost, although they may have significant impacts on stakeholders' economies. Most measures are non-structural, and directed to specific water use groups. Demand management measures include partial restrictions for water uses that do not affect drinking water, or water exchange between uses. There may be the potential for conflict as water users' rights and priorities under normal conditions are overruled, since water has to be allocated to higher priority uses.

iii. **Emergency** - The management objective is to mitigate impacts and minimize damage. Measures adopted in the emergency stage are of high economic and social cost, and they should be direct and restrictive. There may be the need for special legal statues for exceptional measures, which are approved as general interest actions under drought emergency conditions. The nature of the exceptional measures could be non-structural, such as water restrictions for all users including urban demand, subsidies, and low interest loans, or structural, such as new infrastructure, permission for new groundwater abstraction points and water transfers.

6.4. Continuous Improvement

86. Capacity building is a long-term phenomenon which has to be at the policy, implementation, Institutional, and individual levels. It also includes development of appropriate tools that will be used to convey useful information pertaining to drought. Capacity development generally encompasses various layers of governance by the national and provincial governments, district administration, and local authorities. Capacity building must address the needs of all the target groups of government functionaries. Components of the multi-layer capacity development framework include training, techno-legal framework, knowledge management, and developing organizational/ institutional and individual capacities.

87. Trained and skilled staff are critical to a drought warning and forecast system as well as the drought hazard assessment activity. Staff must have the correct educational background, be well trained, and motivated to continuous improve their skills and the technical aspects of the drought warning and forecast system.

88. A timely and reliable drought warning and forecast system, dependent upon consistent near real-time reporting of hydrometeorological data is one of the basic conditions for protection against and response to droughts. The basic hydrometeorological data collection system must be well maintained and must provide adequate coverage. The use of satellite and global modelled products, key to the identification of severe and extreme weather conditions as well as to the provision of seasonal outlooks,

is critical to a well-functioning drought warning and forecast system. The forecast system must be effective and this requires regular updates to the modelling platform and the incorporation of new knowledge and science as it becomes available. Easy and transparent access to drought related forecasts and current conditions are critical. The establishment of a web based source, such as a drought management portal, is necessary.

89. Reliable and timely monitoring of hydrometeorological conditions using automatic weather stations is critical to defining and understanding the spatial extent and severity of drought. In addition to the typical suite of sensors the monitoring stations must also include moisture sensors for obtaining information about the soil moisture levels under natural environment. The use of remote sensing applications and modelled products are key to predict the potential and onset of drought conditions. Access to the data and information observed by the monitoring network via a dedicated webpage on drought monitoring and forecast is critical.

90. Long-term comprehensive hydrometeorological datasets of good quality are required to assess climate conditions, trends, and shifts as well as enable drought severity indexes to be developed and used effectively. Continued attention is required to quality control, maintenance, and the analysis of this dataset as well as to improve the tools and models used to predict drought and its severity.

91. Drought assessments must be current and consider vulnerability that reflects a communities' potential for water shortages and the exposure of the communities. Vulnerability maps are an important tool to understanding the impact and spatial extent that a drought will have.

6.5. Public Engagement and Awareness

92. An effective drought management framework requires prevention activities prior to the event, response and mitigation activities during the event, and rehabilitation and recovery activities post event. Each of these key activities requires public engagement and awareness. Prevention activities include structural measures such as dams, water retention ponds, groundwater exploitation, and rainwater harvesting schemes as well as non-structural measures such as drought response policies, watershed improvements, and drought preparedness through planning, education, and awareness. Drought response and mitigation activities encompass seasonal outlooks and the use of drought severity indexes for early warning, and planning emergency relief activities. Post event recovery involves financial support, resettlement, reengineering of drought mitigation works, and review of drought plans and drought management systems and institutional arrangements.

93. Developing a drought communication plan and early warning system to facilitate timely communication of relevant information to officials, decision makers, emergency managers, and the general public is key. It is essential that communities understand their risks, respect the drought warning service, and know how to react. Education and preparedness programs play a key role. It is also essential that drought management plans be in place, well-practiced, and tested. Communities should be well informed on options to mitigate the impact of droughts.

94. Spreading community awareness and developing community leadership for effective drought management is a critical step. Sensitizing communities is an important activity. Communities need to understand the importance of drought preparedness and mitigation. The is to promote an informed, alert, self-confident, and motivated community that will cope with the drought.

7. Ecosystem-based Adaptation for climate resilience in the water sector

7.1. General considerations

95. This guidance on the Ecosystem-based adaptation (EbA) for structural flood and drought control measures focuses on the "….more natural and sustainable complementary or alternative measures such as wetlands and natural buffers", and the "Non-structural measures which are actions taken to mitigate flood and drought loss and damages through better planning and management of watershed development."[1] It provides an adaptive approach to "living with floods" and "living with drought". The flood and drought structural measures such as wetland restoration and water retention ponds, groundwater recharges and watershed protection and rehabilitation measures should be designed using the EbA approach. Non-structural measures such as catchment management to reduce flood and drought susceptibility, restoration of wetlands and introduction of drought tolerant crops and the preservation of the natural capacity of flood plains through floodplain zoning and regulations are all examples of EbA.

96. The EbA measures complement and enhance the performance of conventional structural measures; the ecosystem-based approach is not an alternative but should be an essential part of designing integrated flood and drought management. EbA measures cannot solve all the problems but should be used alongside engineering solutions. This guidance should also fit with the five Best Practice Guidelines prepared by the Mekong River Commission's Flood Management and Mitigation Programme on 1) Flood Risk Assessment, 2) Flood Risk Management, 3) Structural measures and Flood Proofing, 4) Integrated Flood Risk Management for Basin Development Planning, and 5) Integrated Planning and Design of Economically Sound and Environmentally-friendly in the Mekong Floodplain in Cambodia and Vietnam (MRC 2010).

97. **Ecosystem-based adaptation is defined** as *'the use of biodiversity and ecosystem services to help* people *adapt to the adverse effects of climate change. This may include sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities.' (CBD 2010).*[2] [3] In the context of climate resilience for the water sector in Cambodia, EbA is not just about protecting ecosystems, but using ecosystem functions and enhancing ecosystem services for flood and drought management objectives.

7.1.1 Principles of Ecosystem-based Approach

98. The following general principles underpin the Ecosystem-based approach to adaptation[4]

1. **Multisectoral:** EbA requires collaboration and coordination between sectors and stakeholders managing and benefiting from ecosystem services;

[1] Taken from the preceding chapters in the *Climate resilient design guidelines for structural flood and drought control measures*.

[2] Convention on Biological Diversity, 2nd Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change. added at COP-10 of the CBD held in Nagoya, Japan, in 2010

[3] Reid H, Seddon N, Barrow E, Hicks C, Hou-Jones X, Kapos V, Rizvi A R, Roe D, Wicander S (2017) *Ecosystem-based adaptation: question-based guidance for assessing effectiveness*. IIED, London. Published

[4] Angela Andrade et al (2011) *Draft Principles and Guidelines for Integrating Ecosystem-based Approaches to Adaptation in Project and Policy Design.* CATIE, Turialba, Costa Rica.

2. **Landscape-scale approach**: use integrated approaches for natural resource and ecosystem management, e.g. Integrated Water Resources Management (IWRM) and catchment management, including the wider socio-economic aspects
3. **Adaptive management:** EbA requires a flexible approach that can adapt to changes in conditions as they develop. It has been found to be more effective for management to be delegated to the lowest most appropriate level to enable greater efficiency, equity and ownership of the EbA solutions.
4. **Participatory planning for impact and vulnerability assessments:** The identification of EbA solutions through the involvement of local communities facilitates the understanding of unintended negative social and environmental impacts and the trade-offs and benefits Participatory planning helps to build the consensus for the EbA solutions.
5. **Participatory, transparent, accountable, and culturally appropriate, while actively embracing equity and gender issues:** Planning should encourage full participation of stakeholders focusing on equality and the special needs of marginalized social groups. Vulnerability assessment processes and adaptation measures must be gender sensitive.
6. **Best available science and local knowledge:** The best available scientific knowledge and climate modelling should be used in conjunction with local knowledge.
7. **Promoting resilient ecosystems and using nature-based solutions:** Understand what makes ecosystems and the services they provide more resilient. Nature-based solutions are practical measures to increase resilience that enhance ecosystem functions. Working with rural communities and vulnerable people to create local ownership and resilient local institutions.
8. **Working with nature, rather than against it** - Losses in ecosystem services due to climate change and other pressures directly affect human wellbeing and further increase the vulnerability of local communities. Badly planned engineering solutions for adaptation could work against nature by constraining regular ecological cycles, which may lead to mal-adaptation and increased social vulnerability e.g. a poorly designed dam.
9. **Recognising the services provided by ecosystems and their limits.** When incorporating ecosystem-based approaches into the overall flood and drought management plan, planners should recognise that ecosystems provide 'natural resources' and services such as water supply, erosion protection, climate regulation, disaster risk reduction and genetic diversity. But ecosystems have limits and are increasingly under stress from population change and other developments factors, as well as climate change,

7.1.2 Important ecosystems for the water sector in Cambodia

99. An ecosystem is a community of living things forming a system with the non-living features of their environment linked together through food cycles and energy flows. Energy enters the system through photosynthesis allowing the growth of plants. By feeding on plants and on one-another, animals play an important role in the movement of matter and energy through the system. They also influence the quantity of plant and microbial biomass present. By breaking down dead organic matter, decomposers release carbon back to the atmosphere and facilitate nutrient cycling by converting nutrients stored in dead biomass back to a form that can be readily used by plants and other microbes. The balance of biodiversity within an ecosystem characterises the way in which it functions.

100. The functioning of ecosystems is influenced by external factors such as climate, the soil type and topography, and the flows of ground and surface waters. They are also affected by human activities such

as the cutting of vegetation, diversion of water, and discharge of pollutants. Ecosystem services are the different benefits which people derive from the ecosystems, such as food, availability of good quality water and the regulation of water flows.

101. Within Cambodia, the important ecosystems for the water sector are best described within a watershed as shown in Figure 7-1. In the upper part of the watershed are the forest ecosystems which are important for maintaining the stability of the soils, controlling the flows and infiltration of water as well as providing habitat for wildlife. There may be upland villages that use the forest ecosystems and have their own agricultural cropping systems. As the streams merge and form river ecosystems in the mid-elevations, many villages become established along the banks, using the river for water supply, fishing and river transport. As the river emerges onto the flatter, low lying areas, floodplain ecosystems consist of wetland ponds, swamps and marshes in the depressions – the *trapeangs* are good examples of seasonally flooded grasslands within lowland forests, important for wildlife, but also used for animal grazing. They may be surrounded by seasonally flooded forests along the banks of rivers and lakes, such as the Tonle Sap. As the river meets the sea, there are estuary and coastal ecosystems, such as mangroves, mudflats and beaches, which are especially important for coastal protection. Within each of these ecosystem types there may be different habitats, e.g. a wetland habitat within a forest ecosystem, or a forest habitat within an agricultural area.

Figure 7-1: A watershed is the natural boundary of land draining into a common outlet along a river or stream

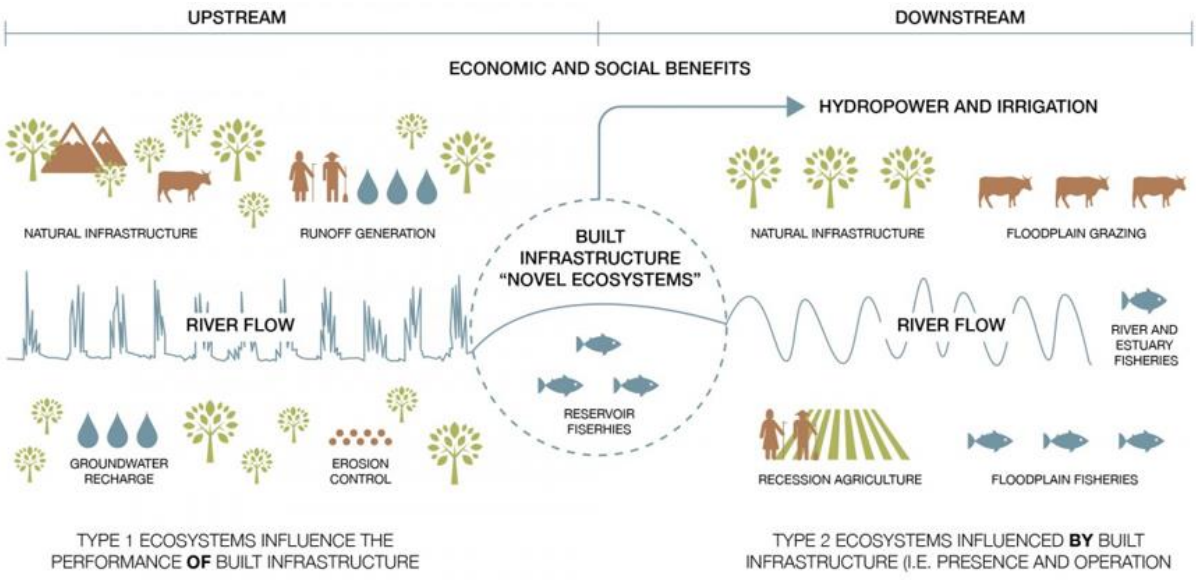
Source: Bach, H et al (2011)

102. Ecosystems are not restricted to purely natural features. The floodplain areas have often been converted to agricultural land, especially for paddy. These have their own agro-ecosystems, which also

have specific ecological character and biodiversity. In towns, there are often rivers, ponds and lakes which will have an urban ecological character and provide very necessary services, such as flood drainage.

103. Ecosystems are increasingly influenced by built infrastructure as shown in Figure 7-2. Irrigation and hydropower schemes change the patterns of river flow and may create novel ecosystems (in the reservoir). Upstream of the built infrastructure, the state of natural ecosystems may influence the performance of the scheme, e.g. by controlling soil erosion and sediment transport, while downstream the natural and agroecosystems are influenced by the presence and operation of the scheme.

Figure 7-2: Ecosystem services influenced by built infrastructure



Source: McCartney and Sood (2016)

7.1.3 Values of ecosystem services

104. Maintaining or enhancing the value of ecosystem services is an important part of EbA. Ecosystem costs and benefits should be built into economic and financial justifications to demonstrate the viability of a flood and drought management project, although the cost-benefit analysis of ecosystem services may be challenging, since many services do not have a market value. If they can be incorporated into the cost-benefit analysis, the economic values and benefits of ecosystem services will be more convincing for decision makers. This guide suggests some tools for such cost-benefit analysis.

Table 7-1: Classification of ecosystem services

Ecosystem Services			
Provisioning	**Regulating**	**Supporting**	**Cultural**
Food – Capture fisheries, wild foods, livestock, forest products, crops	Climate regulation (global, regional, local)	Nutrient cycling	Spiritual & religious values
Fresh water	Air quality regulation	Soil formation	Aesthetic values
Wood (for timber and fuel) and fibre	Water regulation, (surface and ground water flows)	Primary production (Photosynthesis)	Recreation & ecotourism
Genetic resources	Erosion regulation		

Biochemicals, natural medicines & pharmaceuticals	Water purification and waste treatment		
	Disease regulation		
	Pest regulation		
	Pollination		
	Natural hazard regulation (floods and droughts)		

Source: Adapted from Millennium Ecosystem Assessment (2005)

105. While many of the above ecosystem services are related water, the most important ecosystem services for water management are:

- **Fresh water provisioning** – ensuring that fresh water is available from ground and surface waters for drinking, washing, bathing, livestock, irrigation and urban and industrial water supply
- **Food provisioning** – the natural resources in rivers and streams, lakes, ponds and wetlands include fish and other aquatic animals and plants. Rice fields are a modified natural wetland ecosystem, providing the main paddy crop, but also fish, frogs, snails etc.
- **Wood and fibre provisioning** – wetland ecosystems, such as flooded forests, reed beds, marshes etc. provide timber, fuel wood, fibres for weaving and packaging materials
- **Climate regulation** (global, regional, local) – wetlands are a recognised sink for atmospheric carbon, management of wetlands to enhance carbon sequestration contributes to global climate change efforts to reduce green-house gases. On the other hand, the draining of wetlands can lead to the release of stored carbon into the atmosphere. At a local level, wetlands and forests in the watersheds can moderate temperatures and influence local rainfall patterns.
- **Water regulation** - the flows of ground and surface waters are regulated in river basins and depend upon many factors such as the topography, soils, vegetation cover as well as the rainfall and its seasonality. Ecosystems regulate the surface run-off, ground water flow and recharge, and can moderate extreme flows – floods and drought.
- **Erosion regulation –** Forest cover on the hillsides protects the soil from erosion caused by heavy rainfall and run-off. Excessive erosion in the watershed can lead to land degradation, landslides and increased sediment in the rivers. Too much sediment in the rivers and irrigation canals can lead to serious problems for navigation and clogging, increasing maintenance costs. Sediment may be trapped in water storage reservoirs for hydropower and irrigation and limit the capacity and life of these systems, while the shortage of sediment downstream of such structures can lead to increased bed and bank erosion in the rivers. Natural flows of sediment down rivers are critical for maintaining coastlines and deltas and make a valuable contribution to soil fertility and sand for construction.
- **Water purification and waste treatment** – rivers, lakes and ponds and wetlands have a natural capacity to purify water making it more suitable for drinking, and for the treatment of liquid wastes from human settlements, sewage and industrial discharges. All too often this natural capacity becomes polluted beyond the limits, and the aquatic habitats degrade quickly. Constructed wetlands have been developed to manage and enhance this ecosystem service. The capacity limits for water purification and waste treatment of any body of water must be recognised.
- **Natural hazard regulation** – Extreme events such as very high and intense rainfall or long periods of very low rainfall causing flash floods and droughts can be moderated by the

ecosystems in the watershed and floodplains. Sea level rise and storm surges are moderated by fringing mangroves along the coast and estuaries, by dunes, reefs and saltmarshes, which can all provide protection.

7.1.4 Examples of ecosystem-based solutions

106. The EbA approach identifies appropriate ecosystem functions and services within an area and tries to manage and enhance these the way in which the ecosystem works to provide required services. By managing the ecosystems in an area for water regulation and floods and droughts, other services such as erosion regulation and the provision of water and food will also bring benefits to local communities and downstream urban populations.

107. Some examples of ecosystem-based solutions include[5]:

- Wetland restoration and protection for water purification and carbon sequestration and climate mitigation and moderation.
- Wetland and floodplain management to prevent floods and maintain water flow and water quality in the face of changing rainfall regimes
- Floodplains also provide space for dispersion of flood waters. Retaining floodwater access to floodplains facilitates better flood reduction.
- Watershed management, including re-afforestation and check dams for reducing soil erosion and increasing ground water recharge
- Conservation and restoration of forests and other natural vegetation to stabilise slopes, prevent landslides and regulate water flows preventing flash flooding
- Planning and management of river basins – One of the underlying principles of Integrated Water Resources Management (IWRM) is to use evidence-based science/information to analyse water resources at a basin scale. The ecosystem approach provides one framework for such analysis and for developing appropriate solutions.
- Ensuring river bank vegetation and green engineering solutions for river bank protection
- Restoring coastal ecosystems such as coral reefs, mangrove forests, dune systems and salt marshes, in order to dissipate the energy of powerful tropical storms

[5] Specific examples of EbA are provided in the SPCR working paper on Ecosystem-based Adaptation for Climate Resilience in the Water Sector, ADB TA 8179

Figure 7-4: Flow directions in the rehabilitated Angkorian water management system

An example from Cambodia's past

Ecosystem-based solutions for water management are not new to Cambodia. The strength of the Khmer civilisation at Angkor was underpinned by its water management systems drawing upon the "water tower" in Phnom Kulen, providing for water storage and supply, irrigation for rice cultivation, diverting flood waters, and maintaining stable foundations for its temples and monuments built on the alluvial flood plain around the Tonle Sap. The move away from Angkor is partly attributed to the failure of the system in the light of climate changing in the mid-14th century bringing a long period of very dry years.

Prompted by the floods in 2009 and 2011, and concerned by the falling ground water levels due to abstraction for water supply to the growing population and large hotels in Siem Reap city, the APSARA Authority, rehabilitated parts of the historic water management system, including the diversion of water to the ancient barays (reservoirs) to increase ground water recharge and maintain the foundations of the Angkor temples. Further adaptations may include the rehabilitation of the East Baray, to further enhance groundwater recharge, or pump and treat water from the Tonle Sap, both very expensive options.

In the face of climate change with more variable rainfall, ecosystem-based adaptation may consider enhanced watershed management, restoring the forest cover in the Phnom Kulen National Park, which has suffered agricultural encroachment and forest degradation.

Figure 7-3: Flow directions in the rehabilitated Angkorian water management system

Source: Adapted from Dr Hang Peou, APSARA

7.2. Policies and Strategies

108. With regard to water resource management, Cambodia has adopted several laws providing the legal framework for water resources management, including the Law on Water Resources Management, Land Law, Forestry Law, Law on Environmental Protection and Natural Resource Management, etc. All of these have specific provisions related to management of water resources. Since 2003, the water vision for Cambodia has been developed by inter-governmental agencies, reportedly led by Ministry of Water Resources and Meteorology (MOWRAM). A Vision for Water in Cambodia includes the following objectives:

- Access for all to safe, adequate and affordable drinking water, hygiene and sanitation.
- Freedom for all from the threat of loss of life and livelihood as a result of floods and droughts.
- Sufficient water where it is needed, to provide for food security, people's livelihoods, and economic activity.
- A water environment that is unpolluted and supports healthy fisheries and aquatic ecosystems.

109. The Law on Water Resources Management was passed on 29 June 2007, which clearly defined the principles, framework, mechanism, governance and objectives for effective water resource management in the Kingdom of Cambodia. This Law determines 1) the rights and obligations of water users, 2) the fundamental principles of water resources management, and 3) the participation of users and their associations in the sustainable development of water resources. The law has given full authority to MOWRAM to manage, lead and supervise the implementation of the present law, and develop the policy on the water resources management, conservation and development taking into account the specific requirements and demand of each zone/region in the Kingdom of Cambodia.

110. The law also indicates the management framework by adopting the integrated water resources management (IWRM) which takes into account: 1) all aspects of water resources; 2) linkages between water resources and other components of the natural environment; and 3) requirement for an effective and sustainable water use for human being, environment and other sectors. This shows the need of EbA approach for the management, conservation and development water sector

111. In recent years, the EbA approach has been recognised for a number of years in the policies and strategies of the Royal Government of Cambodia. The Strategy for Agriculture and Water 2006 – 2010 developed by the Technical Working Group on Agriculture and Water, for MOWRAM and MAFF, states:

112. "*Essential aspects of the step to mobilise natural resources are to ensure that critical ecosystems and biological diversity are conserved, rivers and lakes are protected from contamination by agri-chemicals and other pollutants, watersheds are protected against erosion and other forms of degradation, and appropriate steps are being taken to respond to climate change and variability. Natural resources must be used sustainably, and also must be made available on an equitable basis, particularly to poor and female-headed households.*" [6]

and

***"Apply river basin approach to land and water** - Water, land and soil resources must be managed within a framework that enables stakeholders to influence management of the resources on which they depend. …….. River basins are widely viewed as the best unit within which to manage water, as an element of the Integrated Water Resources Management (IWRM) concept."*

113. As for the River Basin Management sub-decree adopted on 24 July 2015[7], that is to regulate the management, conservation and development of the river basins in an effective and sustainable manner as stated in the Law on Water Resources Management in the Kingdom of Cambodia. It adopts the key

[6] Agriculture and Water Strategy 2006-2010.

[7] Other relevant Sub-decrees includes :Farmer Water User Groups, its establishment and dissolution (2015), SD on Water licensing (draft), SD on Water Quality (draft) and the National Water Resources Policy for the Kingdom of Cambodia (2004)

principle for river basin management and also strongly indicates the need of EbA approach under the framework of Water Law. These key principles include:

- managing water sources to serve the use, conservation and development of water resources in the river basin;
- managing, conserving and developing water resources based on integrated water resources management (IWRM) concepts and approaches in accordance with the Law on Water Resources Management, and enhanced resilience to climate change;
- managing water resources in the river basin in a unified manner across administrative boundaries, recognizing upstream and downstream linkages, and based on equity and harmony;
- ensuring minimum flows on watercourses to support water related ecological systems and ensure community values;
- managing water resources in international river basin, based on international agreements, ensuring territorial sovereignty and national mutual interest;
- developing and use water resources in harmony with other natural resources available in the basin;
- allocating the use of water in an effective and equitable manner;
- promoting people's livelihood ensuring their access to water, both quantity and quality;
- encouraging the conservation and development of water resources in the river basin; and
- cooperating with neighbouring countries in the of water for all fields.

114. The Climate Change Action Plan (CCAP) for water resources aims to:[8]

"Strengthen an integrated approach to water resources and agriculture development and management, that considers all sources of water, links between water resources and agriculture, and other aspects such as land management, natural environment, the varying human and ecological demands on water resources, and the need for many different disciplines to carry out effective management;"

and

"Water ecosystems, such as wetland and marine water, are considered areas for carbon sequestration and carbon stock. When water areas, such as wetlands, change for other development purposes, for example, agriculture activities, carbon stock areas will be lost. In this regard, the climate change mitigation strategy in water resources management should be to reduce the change of land use as much as possible."

115. In the 2010 Agriculture and Water Strategy, the TWGAW identified as an objective that *Water* resources *are being developed and used in a way that considers river basins as the fundamental physical unit for management, minimizes degradation of aquatic resources and organize and regulate competition among users, and where appropriate uses of the concepts of IWRM and RBM.*

116. Its outputs on Water Resource Management and Agricultural Land Management included:

- Provincial and local authorities, farmers and other stakeholders are involved in IWRM and irrigation infrastructure planning and implementation

[8] MOWRAM, CCAP 2013 – 2017

- 100,000 hectares of wetland and dryland irrigation (25,000 ha per year) is constructed and sustainable water management, harvesting and use practices are adopted by beneficiary farmers.
- MOWRAM and MAFF develop and implement drought and flood mitigation measures

117. The development of integrated water management is described as a comprehensive approach to the management of water resources, and in establishing the framework for provision of water services. The objective of IWRM is to ensure wise water governance which contributes to the economic development, social equity and environmental sustainability of the society.

118. The IWRM tasks focus on delineating and classifying river basins and developing a water management framework plan for the Tonle Sap basin within the hydrological network. River basin management is to be achieved through the creation of basin committees with representatives of government, stakeholders and beneficiaries. Environmental, social and economic aspects will inform basin models and proposals for development with conservation considerations.

7.2 Institutional context for ecosystem-based adaptation

119. Recognising that Ecosystem-based Adaptation involves the collaboration and coordination of multiple sectors, it is the Ministry of Water Resources and Meteorology (MOWRAM) that has the prime responsibility for implementing EbA in relation to water resources and flood and drought management. Its mandate includes[9]:

- studying and researching potential water resources in terms of surface, underground and atmosphere in order to establish the basic scientific techniques;
- developing the short, medium and long-term plans for exploration, development and conservation of water resources and atmosphere in order to conserve the national economy and living standard of Cambodia;
- managing all direct and indirect utilisation of water resources and minimising the disasters;
- developing legislations related to water resources management, and their application;
- providing necessary technical support and advice to private sectors, organisations, communities, and all people who are related to the improvement and exploitation of water resources.

120. All the MOWRAM departments should have a responsibility for EbA, but there are three important departments directly involved - Department of Water Resources Management and Conservation, Department of Hydrology and River Works and Department of Meteorology. River Basin Organisations (e.g. for Stung Sreng, Stung Sen, Pursat, Battambang) are also established under MOWRAM.

121. The Department of Water Resources Management and Conservation has the following functions and duties:

- developing and carrying out the strategic plans for various development activities, e.g., hydropower, flood control, irrigation, except the projects which are serving an electric power production which is the first priority for the government;

[9] Sub-decree on Organization and Function of MOWRAM, dated 30 June 1999.
Law on water resource management of the Kingdom of Cambodia, promulgated 29 June 2007

- managing watershed areas and develop relevant programmes for ensuring the utilisation and conservation of water resources in a very effective and sustainable manner;
- developing necessary policies, legislations, and regulations in order to serve water resources conservation for the policy-makers

122. Within the Department of Water Resources Management and Conservation, there are two very relevant offices – Hydropower and Flood Control Office and Watershed Management Office.

123. The Department of Hydrology and River Works has the following functions and duties:

- developing necessary projects and hydrological stations at designated water areas in order to serve the water resources development;
- developing the short, medium, and long-term plans for erosion, sedimentation, and river bank protection and management;
- observing the hydrological regime both surface and ground water by establishment of hydrological stations, as well as collecting and analysing data for the related sectors;
- measuring and evaluating the water level, discharge, sedimentation and other related tasks;
- monitoring water quality at the hydrological stations at the designated water areas, which have been installed along the Mekong River, Tonle Sap Great Lake and their tributaries;
- researching and studying the hydrological phenomena, hydrological modelling, hydrological calculation, and surface and ground water potential;
- managing the hydrological information, forecasting, and providing information in advance of floods and water shortages.

124. The Department of Meteorology has the following functions and duties:

- preparing short, medium and long term plans for restoration and developing the meteorology at national scale;
- installing and managing the meteorological stations for the whole country;
- observing and monitoring the climate parameters at all scale, including land surface and spatial, for uses of all relevant sectors;
- collecting and exchanging the national and international meteorological data for analysis to create the basic document;
- carrying out short and long term forecasting of needs of relevant agencies, and early warning of natural disaster, which may eventually happen, for necessary prevention;
- Exchanging and searching the modern technologies of meteorology at national and international levels;
- preparing annual reports on the meteorological situations in the Kingdom of Cambodia and other reports necessary for royal government to implement the functions and duties related to international agreements and conventions;
- managing and coordinating cooperation related to meteorological sectors of Cambodia with the UN agencies and meteorological organizations of the countries permanently representing the World Meteorological Organization to Cambodia.

125. Other sector agencies and relevant departments which could be involved in EbA initiatives include:

- Ministry of Environment
- National Council for Sustainable Development (NCSD)
  - Department of Climate Change,
  - Department of Biodiversity
- Ministry of Agriculture, Forests and Fisheries
- Ministry of Rural Development
- Ministry of Public Works and Transport
- Ministry of Mines and Energy
- Ministry of Women's' Affairs
- Tonle Sap Authority
- Cambodia National Mekong Committee – for issues related to transboundary Mekong river basin

7.3. Entry points for MOWRAM's application of ecosystem-based adaptation

126. The entry points for application of ecosystem-based adaptation into MOWRAM's work can be identified from the priorities listed in the Climate Change Action Plan for Water Resources and Meteorology. There are four main areas with relevant action points:

1. **Hydro-meteorology:** Improving the climate information system, including the gauging stations to monitor temperature, rainfall, wind speed, river flows and levels, sea level rise and storm surge etc. This is essential to understand the hydrological functioning of ecosystems.
2. **Irrigation related works: 1)** Climate risk management and rehabilitation of small, medium and large irrigation infrastructure; 2) Promoting innovative irrigation technology in areas affected by torrential rain such as in Mondulkiri, Pursat and Koh Kong. These actions should be undertaken with an understanding of the local ecosystems, and how they can be used to increase resilience.
3. **Flood and drought:** Development and rehabilitation of flood protection dikes for agricultural and urban development. The inclusion of ecosystem-based adaptations together with conventional infrastructure should be an essential component of flood and drought protection measures.
4. **Sea level rise and Saline intrusion: 1**) Promoting climate resilience in agriculture through building sea dikes in coastal areas, 2) Assessment of potential impact of sea level rise and saline intrusion. The combination of building sea dikes with ecosystem-based adaptation in agriculture, e.g. through choice of crops and agronomic techniques, and use of natural coastal protection systems should be planned.

127. Other factors that may contribute to increasing vulnerability include land-use change, including loss of forest cover, infrastructure developments with impacts upon hydrology and hydraulics of the river systems, and other natural resource use developments. These should be considered when designing ecosystem-based adaptation for a particular area.

128. The process of designing ecosystem-based adaptation will vary depending on the starting point or objective of what the agency wants to do:

1. **Retrofitting EbA to an existing system** - design of EbA measures to existing infrastructure and facilities, e.g. an irrigation scheme, to make them more resilient. The starting point would be an analysis of the vulnerability of this infrastructure to climate changes and extreme events, together

with an analysis of the ecosystem assets that support the infrastructure, their status and vulnerability.

2. **Designing a new project for using and managing the water resources** such as a flood prevention scheme or drought risk reduction. This would integrate a mix of complementary EbA measures with hard infrastructure within the project design. The starting point would be a clear identification of the project objective and developing an understanding of how the ecosystem assets in the area (both upstream and downstream) can be used or managed to contribute to this objective.
3. M**anaging and enhancing the sustainability of the water resources in the river basin and its watersheds**. Develop a river basin (or watershed) profile including the description of the key ecosystem assets, the functions and services they provide, and the challenges they face both from climate change and other development pressures. The river basin plan would include the existing and future uses for water and the overall hydrological balances. Measures to enhance the ecosystem functions and services of these assets should be identified first and implemented before hard infrastructure solutions are put in place.

7.4. Ecosystem-based adaptation design process

129. The EbA design process is likely to include the following phases and steps[10]

130. ***Phase 1: Understand and analyse the linkages among ecosystems, livelihoods and climate change in the context of water management for flood and drought control***

1. **Geographical scaling**: The first step for building EbA measures defines the geographic boundaries of the areas. Sub-regions are identified within each project area and major hydro system features as well as economic activities are mapped out.
   a. Identifying ecosystem assets both in the watershed and floodplain
   b. Describing the status of the ecosystem assets
   c. Mapping the ecosystem functions and services especially the links to water resources, floods and drought

   Note that EbA can be applied at various scales from a whole catchment to smaller river reaches or habitats, depending upon the scale of the project.

2. **Scoping**: Scoping addresses the major concerns and issues by assessing their environmental and socioeconomic impacts. This should include the cumulative impacts (both positive and negative) of water resource developments in the area.
3. **Identifying the causes of threat to the ecosystems and habitats**: This analysis traces the major concerns and issues to their root causes, immediate causes and environmental or socio-economic impacts. It may use problem-tree or causal chain analysis and helps in the selection of solutions.
4. **Data collection, analysis**: Data collection and analysis is a critical step that collects and organizes all data from available sources and prepares it for analysis and then conducts the analysis. This is likely to include surveys and consultation with local communities and ecosystem users

[10]This has been adapted from the IISD ALivE tool and the EbA road map used by ECOSWAT and the IISD "ALivE", a computer-based tool designed to support its users in organising and analysing information to plan effective EbA options within a broader EbA planning process. ALivE stands for Adaptation, Livelihoods and Ecosystems developed in 2017. https://www.iisd.org/project/ALivE

5. **Understanding the system:** A series of tools may be used to understand how the system works and is likely to respond to climate change and other pressures
   a. **Considering climate change consequences:** To address climate change impacts, future climate information for the basins needs to be obtained. According to the geographic boundaries, the global climate change information should be downscaled and the effects on the chosen regions would then have to be modelled. The Climate Change Toolbox for Decision Support developed through the ADB Strategic Program for Climate Resilience in Cambodia (SPCR), provides downscaled information on climate change projections throughout Cambodia.[11]
   b. **Considering other changes and developments in the area.** Land-use change and other developments, especially if they change water resource use, should also be considered as part of the pressures on the ecosystems. Techniques such as cumulative impact assessment may be used to understand how the system is likely to respond to these pressures.
   c. **Modelling:** Water resources modelling, or hydro-system modelling should be state of the art in order to adequately address behaviour and mutual dependencies of water resources components. The results of water resources modelling allow the project proponent to derive effects on other sectors, both upstream and downstream, and to verify assessments and observations made earlier. Studies such as the MRC's BDP 1 and 2[12], the Council study[13] and the Regional Flood Management and Mitigation Centre[14] may be used to complement modelling exercises.
   d. **Socio-economic assessment** of the use of the ecosystems, services and benefits
   e. **Verification of cause-effect relations:** Verification substantiates the causal-chains. Whenever possible, this should be backed with data, calculations or any other proven indicators.

131. ***Phase 2: Identify and prioritise EbA options for community and ecosystem resilience.***

6. **Selection of EbA Measures to adapt to vulnerabilities**: Technically feasible measurements are prioritized economically. Design and enhancing the ecosystem asset to meet flood and drought management objectives. The first measures are likely to be those that address the issues and opportunities for water regulation services. The assessment of cumulative impacts of water resource developments will contribute towards the identification of mitigation and resilience measures.
7. **Identification and valuation of other ecosystem services** and benefits that will be enhanced (or lost) by the EbA measures adopted, followed by cost-benefit analysis of the proposed interventions.
8. **Public hearings and stakeholder participation** throughout the design process to ensure appropriate measures are selected and gain acceptance from local communities.

132. ***Phase 3: Design project activities that facilitate implementation of priority EbA options***.

133. This is the detailed design process which will involve specifying the engineering and habitat design, rehabilitation and management measures.

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[11] : http://dss.icem.com.au/CambodiaDSS/

[12] MRC's Basin Development Plan documents summarised in the Basin Development Strategy 2016 – 2020. http://www.mrcmekong.org/assets/Publications/strategies-workprog/MRC-BDP-strategy-complete-final-02.16.pdf

[13] The Council study documents may be found on the MRC website: http://www.mrcmekong.org/assets/Publications/the-CS-reports-cover.pdf

[14] Annual reports of Regional Flood Management and Mitigation Centre (RFMMC) of the Mekong River Commission, for example http://www.mrcmekong.org/assets/Publications/Annual-Mekong-Flood-Report-2014.pdf

134. ***Phase 4: Identify key elements and indicators for a monitoring and evaluation (M&E) framework***.

135. In this step the monitoring indicators are identified to show how effectively the Ecosystem based adaptation measures are working and when they may need to be changed to suit changing conditions. The M&E framework should include indicators of the overall objective of the scheme or project, e.g. flood protection for a particular area, and then consider the contributions to that objective made by the different components of the scheme – both the built and natural infrastructure. Indicators may be selected from the MRC's Indicator Framework, and the indicators of ecosystem integrity developed for the Council Study.

136. Indicators of effectiveness of the natural infrastructure should include the functions and services that are maintained or enhanced by the scheme:

- Changes in the condition or status of the natural infrastructure, e.g. the wetlands used for flood diversion
- Performance of the natural infrastructure at times of extreme events, e.g. how did the wetland perform in diverting floods, or maintaining water in times of drought
- Changes in the values of ecosystem services provided, e.g. the fish production from the wetland
- Changes in uses and threats to the ecosystem from user communities, e.g. agricultural encroachment on wetlands
- Annual maintenance requirements and losses after extreme events

137. All of these need to be compared with main climate variables – temperature, rainfall and evaporation and occurrence of extreme events such as storms, floods and drought. The climate stresses in a particular year should be used to assess the effectiveness of the ecosystem-based adaptation. In a normal year, effectiveness is best assessed by comparing the condition and services provided. In an extreme climate year, effectiveness is best assessed by comparing damages both in the surrounding area and to the ecosystem component itself, to damages in previous years without the scheme and its enhanced natural infrastructure.

7.5. The Adaptive Watershed

138. The Adaptive Watershed (TAW) is watershed-based ecosystem management that explicitly addresses the need to understand and manage for a rapidly changing climate, while also incorporating the needs of vulnerable communities and women. The steps in the process have been outlined from the TAW training programme developed by IISD.[15] This highlights the need for understanding both the processes, functions and benefits from natural ecological units as well as the natural, hydrologic units appropriate for assessing, predicting and managing water for enhanced water quality, sufficient quantity and availability, improved access etc. The flow chart of the Adaptive Watershed is shown in Table 7-2.

Table 7-2: The Adaptive Watershed flow chart

Step	Theme	Tasks

[15] https://www.iisd.org/library/adaptive-watershed-training-program-inclusive-ecosystem-based-watershed-management

Step 1	Understanding the watershed and its communities	• Map the watershed and its socio-economic context – – Significant land uses, – Water infrastructure – Habitats and ecosystem functions and services, especially hydrological and hydraulic functions • Identify communities, stakeholders and vulnerable groups, and their livelihoods
Step 2	Engaging with stakeholders	• Throughout the design and watershed management process, engage with communities and other stakeholders, and sectors
Step 3	Analyse risks to ecosystems and communities	• Climate change projections and impacts in the watershed • Non-climate stressors and their impacts on the watershed
Step 4	Identify and prioritise adaptation options	• Explore possible adaptation options – both built and natural infrastructure • Determine ecosystem management options and the data required • Enhance other ecosystem services and benefits • Cost-benefit analysis of ecosystem services and benefits
Step 5	Detailed design of ecosystem-based adaptation measures in the watershed	• Design of watershed management measures • Design of M & E system for monitoring effectiveness of watershed management
Step 6	Implementation of the adaptive watershed management	• Putting in place the measures for both built and natural infrastructure • Soft ecosystem-based watershed management measures

7.6. Ecosystem-based adaptation structures for increased water resilience

139. Ecosystem based adaptation measures include both built and natural infrastructure[16], or a combination of both. The following table (Table 7-3) describes how these structural adaptation measures can be applied, and the ecosystem services they maintain or enhance, and the resilience offered. Many of the green infrastructure measures are described in greater detail in the Water Resources Adaptation Guide prepared by the ADB Strategic Program on Climate Resilience (SPCR).[17]

Table 7-3: Ecosystem adaptation measures for built and natural infrastructure

Structural EbA measure	Ecosystem service enhanced	How EbA is applied?	Limitations
Wetland restoration	• Carbon sequestration • Local climate moderation • Water storage • Water purification • Biodiversity source • Breeding habitat for fish and wildlife	• Ensuring adequate water availability for the wetland, • Protection of wetland from encroachment and drainage, and extraction of water • Protection from discharges of polluted water • Limiting livestock access to the wetland • Creating a vegetated buffer around the wetland • Control/management of harvesting, fishing and hunting activities	Wetlands need the appropriate amount of water according to size and type of wetland. Water requirements and capacity should be modelled. Limited capacity to absorb pollutants
Constructed wetlands	• Water purification and waste water treatment • Water quality	• Bioretention pond, greywater recycling, • Depending upon the type, ability to reduce BOD, TSS and nitrate etc. • Horizontal or vertical flow designs	Definite capacities for treating water pollutants – do not overload Requires regular maintenance to ensure flows through the system
Water storage in natural lakes, ponds	• Water supply • Drought water security • Fisheries • Biodiversity	• Rainwater harvesting over land directed to natural lakes and ponds • Construction of weirs to maintain water levels	Define clear low water limits and water extraction, do not drain completely. Safety precautions for humans and livestock

[16] Natural infrastructure is defined as a "strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserves or enhances ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon 2006).
[17] NCSD/MOE. 2017. *Water Resources Adaptation Guide*, Working paper prepared by TA 8179-CAM: Mainstreaming Climate Resilience into Development Planning Phnom Penh, Cambodia.

Structural EbA measure	Ecosystem service enhanced	How EbA is applied?	Limitations
		• Protection and strengthening of banks, with vegetated buffer zone around • Protection against livestock and water pollution	
Natural depressions	• Flood water diversion and retention • Groundwater recharge • Drought water security • Biodiversity • Fish and rice production	• Clear identification of such areas for flood management, discussions with local farmers on functions • Preparation of flood water diversion channels/ditches/trenches • Do not build in these depressions • Maintain collected water for dry season and drought water security • Dig fish refuge pits in rice fields	May be used for agriculture, but recognise that flooding may occur in some years and so suitable crops must be planted, and may be lost in case of flood event Prevent housebuilding in natural depressions
Natural high ground in floodplain	• Extreme flood refuges for humans and livestock	• Protect and enhance natural high ground as flood refuge	Designate such areas and train communities in their use
Sediment pond	• Water supply safety • Water quality	• Divert sediment laden run-off through sediment pond, especially useful for treating water from construction sites • Specifically designed for sediment deposition – strengthened banks and shape/profile • Remove/dredge accumulated sediment periodically	Do not overload with high water flow rates Sediment may require removal by digging out or dredging, when levels become too high
Bioengineering structures: River & canal banks, storage lakes and ponds, reservoirs etc Riparian zone strengthening	• Prevention of erosion, • Loss of structural integrity and collapse	• Biological geotextiles, bush mattress, live crib wall, live fascine, live staking, log terracing, palisade, • Vetiver grass coverage • Vegetated gabion, vegetated geotextile, vegetated revetment, vegetated rip rap • Planting of trees in the riparian zone	All methods can be used in conjunction with hard structures Live and vegetated structures are long lasting, but structures using dead vegetation will have a shorter life before they degrade. Select appropriate tree species to protect riparian zone

Structural EbA measure	**Ecosystem service enhanced**	**How EbA is applied?**	**Limitations**
River bank protection River bed enhancement River channel modification •	• Flood control and prevention of bank erosion and loss of land • Bank erosion prevention • Maintenance of water quality • Improvement of self-cleaning function of rivers • Improvement of river habitats for biodiversity • Increase in fish and other aquatic animals	• Rehabilitation of vegetation on river banks & green engineering solutions, enrichment of bank vegetation • Stabilise river banks • Reduction of sediment load • Urban river terracing • Restores degraded hyporheic zone[18] • Installation of fish passes around weirs and barriers	Relatively small and locally specific structures Extensive watershed management may require many of these structures to complement other reforestation and upland agricultural practices Fish passes require diversion of minimum flow of water and are effective up to 8m of head

Watershed land management	• Erosion control, Soil and land erosion,
	• Run-off and flood peak and intensity reduction
	• Reduction of flow velocity
	• Sediment retention and removal
	• Water supply safety
	• Increase of groundwater recharge
	• Increasing biodiversity
		• Improved agricultural practices retaining soil moisture and nutrients
		  ○ Minimum tillage and mulching
		  ○ Choice of appropriate crops
		• Improved upland cropping and agronomic techniques, strip cropping, pasture cropping, grassland farming, woodlands and agroforestry
		• Protective agroforestry techniques
			Will require complementary actions with MAFF
			
			Agricultural extension required to change cropping and agronomic practices

Lowland and floodplain rehabilitation, Maintenance of integrity of lowland waterbodies and wetlands to improve structure and function	• Erosion control, Soil and land erosion, River bank erosion • Flood management through diversion to wetlands • Ground water recharge • Water supply safety • Water quality improvement • Improving habitats for biodiversity	• Revegetation and protection of river banks, seasonally flooded areas • Drainage corridor, planting pit, storm water tree pits • Ensuring that built structures, e.g. roads and canals do not stop surface flows of water during floods – build correct sized culverts • Protection of natural wetlands from encroachment • Designation of natural groundwater recharge areas	Ecological functioning of floodplains and wetlands is often threatened by built structures such as roads and canals. Wetlands require appropriate hydrological balance (i.e. not too little water) to remain functioning.

[18] Hyporheic zone - is a region beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water. The flow dynamics and behaviour in this zone is recognized to be important for surface water/groundwater interactions, as well as fish spawning, among other processes. As an innovative urban water management practice, the hyporheic zone can be designed by engineers and actively managed for improvements in both water quality and riparian habitat.

Structural EbA measure	Ecosystem service enhanced	How EbA is applied?	Limitations
	• Provision of fish and other aquatic animals		Access for fishing may require regulation to prevent overexploitation.
Natural Floodplain diversion	• Flood control and management	• Designate areas of "sacrifice" land or wetlands to receive high flood waters and slow down the extent and rate of flooding	Sacrifice land may be used for agriculture, but recognise that flooding may occur in some years and so suitable crops must be planted, and may be lost in case of flood event
Infiltration structures	• Ground water recharge • Increase infiltration and groundwater recharge	• Field trenches, Injection well, • Rain garden, recharge pit, soak pit • Permeable paving	Mostly relatively small scale but can be extensively sited throughout area. Permeable paving suited to urban areas
Conservation & restoration of forests and other natural vegetation Afforestation	• Carbon sequestration • Local climate moderation • Run-off and flood peak and intensity reduction • Erosion control, Soil and land erosion, • Stabilisation of hillslopes and reduction of soil erosion • Increase of groundwater recharge • Water supply safety • Enhancing habitats and biodiversity • Increased availability of timber & Non-Timber Forest products (NTFPs)	• Forest rehabilitation, replanting, assisted natural regeneration • Rehabilitation of natural forests to increase wildlife and NTFPs • Slope stabilisation to prevent landslides and regulate water flows • Structures to prevent flash flooding and landslides	Will require collaboration between MoE. MAFF and MOWRAM for forest rehabilitation in any Protected Areas in the watershed. Will require continued efforts to control illegal timber and wood cutting, and wildlife hunting
Mangrove forest planting	• Protection of coastal areas against high winds and storm surge • Shoreline protection of against erosion of cliffs, beaches and mudflats • Increasing biodiversity • Increased availability of mangrove wood, fish, crustacea and shellfish	• Replanting of mangrove forests – often with community engagement	Careful site selection for mangrove replanting to ensure full survival Maintenance of key processes, such as sediment supply

Structural EbA measure	Ecosystem service enhanced	How EbA is applied?	Limitations
Restoring coastal ecosystems	• Protection against tropical storms and storm surge, • Reduction of risks of soil salinisation • Enhanced habitat for biodiversity	• Protection and rehabilitation of coral reefs, mangrove forests, dune systems and salt marshes	Careful site selection and ecological restoration measures in these sensitive ecosystems

7.7. Non-structural ecosystem-based adaptation

140. Non-structural EbA measures include the institutional mechanisms, planning and design tools, awareness and capacity building aspects and regulatory tools required for both designing and managing the ecosystem assets and their functioning. These should be included and described in any EbA initiative.

141. At the landscape level these include EbA measures focused on water resources:

- **Planning and management of river basins** – Integrated Water Resources Management (IWRM) uses ecosystem approaches as a framework for analysing water resources in the basin, and for developing appropriate solutions.
- **Watershed management** – protecting the water, land and soil resources in the catchments that provide the resources for irrigation, hydropower and water supply.
- **Water resources management –** Water balance and allocation for different ecosystem functions and services as well as uses for irrigation and water supply. Ensuring that different ecosystems continue to receive the water they need and when they need it, so that they can continue to function.
- **Planning for extremes of flood and drought** – assessing the implications of climate change projections for extreme events, especially flash flooding and triggers for different drought events – very low wet season rainfall, late start to the monsoon, gaps in rainfall during the wet season.

142. Some of the processes and tools that may be used

- **Participatory planning** – this an essential component of any EbA initiative. It should be designed to involve the local communities and other stakeholders to develop an adaptation system that draws upon local knowledge, e.g. where the flood levels came to, where the important wetlands are, the fish and other aquatic animals etc. Participatory planning should also lead to the identification of stakeholder roles in the implementation and the associated responsibilities and benefits.
- **Awareness raising and capacity building –** EbA requires an understanding of how ecosystems work, the benefits and how they can be used to enhance water resources management. During participatory planning exercises, it will be essential to develop this understanding and links with local knowledge.
- **Vulnerability assessments –** Vulnerability assessments of the infrastructure and communities served are standard practice for all adaptation initiatives. For EbA such assessments need to consider the vulnerabilities of the different ecosystems and natural infrastructure to climate change as well as to other development and environmental pressures.
- **Valuing ecosystem services –** In addition to the water resource services provided by the different ecosystems, including flood and drought reduction, there usually other benefits associated with these ecosystems. These need to be valued where possible; this will provide additional economic and livelihoods justification. The increased availability of fish and other aquatic animals in an irrigation scheme, designed to enhance these are one of the easiest benefits to value. The benefits of biodiversity enhancement brought about by EbA improvements in degraded watersheds may be more difficult to find an economic value. A survey of over 80 studies of the economic value of wetland ecosystem services in the Lower Mekong Basin gives a mean annual value of over 12,500 USD per

hectare of wetland of which 2,500 USD come from Provisioning Services and 10,000 USD from Regulatory Services.[19]

- **Regulatory mechanisms –** are the tools used to manage the water resources and ecosystem services. They include the regulations for access to and availability of water, access to wetlands and restrictions on encroachment for agriculture, regulations on fishing in certain areas, e.g. near fish passes, and in the breeding season.
- **Monitoring** - It is important to conduct periodic monitoring to assess the performance of EbA structural and non-structural measures. Such monitoring should be designed to assess the continuing structural integrity and functioning of the Eb Adaptation measures and their effectiveness against the changing climate and extreme events.

7.8. Policy Recommendations

143. The policy recommendations that come out of these guidelines on Ecosystem-based adaptation include:

144. **Use of Ecosystem-based adaptation**

1. MOWRAM and related line ministries should reactivate and strengthen the established River Basin Organisations as some of the principal agencies implementing ecosystem-based adaptation for increased resilience in the water sector.
2. Watershed and river basin management should assess the ecosystem functions and services and develop actions designed to protect and enhance these services
3. Flood management programmes should consider natural infrastructure solutions to complement built infrastructure, including using wetlands for flood diversions and high ground for flood refuge.
4. Drought reduction and alleviation schemes should consider the ecosystem services of the watershed and wetlands for groundwater recharge and storage within the floodplain.
5. All new irrigation schemes being proposed should include a component for watershed protection and restoration, and for enhancement of floodplain habitats especially for water storage and fish production.
6. All existing irrigation schemes that are being rehabilitated should consider watershed protection and restoration and for enhancement of floodplain habitats especially for water storage and fish production.
7. General maintenance programmes for irrigation schemes should consider green infrastructure solutions and ecosystem-based operation and management alongside of structural measures

145. **Design and Implementation of Ecosystem-based Adaptation**

[19] MERFI (2015) https://www.merfi.org/copy-of-evs; This tool calculates value ranges for ecosystems and their services based on 508 assessments conducted in the Lower Mekong Basin. Results are presented as value ranges for each ecosystem type, the annual and the multi-year sum over all ecosystem, and the three main types of services: Provisioning Services, Regulatory Services, & Cultural Services.

8. Ecosystem-based adaptation should be planned and implemented with strong community involvement and participation.
9. Design of EbA will require both scientific and local knowledge about the functioning and services of the component ecosystems. The vulnerabilities of ecosystem assets and natural infrastructure to climate change should be assessed using the latest projections for climate change applicable at the local scale.
10. The design, construction and operation of the Eb Adaptation measures should be within the limits of the ecosystem asset or natural infrastructure, especially regarding its hydrological or hydraulic functioning.
11. Many EbA initiatives will require the collaboration with agencies in other sectors working in the wider river basin, watershed or floodplain
12. The additional ecosystem benefits resulting from improved ecosystem management and adaptation should be valued where possible and included in the economic benefits of the irrigation and flood and drought management schemes.
13. Ecosystem-based adaptation in irrigation and flood and drought management schemes, should include non-structural measures for managing, regulating and enhancing the ecosystem services.
14. EbA components should be monitored on a periodic basis for their structural integrity and effectiveness in adaptation and continuing to provide the ecosystem services and benefits.

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8. Application of Cost Benefit Analysis

8.1. Cost Benefit Analysis

146. A cost–benefit analysis (CBA), sometimes called benefit costs analysis (BCA), is a systematic approach to estimating the strengths and weaknesses of alternatives used to determine options that provide the best approach to achieving benefits while limiting cost. A cost–benefit analysis may be used to compare completed or potential courses of actions, or to evaluate the value against the cost of a decision, project, or policy. It is commonly used for assessing project investments to determine if a project or policy is sound and how much its benefits outweigh its costs. The value of a cost–benefit analysis depends on the accuracy of the cost and benefit estimates. Comparative studies have indicated that such estimates are often difficult and subjective due to decisions taken as to what costs and benefits are to be included in an analysis.

147. The cost-benefit analysis of flood and drought protection and mitigation measures are significantly more difficult given the uncertainty in the methods to characterize benefits. The analysis is further complicated for Cambodia as the availability of vulnerability and damage information for floods and droughts at a disaggregated level is limited. Damage and loss information are often only available at an aggregate level making it difficult to develop damage inundations curves for specific areas of interest. As well, the damage or loss due to floods and droughts are often not disaggregated into categories of agricultural, housing, infrastructure, and relief. Lower magnitude floods have significant benefit to the aquatic and natural environment based economic and social functions. Floods are seen as a natural process for nutrient distribution and enrich of agricultural soils. These benefits can often offset damages for the more frequently occurring floods.

148. Given this limited availability of damage and loss data at disaggregated level makes the conduct of a cost and potential benefits analysis of proposed flood and drought measures a challenging task. However, a study conducted from September 2007 until January 2010 under a consultancy services contract between MRCS and Royal Haskoning in association with Deltares and UNESCO-IHE collected aggregated data flood damage data at the two Flood Focal areas in Cambodia and in Vietnam. Component 2 on Structural Measures and Flood Proofing of the Mekong River Commission's Flood Management and Mitigation Programme resulted in a number of reports. Volume 2C - Flood Damages, Benefits and Flood Risk in Focal Areas (2010); and Volume 6E- Flood Risk Management in the Border Zone between Cambodia and Viet Nam (2009) presented flood risk curves and supporting data.

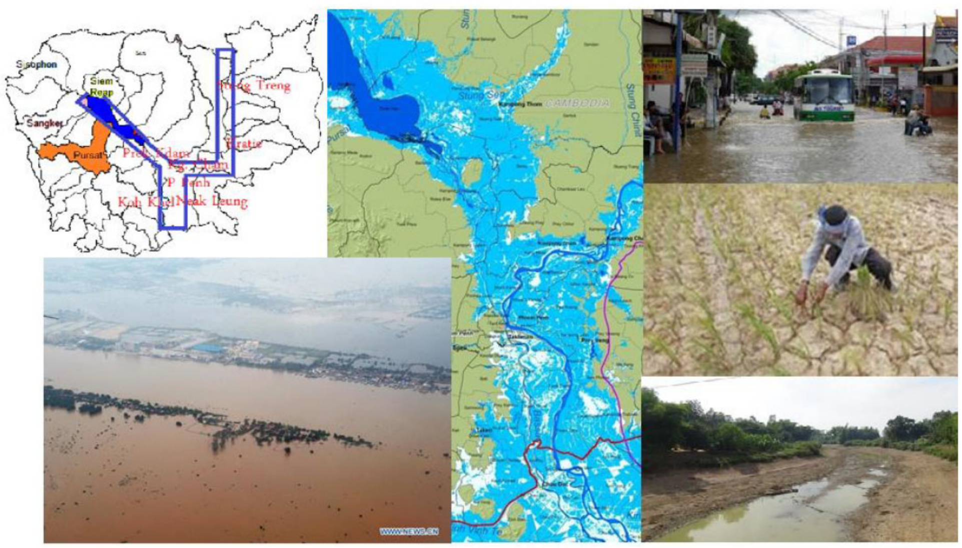
149. In Volume 2C, results of the socio-economic surveys that were carried out as part of the FMMP-C2 assignment are reported, along with the analysis of the results in terms of flood damages and risks. The surveys were carried out in three districts in the Vietnamese Mekong Delta, four districts in Cambodia, two districts in Lao PDR and two districts in Thailand. Aggregated direct and indirect flood damages data were collected at the district level for three categories of damage: agriculture, housing, and infrastructures. The resulting damages were used to derive, flood risks curves. From these curves the potential damage reduction by flood control measures to infrastructure could be estimated for these districts. As well, the study derived curves for agriculture on the basis of the information obtained during the Focal Group Discussions. Environmental risks for the Focal Areas were identified as well as the social aspects of flooding.

150. Considering the availability of damage and loss data at disaggregated level required to conduct a cost and potential benefits analysis, a risk-based approach has been used to develop the flood and drought guidelines. It is important to noted that the consideration of risk has emerged as a key concept in policies and actions related to disaster management.

MINISTRY OF WATER RESOURCES AND METEOROLOGY

USER MANUAL

DESIGN GUIDELINES
FOR
STRUCTURAL FLOOD AND DROUGHT CONTROL MEASURES



GREATER MEKONG SUB-REGION FLOOD AND DROUGHT RISK MANAGEMENT AND MITIGATION PROJECT

Phnom Penh, January 2020

eptisa   KEY CONSULTANTS (CAMBODIA) LTD.   icem

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Foreword

The GMS Flood and Drought Risk Management and Mitigation Project (GMS-FDRMMP) is funded by the Asian Development Bank and the Government of Cambodia. The objective of the Project is to reduce economic losses resulting from floods and drought events. The key components of the Project are:

a. Enhanced regional data, information and knowledge base for the management of floods and droughts;
b. Upgraded Water Management Infrastructure (Damnak Chheukrom Irrigation System Rehabilitation in Pursat Province);
c. Enhanced Capacity for Community-Based Disaster Management.

The Executing Agency (EA) is the Ministry of Water Resources and Meteorology (MOWRAM), and the implementing agencies are the Department of Hydrology and River Works (DHRW) and the Provincial Department of Water Resources and Meteorology of Pursat.

This *User Manual of the Design Guidelines for Structural Flood and Drought Mitigation Measures* is the accompanying user manual of the *Climate Resilient Design Guidelines for Structural Flood and Drought Control Measures,* prepared by the Ministry of Water Resources and Meteorology (MOWRAM) with support from the Project Consultants, as part of the first component of the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project.

The User Manual is prepared to guide agencies and individuals in the application of climate resilient design guidelines for structural flood and drought control measures in Cambodia

This user manual, and the design guidelines, will be useful to the Government Ministries, other non-governmental agencies and private sector to develop polices and regulations within their responsibilities and mandates, and to design climate resilient flood and drought mitigation and adaptation measures in Cambodia.

On behalf of the Ministry of Water Resources and Meteorology, I would like to thank the Asian Development Bank for the financial support to the Project. The Ministry acknowledges the efforts and contributions of H. E. Ponh Sachak, Secretary of State and Project Director, Mr. Bak Bunna, Project Manager, Mr. Yin Savuth, Director of Department of Hydrology and River Works, and the staff of the Central Project Management Unit (CPMU), Ministry of Water Resources and Meteorology (MOWRAM), the Consultant Teams and the stakeholders (participants) in the Concluding Workshop for their inputs, comments and feedbacks during the preparation of the guidelines and the accompanying user manual.

H. E. Lim Kean Hor

Minister of Water Resources and Meteorology

Phnom Penh 2020

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List of Acronyms and Abbreviations

ADB	Asian Development Bank
BCA	Benefit Cost Analysis
BDP	Basin Development Plan
CBA	Cost Benefit Analysis
CBOs	Community-Based Organization
CNMC	Cambodian National Mekong Committee
DEM	Digital Elevation Model
DHRW	Department of Hydrology and River Works
DOM	Department of Meteorology
DSF	Decision Support Framework of MRC
DTM	Digital Terrain Model
EbA	Ecosystem-based Adaptation
FMMP	Flood Management and Mitigation Programme
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resources Management
MOWRAM	Ministry of Water Resources and Meteorology
M&E	Monitoring and Evaluation
MRC	Mekong River Commission
MRC-RFMMC	MRC Regional Flood Management and Mitigation Centre
NCDM	National Committee for Disaster Management
NFFC	National Flood Forecasting Centre
O&M	Operation and Maintenance
RB	River Basin
RBO	River Basin Organization
RCPs	Representative Concentration Pathways
RGoC	Royal Government of Cambodia
TA	Technical Assistance
TSA	Tonle Sap Authority
WMO	World Meteorological Organization

1. Introduction

This user manual is intended to guide agencies and individuals in the application of climate resilient design guidelines for structural flood and drought control measures in Cambodia.

The guidelines take into consideration the mechanics of the flood and drought systems as well as projected climate change implications for Cambodia.

The Lower Mekong basin is a complex floodplain, where floods exhibit positive benefits as well as have negative consequences. The complexity and role of the floodplain has a significant influence on the extent, duration, and storage of flood water.

The critical flood attenuation function of the Cambodian floodplain and the Tonle Sap Lake system is potentially threatened by floodplain development and loss of flood conveyance due to infrastructure. The raising of levees and roads, the installation of culverts and bridges, which restrict natural flood flow pathways, and the greater compartmentalization of flood water retention areas all have the potential to increase vulnerability and to affect flood risk. Therefore, future development, such as the development of new infrastructure, increased population, and changes to land-use on the floodplain; will affect flood behaviour and has the potential to increase flood risk in the Lower Mekong.

Climate change projections for Cambodia indicate a wetter rainy season with a greater percentage of the total rain for the rainy season resulting from extreme events, and a dryer dry season with perhaps less rain but higher temperatures. Projected runoff is to be higher and sea level rise will have implications for existing flood prone areas. Cambodia is expected to experience a reduced number of intense cyclones. These climate change projections have implications for floods and droughts in Cambodia.

The guidelines have been developed to preserve the flood mitigating behaviour of the floodplain. The guidelines consider how floods and droughts will affect these developments and initiatives and the need for protection, but more importantly, consider how these developments and initiatives will increase or decrease flood and drought vulnerability.

Both structural and non-structural measures to reduce vulnerability to floods and droughts are presented. As well Ecosystem-based Adaptation (EbA) approaches are presented and complements engineering approaches to flood and drought management.

An important consideration with respect to floods in Cambodia is the transboundary nature of the Mekong River basin. Much of the floodwaters in Cambodia are derived from upstream countries, including Viet Nam as well, downstream developments in the Mekong Delta affect water levels at Phnom Penh. Therefore, approaches to flood and drought management must consider transboundary implications and support regional cooperation through information sharing and the development of regional solutions.

2. Design Life, Climate Implications, and Risk Considerations

Design guidelines for flood and droughts must consider the design life of structural measures. The longer the design life, the more important are the consequences of climate change and future developments in the floodplain.

Design guidelines for floods must consider the importance of the facilities being protected, which can be designated as critical to non-critical facilities. For example, hospitals, emergency control and response centres, and key transportation corridors and infrastructure are critical and require a higher level of protection. Major industrial and population centres will also require a higher level of protection given the significant economic and potential for loss of life and livelihood associated with these centres. As well, sources of significant toxic contamination from hazardous substance such as oil, pesticides, or fertilisers must be well protected or placed outside the flood zone.

Design guidelines are often based on a frequency analysis, which is a standard statistical procedure to assign the likelihood of occurrence to a flood or drought event. However, a basic assumption of the statistical analysis is stationarity. That is, for extreme flood or drought events the statistics do not change in time and past observations can be considered as representative of future observations. With a changing climate the assumption of stationarity may not be applicable and more advanced statistical methods that account for the non-stationarity are required.

The current flood protection and conveyance infrastructure in Cambodia cannot absorb the increases in extreme floods that most of the climate scenarios indicate. Considering a 2060 design horizon. which provides a design life of some 40 years for infrastructure currently in the planning stage, sea level rise is expected to approach 0.5 m by 2060, which will increase water levels at Phnom Penh by about 0.2 m. Peak water levels at Phnom Penh for a 1:100 event is expected to be 0.3 m higher for a moderate climate change scenario and over 1.2 m higher for the extreme scenario. The increase in water level for even the moderate scenario is expected to lessen the existing flood protection works to less than a 1:20 year event. The duration of flooding is predicted to be extended by 14 days for a moderate scenario.

The consideration of risk has also emerged as a key concept for the selection of actions related to disaster management and for the selection of appropriate design criteria. Flood risk assessment refers to the quantitative analysis of the level of flood risk for a river reach or basin. The identification and mapping of flood risks requires information on flood hazard such as the extent and duration of flooding and the level of vulnerability in the area affected by flooding. The flood hazard is defined in terms of inundation area, height of water, water velocity, and duration considering meteorological, hydrological, river channel, and floodplain characteristics. The level of risk is also related to the probability that a flood event of a specific magnitude will occur.

An adaptive approach of “living with floods” and “living with droughts” is a strategic direction for flood and drought management in Cambodia. The people of Cambodia have adapted to the occurrence of annual floods and are accustom to “living with floods” through adaptation, however rare and extreme flood events still result in significant loss of livelihood and damage.

3. Flood Design Process

Given that storage and conveyance features of the floodplain have a direct effect on flood levels, extent, duration, and timing of flooding; the flood design approach uses a zone approach that considers flood behaviour based on local natural influences and requirements. The zoning of the Cambodian floodplain is shown in Figure 1.

Figure 1: Flood Zones

The flood design process follows the following steps:

Step One: Determine Design Flood Requirements

- Identify the Flood Zone and use **Table 1** to select design flood event criteria considering the planned development type as Critical, Semi-critical, or Non-critical
- The flood in 2000 is considered to represent the design flood for the 1:200-year flood event

Step Two: Determine Level of Flood Hazard

- Consult the appropriate return period flood hazard map (Annex 1: Flood Maps for Various Return Periods - NFFC 2017) to identify the location of the planned development and determine the expected level of the flood hazard (depth of water)

Step Three: Assess the implications of the proposed development on the 1:200-year flood event

- Assess the impact of the planned development's impact on the flood level due to the loss of floodplain storage and/or flood conveyance considering the flood hazard as defined by the 1:200-year flood event
- Major works such as roads, levees, irrigation embankments, and water management structures will require the configuration and calibration of a suitable flood hydrodynamic model to assess the effect of the planned development on local flood levels for the required design criteria, if placed in the 1:200-year flood event effected area
- Propose mitigating measures to ensure there is no net loss of flood storage and flood conveyance

Step Four: Consider Trans-border Flood Effects

- Consider changes to water control structures occurring in Viet Nam that will affect water levels upstream in Cambodia trans-border flooding
- Consider the effects that the planned development may have on flood levels in Viet Nam
- Advise the National Mekong Committee of any trans-border flooding concerns

Step Five: Establish Flood Protection Design Level

- Select the design level for flood protection works considering the maximum water level projected to the HATIEN MSL
- For semi-critical and non-critical works add a freeboard of 0.3m to accommodate for waves, localized influences, and uncertainty in the reference level
- For critical works add a freeboard of 0.6m to accommodate for waves, localized influences, and uncertainty in the reference level.

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Table 1: Flood Design Criteria considering Flood Zone and Development Type

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
Zone C1 comprises the Great Lake and part of the connecting Tonle Sap River to Prek Kdam	This Zone contains the wet season maximum extent of the Tonle Sap Great Lake and Tonle Sap river floodplain to Prek Kdam and is a key part of the functioning of the natural response of the Mekong to the annual flood pulse. There are a number of significant provincial towns around the periphery of the flood season extent of the Tonle Sap Great Lake that are potentially at risk.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
Zone C2 lies on the Mekong right bank and Tonle Sap left bank and is bounded by the high ground to the north, Road 6 to the Prek Kdam bridge, and the Mekong to the south	Key features include the Provincial town of Kampong Cham and the Muk Kampul River which flows parallel to the Mekong eventually crossing the Road 6A and flowing back into the Tonle Sap.	All development should be limited in this Zone given the Zones importance for flood conveyance to the Tonle Sap Great Lake for significant flood events	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C3 lies to the south of Phnom Penh and to the west of the Bassac comprises of the region from Ta Khmau to the border with Vietnam, delimited to the east by the RN 21. There are some 90 artificial and natural colmatage canals transferring flood water from the Mekong/Bassac rivers to this zone through the RN 21. The population density is high along the Bassac river banks and the RN 21.	The area includes important wetlands and minor irrigation development. The Prek Thnot enters the Bassac at Ta Khmau, which is becoming part of the City of Phnom Penh as urbanization expands south. The border area is controlled by dike embankment along the right bank of the Vin Te canal in Vietnam and controlled openings to Zone V1 by two rubber dikes.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater and changes occurring in Vietnam that will affect water levels upstream in Cambodia • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigation
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas Proper planning and managements	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Banned ground floor construction to prevent free flow constriction across RN 21 and Bassac river banks. • Provide permanent flood proofing to above the 1:100-year flood level

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		of colmatage canals to prevent excessive rise of water level in the areas.	• Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Must identify transboundary impacts based on medium to long term development scenarios in Cambodia and in Vietnam
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection. Needs medium to long term planning supported by detail development scenarios integrated with other flood zones (C4, C7 and C8) to provide inputs for transboundary flood management and planning.	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Develop strategy for cropping pattern to reduce risk to flood and droughts taking into consideration of space for flood conveyance, storage and storage for dry season cropping
Zone C4 represents the Trans Bassac area is still under developed as compared to Vam Nao polder area in Vietnam but it is one of the least disturbed fishery ecosystems in the Mekong floodplain and under increasing pressure from development.	The area is relatively underdeveloped except for the land along the banks of the Mekong and Bassac and in the vicinity of Road 1 that passes from Phnom Penh to Vietnam. There are four controlled colmatage canals crossing the RN1 between Kien Svay and Neak Leung and during flood season the flood water levels in the northern part of this zone are largely determined by the Bassac River and may be 1m lower than the Mekong	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigation

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
	side of the road. Roads are progressively being improved and raised and a major ring-road and bridge crossing of the Bassac has been opened defining the next stage of urban development close to Phnom Penh. Further south during flood season large part of flood water spill over the right bank of the Mekong into this zone to the flood zone C3. During the dry season and high tide period when flow from the Tonle Sap River stops, the Bassac River flows into the Lower Mekong River. With no waste water treatment facilities, this flow might similarly impact on water intake facilities on the Tonle Sap, the water intake on the Mekong.		• Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Re-establish, rehabilitate existing natural and artificial drainage channels in the areas connecting the Bassac with the back swamp and lakes
Zone C5 lies on the left bank of the Mekong River, is the largest maximum flood storage areas up to 8.6 MCM and during extreme flood receives more than 65% of the Mekong overbank flow.	The area is one of the key conveyors of floodplain flows via the Tonle Toch and associated floodplain areas. These include a number of flow paths including the lake at Prey Veng down to the connection of the Tonle Toch with the Mekong at Banam and Prek Kampong Trabek rivers spreading the Mekong overbank flow between Neak Leung and Kampong Trabek towns where RN 1 crosses the floodplain. Two important river branches drain this area namely the Stung Slot and the Prek Kampong Trabek.	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events. An inter-sectoral strategy should be developed taking into consideration of its flow conveyance function, wetland ecosystem services, adaptable cropping patterns (early crop, recession crop and wet season crop) as basis for medium to long term spatial planning.	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Strategy for deep and shallow flooded areas development and management.
Zone C6 lies on the left bank of the Mekong River and is an	The area receives flow in time of high flood as water passes through culverts in	Critical Infrastructure for emergency response and public safety (important	• Place outside of flood prone area such as on natural high ground, artificially raised area, or

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
area remote from the main flood areas of Zone C5 with mild maximum flood storage volume.	RN 8 and RN 11 connecting to the West Vaico in Vietnam. It is also an area of localised flooding and source of water for Svay Rieng and other border areas. Large irrigation canals were built connecting with the Mekong flood water and with pumping during the dry season. Important area for ground water recharge for areas downstream, groundwater recharge facilities and management.	transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance.	on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Medium to long term plan scenarios development for transboundary impact assessment
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas. Reforestation and soil conservation improvements are required.	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate • Retain deep flooded areas for ecosystem conservation and no protection during high flood and consider full protection for shallow flooded areas
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to	• Design infrastructure considering the 1:20-year flood event or greater

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		river channels, and river bank protection and use of green engineering	• Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate
Zone C7 lies on the left bank of the Mekong River below Neak Leung south of the RN1 and north of borders with Vietnam	The area is a key spill area on the left bank of the Mekong River. The Zone includes the Stung Slot and Trabek rivers and borders the Plain of Reeds in Vietnam (Dong Thap) and is one of the most important with respect to trans border concerns. Impacted by water management in Vietnam due to dike embankment along the Prek Smao/Soha Kaico along the border. (flooded land and water shortage for recession crops). Is experiencing decreased ecosystem services.	All development should be limited in this Zone given the Zones importance for flood conveyance during significant flood events. River navigation rather than road for bulk transport, river regulation with rubber dams for flow and tidal impacted water management Elevated or polders for restricted settlement areas	• Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • There is a concern with development restricting floodplain flow, which lowers important trans border flooding for Vietnam and increases flood levels upstream in Cambodia • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia • Develop medium to long term development scenarios to assess trans border impacts with other flood zones C8, C6, C3 and C4
Zone C8 is a trans border area to the east of Zone C7, severely flooded during the 2000 highest flood; acid sulfate soil, large barren land areas.	The area is a trans border area and has significantly less floodplain flow than Zone C7. It is the source of the West Vaico in Vietnam and flooding on the Cambodia side near the border is closely linked to the hydraulic conditions on the Vietnam side.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance, forest regeneration,	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		reforestation, soil conservation, green technology	• Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Viet Nam that will affect water levels upstream in Cambodia
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage, flood conveyance and trans border flooding and mitigate • Must consider changes occurring in Vietnam that will affect water levels upstream in Cambodia

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
			• Develop medium to long term development scenarios to assess transboundary impacts with other flood zones C7, C6, C3 and C4
Zone C9 contains the Mekong River from Kratie to the upper end of Zone C2 and C5 at Kampong Cham	The area has a limited floodplain extent on both side of the Mekong River not well connected and increasingly disconnected with the Mekong with road development along both river banks. The Kratie town is the uppermost location of the Mekong Delta, where the downstream water level start to back up once the water level at Kratie has reached the level above 18.0 m. At high stage large amount of flow bypasses the control of the Kampong Cham hydrological station and rejoints the Mekong at the northern side of the zone C5. During severe floods Kampong Cham town despite its dike embankment along the Mekong river bank will be vulnerable to floods from its western site. Furthermore, the bypass flows across RN 7 between Kampong Cham and Suong town can only pass through Moat Khmung bridge, where land encroachment upstream is intensifying.	Critical Infrastructure for emergency response and public safety (important transportation and navigation corridors, emergency response centres and shelters, hospitals) major water management structures, electrical power generation facilities, water supply facilities, urban centres as well facilities of major social-economic importance Flood protection ring dike of the Kampong Cham town should be verified for its design frequencies. The failures of the dike would have dramatic consequences downstream, including Phnom Penh	• Place outside of flood prone area such as on natural high ground, artificially raised area, or on columns designed to be above the 1:200-year flood level • Provide permanent flood proofing to above the 1:200-year flood level • Design bridges and crossing on important transportation corridors to pass the 1:200-year flood • Design major water management infrastructure considering the 1:200-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate. • Medium to long term development scenarios should be included in the overall Mekong-TLSGL floodplain development and management.
		Semi-critical Infrastructure such as secondary water management and erosion protection structures, embankments along main irrigation canals, agriculture facilities important for food security as well as schools and historical cultural and touristic areas	• Place on natural high ground, artificially raised area, or on columns designed to be above the 1:100-year flood level • Provide permanent flood proofing to above the 1:100-year flood level • Design secondary water management and erosion protection structures and embankments along main irrigation canals considering the 1:100-year flood • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate

Flood Zone	Zone Characteristics	Planned Development Type	Flood Design Resiliency Criteria
		Non-critical Infrastructure such as secondary irrigation works, recreational and environment protected areas, changes to river channels, and river bank protection	• Design infrastructure considering the 1:20-year flood event or greater • Must identify the development impact on the flood level due to the loss of floodplain storage and flood conveyance and mitigate

4. Drought Design Guidelines

In Cambodia, the occurrence of relatively moderate drought events has significant impact given the high level of vulnerability and limitations in the ability of rural people to cope with the impact of drought events. Under a normal year, typical rainfall distribution is from May to October with heavy rainfall from August to mid-October. A dry spell of about 2 to 3 weeks in July and August is typical. In Cambodia, droughts occur with a frequency of once in every three years.

Climate change has a number of consequences for drought management in Cambodia. There is general consensus that Cambodia and the Mekong River basin will experience increased rainfall during the wet season through more intense rain storm events. Rainfall during the dry season is expected to remain unchanged or be slight lower. The estimate for the magnitude of change varieties under the various climate scenarios, however the direction of the change is consistent. Temperatures during the dry season are expected to increase, which will have significant consequences for the increased potential of prolonged droughts.

The design guidelines for drought involve long term actions related to adaptation and mitigation combined with selected and cautious use of structural measures. Droughts in a defined area require an integrative approach and integrated management based not only on the natural features, but also on socio-economic, institutional, and environmental considerations. The fundamental actions are to increase water availability, to reduce water demand, and to mitigate drought impacts using social and economic tools.

Drought design guidelines encompasses:

- Develop drought indicators that identify the types and the severity of drought. The impact of drought has an environmental, economic, and social dimension and the indicator must capture these dimensions. The environmental indicators include, rainfall, water level in the reservoirs and other surface storage systems, ground water depth, and soil moisture.
- Develop drought prevention and preparedness measures that involve water supply augmentation and conservation, expansion of irrigation facilities, and public awareness and education.

The development of integrate watershed management plans that encourage reforestation and maintenance of upland forest areas to preserve natural infiltration of rain water necessary to sustain base flow in upland tributaries is essential for drought mitigation.

Farmers should be encouraged to apportion at least 1% of their land holding for digging farm ponds. This will have a beneficial effect not only on tiding over the periods of drought due to lack of direct water availability but also help in recharging the local ground water table.

During a drought, farmers are encouraged to definite cropping plan designed for late sown crops with short duration varieties.

Ecosystem-based adaptation measures have a significant role in the migration of drought effects.

5. Ecosystem-based Adaptation for climate resilience in the water sector

Ecosystem-based adaptation (EbA) for structural flood and drought control measures focuses on the more natural and sustainable complementary or alternative measures such as wetlands and natural buffers, and the on non-structural measures, which are actions taken to mitigate flood and drought loss and damages through better planning and management of watershed development.

In the context of climate resilience for the water sector in Cambodia, EbA is not only about protecting ecosystems, but using ecosystem functions and enhancing ecosystem services for flood and drought management objectives.

The process of designing ecosystem-based adaptation varies depending on the starting point:

- Retrofitting EbA to an existing system - design of EbA measures to existing infrastructure and facilities, e.g. an irrigation scheme, to make them more resilient. The starting point would be an analysis of the vulnerability of this infrastructure to climate changes and extreme events, together with an analysis of the ecosystem assets that support the infrastructure, their status and vulnerability.

- Designing a new project for using and managing the water resources such as a flood prevention scheme or drought risk reduction. This would integrate a mix of complementary EbA measures with hard infrastructure within the project design. The starting point would be a clear identification of the project objective and developing an understanding of how the ecosystem assets in the area (both upstream and downstream) can be used or managed to contribute to this objective.

- Managing and enhancing the sustainability of the water resources in the river basin and its watersheds. Develop a river basin (or watershed) profile including the description of the key ecosystem assets, the functions and services they provide, and the challenges they face both from climate change and other development pressures. The river basin plan would include the existing and future uses for water and the overall hydrological balances. Measures to enhance the ecosystem functions and services of these assets should be identified first and implemented before hard infrastructure solutions are put in place.

The EbA design process includes the following phases and steps:

Phase 1: Understand and analyse the linkages among ecosystems, livelihoods and climate change in the context of water management for flood and drought control

1. Geographical scaling: The first step for building EbA measures defines the geographic boundaries of the areas. Sub-regions are identified within each project area and major hydro system features as well as economic activities are mapped out.
   i. Identifying ecosystem assets both in the watershed and floodplain
   ii. Describing the status of the ecosystem assets
   iii. Mapping the ecosystem functions and services especially the links to water resources, floods and drought

   Note that EbA can be applied at various scales from a whole catchment to smaller river reaches or habitats, depending upon the scale of the project.

2. Scoping: Scoping addresses the major concerns and issues by assessing their environmental and socioeconomic impacts. This should include the cumulative impacts (both positive and negative) of water resource developments in the area.
3. Identifying the causes of threat to the ecosystems and habitats: This analysis traces the major concerns and issues to their root causes, immediate causes and environmental or socio-economic impacts. It may use problem-tree or causal chain analysis and helps in the selection of solutions.
4. Data collection, analysis: Data collection and analysis is a critical step that collects and organizes all data from available sources and prepares it for analysis and then conducts the analysis. This is likely to include surveys and consultation with local communities and ecosystem users
5. Understanding the system: A series of tools may be used to understand how the system works and is likely to respond to climate change and other pressures
    i. Considering climate change consequences: To address climate change impacts, future climate information for the basins needs to be obtained.
    ii. Considering other changes and developments in the area. Land-use change and other developments, especially if they change water resource use, should also be considered as part of the pressures on the ecosystems. Techniques such as cumulative impact assessment may be used to understand how the system is likely to respond to these pressures.
    iii. Modelling: Water resources modelling, or hydro-system modelling should be state of the art in order to adequately address behaviour and mutual dependencies of water resources components. The results of water resources modelling allow the project proponent to derive effects on other sectors, both upstream and downstream, and to verify assessments and observations made earlier.
    iv. Socio-economic assessment of the use of the ecosystems, services and benefits
    v. Verification of cause-effect relations: Verification substantiates the causal-chains. Whenever possible, this should be backed with data, calculations or any other proven indicators.

Phase 2: Identify and prioritise EbA options for community and ecosystem resilience

1. Selection of EbA Measures to adapt to vulnerabilities: Technically feasible measurements are prioritized economically. Design and enhancing the ecosystem asset to meet flood and drought management objectives. The first measures are likely to be those that address the issues and opportunities for water regulation services. The assessment of cumulative impacts of water resource developments will contribute towards the identification of mitigation and resilience measures.
2. Identification and valuation of other ecosystem services and benefits that will be enhanced (or lost) by the EbA measures adopted, followed by cost-benefit analysis of the proposed interventions.
3. Public hearings and stakeholder participation throughout the design process to ensure appropriate measures are selected and gain acceptance from local communities.

Phase 3: Design project activities that facilitate implementation of priority EbA options

This is the detailed design process which will involve specifying the engineering and habitat design, rehabilitation and management measures.

Phase 4: Identify key elements and indicators for a monitoring and evaluation (M&E) framework

Monitoring indicators are identified to show the effectiveness of the Ecosystem based Adaptation measures and to show if they need to be changed to suit changing conditions. The M&E framework should include indicators of the overall objective of the scheme or project, e.g. flood protection for a particular area, and then consider the contributions to that objective made by the different components of the scheme – both the built and natural infrastructure. Indicators may be selected from the MRC's Indicator Framework, and the indicators of ecosystem integrity developed for the Council Study.

Indicators of effectiveness of the natural infrastructure should include the functions and services that are maintained or enhanced by the scheme:

- Changes in the condition or status of the natural infrastructure, e.g. the wetlands used for flood diversion
- Performance of the natural infrastructure at times of extreme events, e.g. how did the wetland perform in diverting floods, or maintaining water in times of drought
- Changes in the values of ecosystem services provided, e.g. the fish production from the wetland
- Changes in uses and threats to the ecosystem from user communities, e.g. agricultural encroachment on wetlands
- Annual maintenance requirements and losses after extreme events

These indicators need to be compared with main climate variables – temperature, rainfall and evaporation and occurrence of extreme events such as storms, floods and drought. The climate stresses in a particular year should be used to assess the effectiveness of the ecosystem-based adaptation. In a normal year, effectiveness is best assessed by comparing the condition and services provided. In an extreme climate year, effectiveness is best assessed by comparing damages both in the surrounding area and to the ecosystem component itself, to damages in previous years without the scheme and its enhanced natural infrastructure.

Ecosystem based adaptation measures include both built and natural infrastructure, or a combination of both. Table 2 presents a number of EbA built and natural infrastructure measures, describes how structural adaptation measures can be applied, and their limitations. These green infrastructure measures are described in greater detail in the Water Resources Adaptation Guide prepared by the ADB Strategic Program on Climate Resilience (SPCR).[1]

[1] NCSD/MOE. 2017. *Water Resources Adaptation Guide*, Working Paper prepared by TA 8179-CAM: Mainstreaming Climate Resilience into Development Planning Phnom Penh, Cambodia.

Table 2: Ecosystem adaptation measures for built and natural infrastructure

EbA built and natural infrastructure measures	How EbA is applied	Limitations
Wetland restoration	• Ensuring adequate water availability for the wetland, • Protection of wetland from encroachment and drainage, and extraction of water • Protection from discharges of polluted water • Limiting livestock access to the wetland • Creating a vegetated buffer around the wetland • Control/management of harvesting, fishing and hunting activities	Wetlands need the appropriate amount of water according to size and type of wetland. Water requirements and capacity should be modelled. Limited capacity to absorb pollutants
Constructed wetlands	• Bioretention pond, greywater recycling, • Depending upon the type, ability to reduce BOD, TSS and nitrate etc. • Horizontal or vertical flow designs	Definite capacities for treating water pollutants – do not overload Requires regular maintenance to ensure flows through the system
Water storage in natural lakes, ponds	• Rainwater harvesting over land directed to natural lakes and ponds • Construction of weirs to maintain water levels • Protection and strengthening of banks, with vegetated buffer zone around • Protection against livestock and water pollution	Define clear low water limits and water extraction, do not drain completely. Safety precautions for humans and livestock
Natural depressions	• Clear identification of such areas for flood management, discussions with local farmers on functions • Preparation of flood water diversion channels/ditches/trenches • Do not build in these depressions • Maintain collected water for dry season and drought water security • Dig fish refuge pits in rice fields	May be used for agriculture, but recognise that flooding may occur in some years and so suitable crops must be planted, and may be lost in case of flood event Prevent housebuilding in natural depressions
Natural high ground in floodplain	• Protect and enhance natural high ground as flood refuge	Designate such areas and train communities in their use
Sediment pond	• Divert sediment laden run-off through sediment pond, especially useful for treating water from construction sites • Specifically designed for sediment deposition – strengthened banks and shape/profile • Remove/dredge accumulated sediment periodically	Do not overload with high water flow rates Sediment may require removal by digging out or dredging, when levels become too high
Bioengineering structures	• Biological geotextiles, bush mattress, live crib wall, live fascine, live staking, log terracing, palisade,	All methods can be used in conjunction with hard structures

EbA built and natural infrastructure measures	How EbA is applied	Limitations
River and canal banks, storage lakes and ponds, reservoirs etc Riparian zone strengthening	• Vetiver grass coverage • Vegetated gabion, vegetated geotextile, vegetated revetment, vegetated rip rap • Planting of trees in the riparian zone	Live and vegetated structures are long lasting, but structures using dead vegetation will have a shorter life before they degrade. Select appropriate tree species to protect riparian zone
River bank protection River bed enhancement River channel modification	• Rehabilitation of vegetation on river banks and green engineering solutions, enrichment of bank vegetation • Stabilise river banks • Reduction of sediment load • Urban river terracing • Restores degraded hyporheic zone[2] • Installation of fish passes around weirs and barriers	Relatively small and locally specific structures Extensive watershed management may require many of these structures to complement other reforestation and upland agricultural practices Fish passes require diversion of minimum flow of water and are effective up to 8m of head

Watershed land management	• Improved agricultural practices retaining soil moisture and nutrients
	  o Minimum tillage and mulching
	  o Choice of appropriate crops
	• Improved upland cropping and agronomic techniques, strip cropping, pasture cropping, grassland farming, woodlands and agroforestry
	• Protective agroforestry techniques
		Will require complementary actions with MAFF
		
		Agricultural extension required to change cropping and agronomic practices

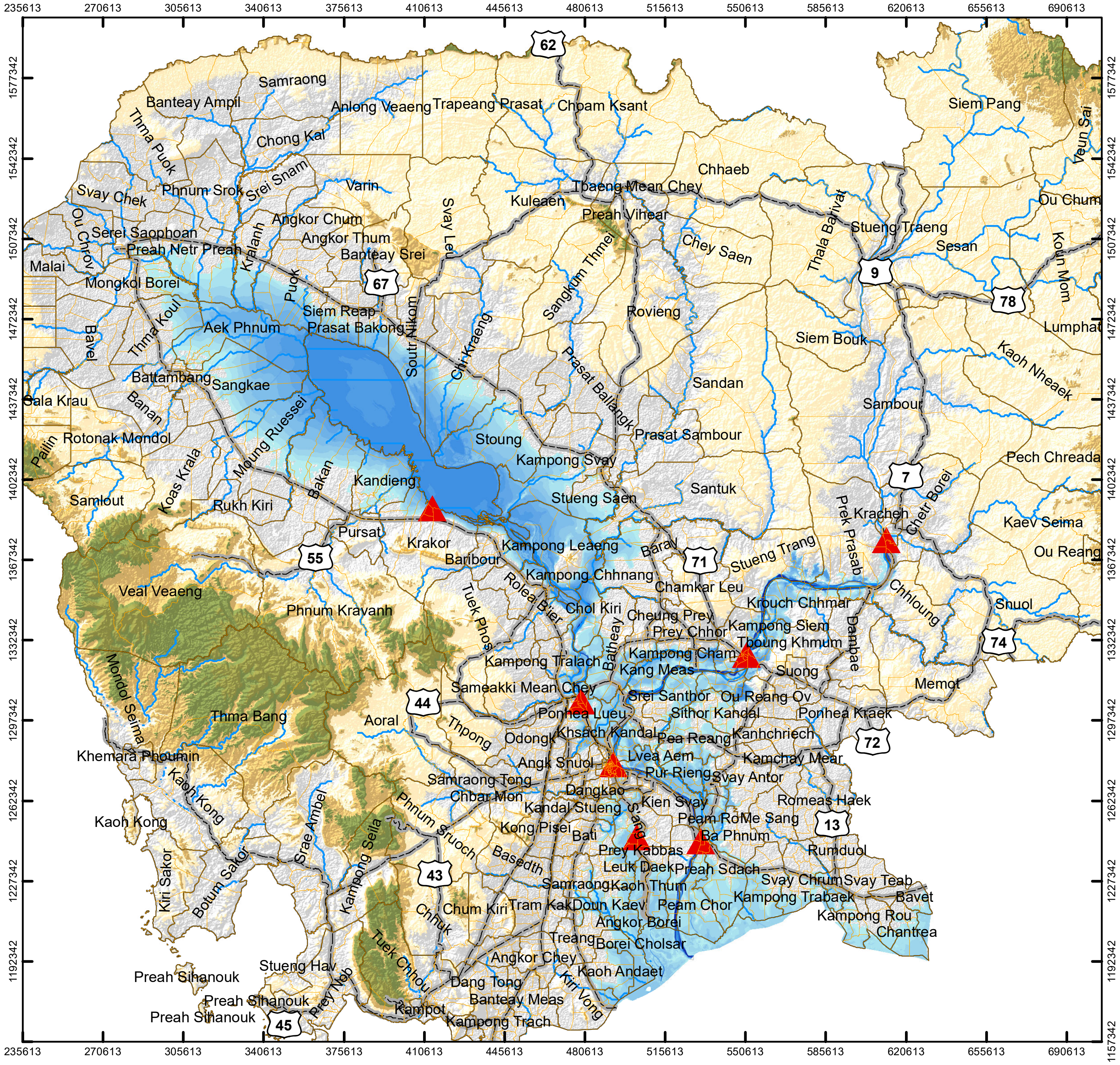
Lowland and floodplain rehabilitation Maintenance of integrity of lowland waterbodies and wetlands to improve structure and function	• Revegetation and protection of river banks, seasonally flooded areas • Drainage corridor, planting pit, storm water tree pits • Ensuring that built structures, e.g. roads and canals do not stop surface flows of water during floods – build correct sized culverts • Protection of natural wetlands from encroachment • Designation of natural groundwater recharge areas	Ecological functioning of floodplains and wetlands is often threatened by built structures such as roads and canals. Wetlands require appropriate hydrological balance (i.e. not too little water) to remain functioning. Access for fishing may require regulation to prevent overexploitation.

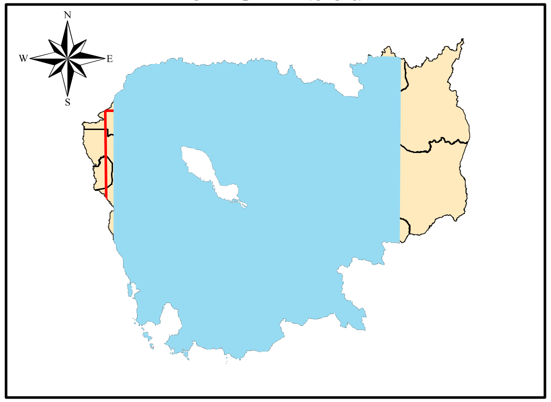
[2] Hyporheic zone - is a region beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water. The flow dynamics and behaviour in this zone is recognized to be important for surface water/groundwater interactions, as well as fish spawning, among other processes. As an innovative urban water management practice, the hyporheic zone can be designed by engineers and actively managed for improvements in both water quality and riparian habitat.

EbA built and natural infrastructure measures	How EbA is applied	Limitations
Natural Floodplain diversion	• Designate areas of "sacrifice" land or wetlands to receive high flood waters and slow down the extent and rate of flooding	Sacrifice land may be used for agriculture, but recognise that flooding may occur in some years and so suitable crops must be planted, and may be lost in case of flood event
Infiltration structures	• Field trenches, Injection well, • Rain garden, recharge pit, soak pit • Permeable paving	Mostly relatively small scale but can be extensively sited throughout area. Permeable paving suited to urban areas
Conservation & restoration of forests and other natural vegetation Afforestation	• Forest rehabilitation, replanting, assisted natural regeneration • Rehabilitation of natural forests to increase wildlife and NTFPs • Slope stabilisation to prevent landslides and regulate water flows • Structures to prevent flash flooding and landslides	Will require collaboration between MoE. MAFF and MOWRAM for forest rehabilitation in any Protected Areas in the watershed. Will require continued efforts to control illegal timber and wood cutting, and wildlife hunting
Mangrove forest planting	• Replanting of mangrove forests – often with community engagement	Careful site selection for mangrove replanting to ensure full survival Maintenance of key processes, such as sediment supply
Restoring coastal ecosystems	• Protection and rehabilitation of coral reefs, mangrove forests, dune systems and salt marshes	Careful site selection and ecological restoration measures in these sensitive ecosystems

Annex 1: Flood Extent Maps for Various Return Periods – NFFC 2019

Maximum Flood Extent Map for 2 Years Return Period for Cambodia





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-19
- 20-29
- 30-39
- 40-43

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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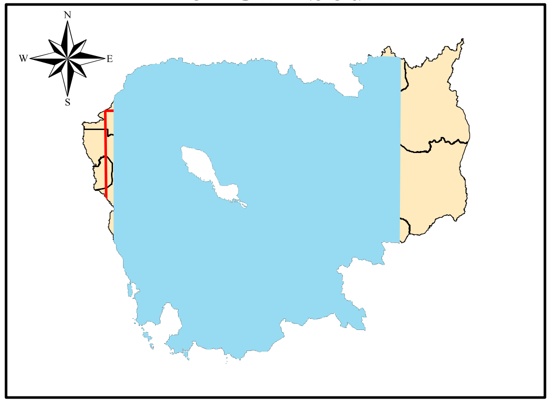
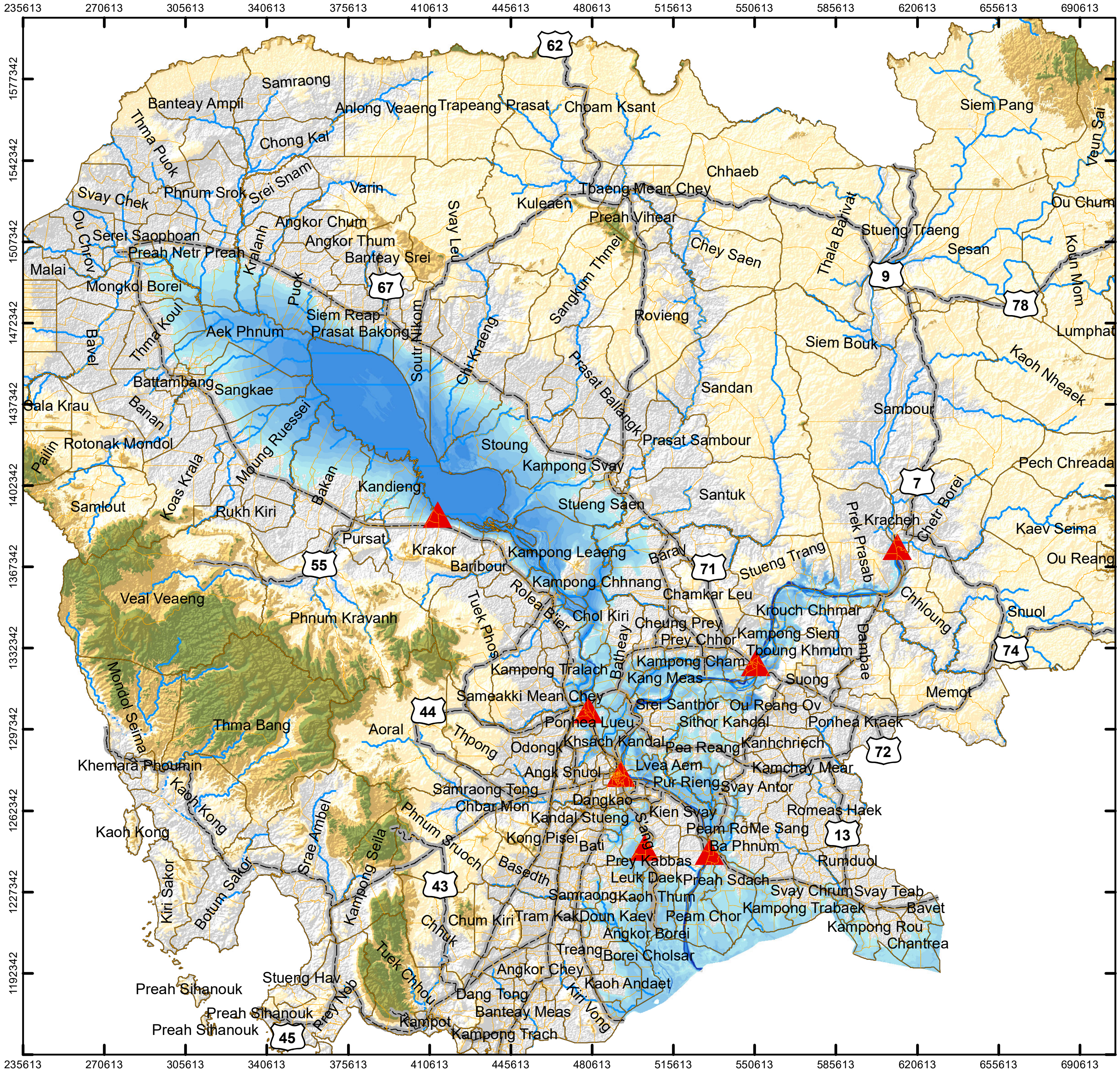
GMS-GDRMMP-CS.003

National Flood Forecasting Center (NFFC)

Maximum Flood Extent Map for 5 Years Return Period for Cambodia





Legend

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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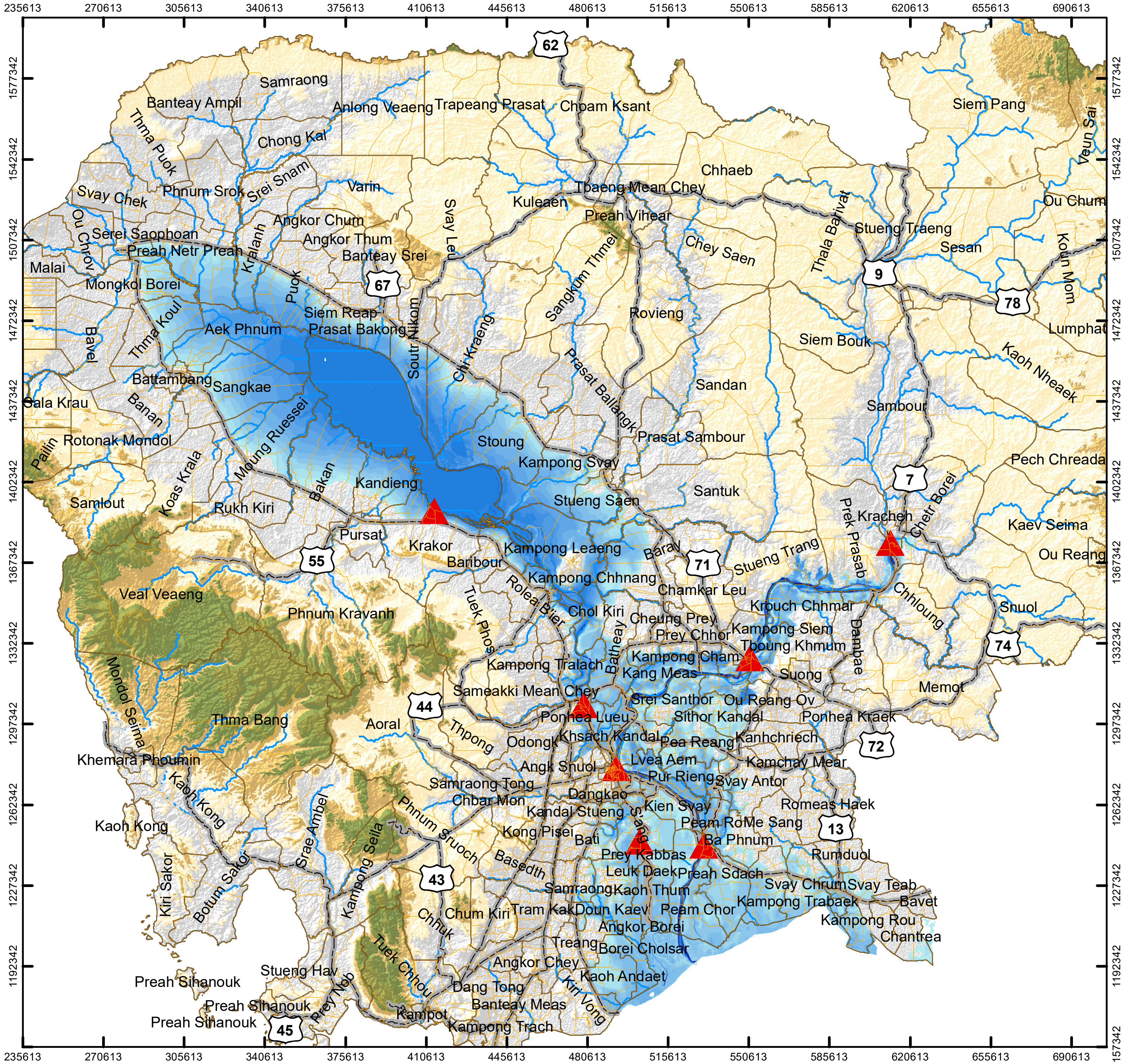
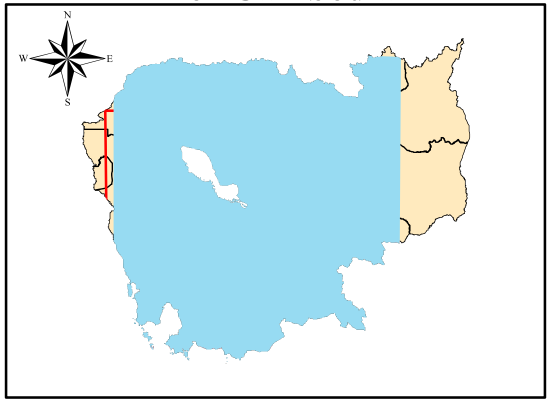
Maximum Flood Extent Map for 10 Year Return Period for Cambodia





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-19
- 20-29
- 30-39
- 40-47

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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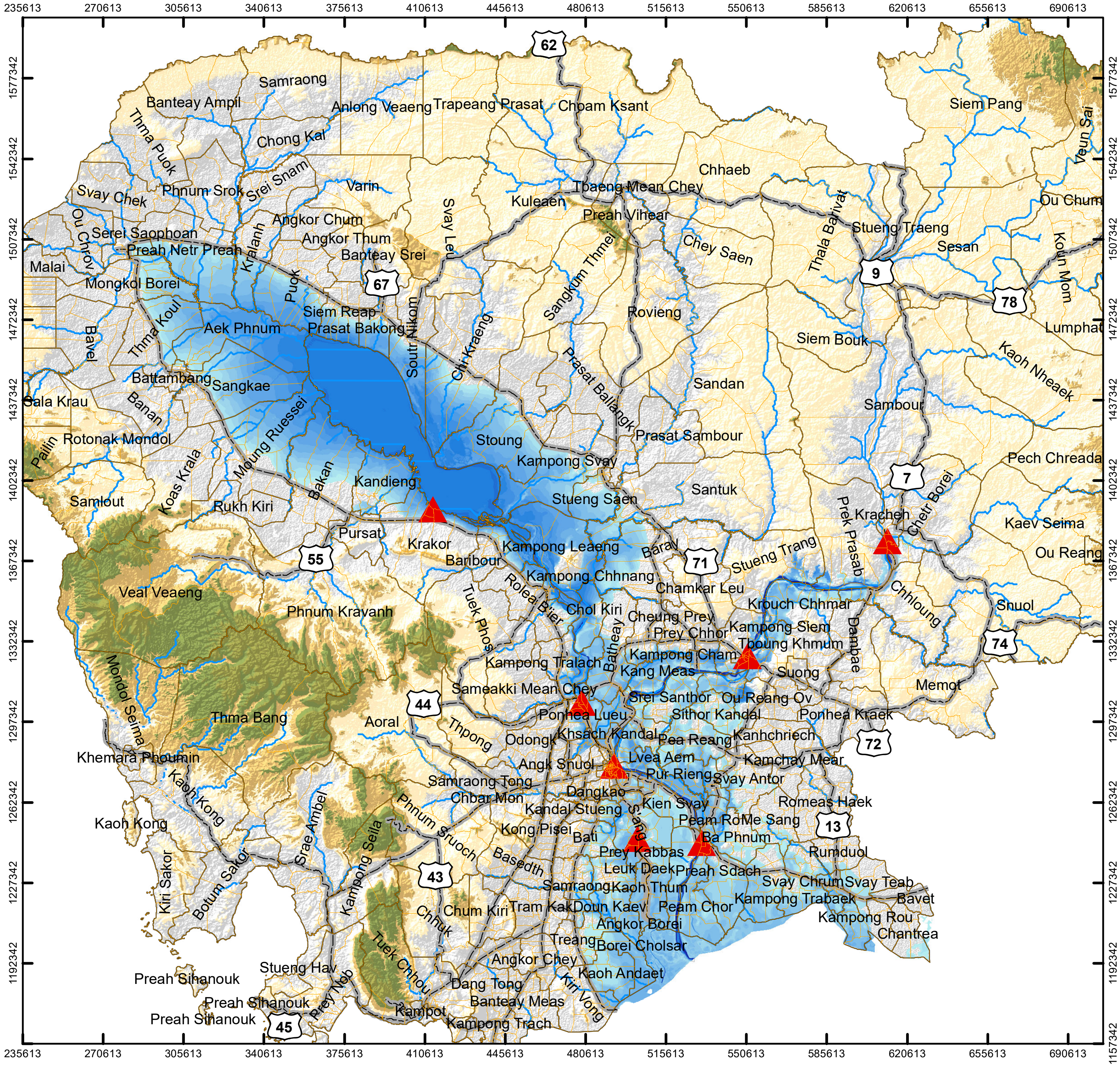
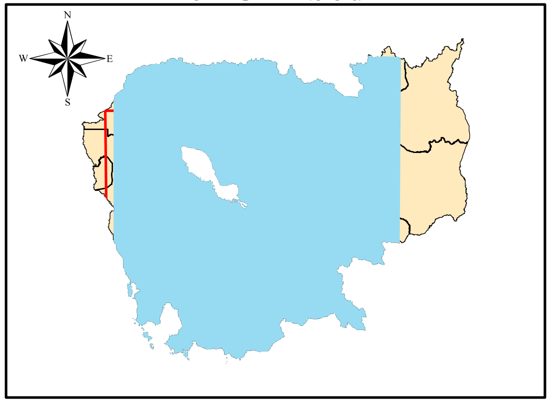
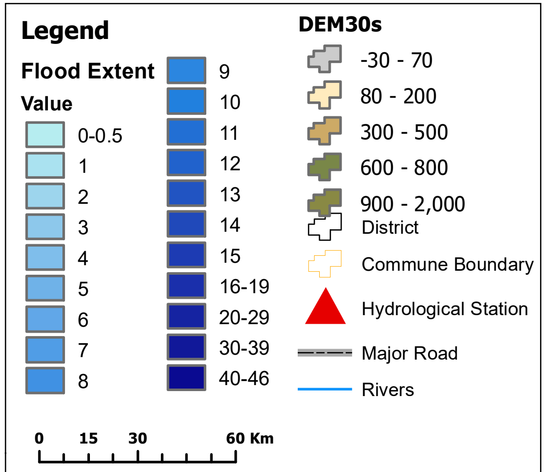
Maximum Flood Extent Map for 20 Years Return Period for Cambodia







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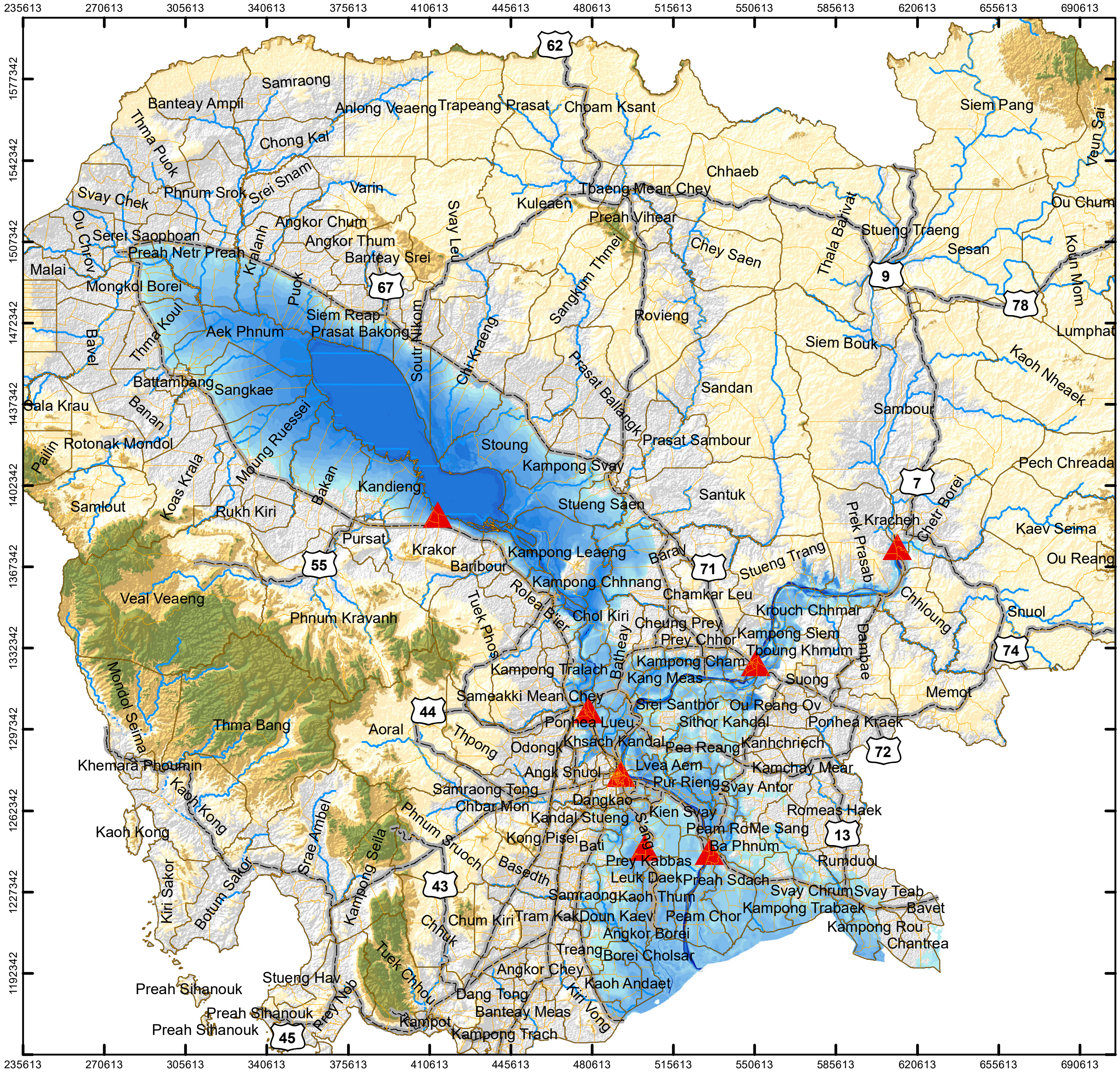
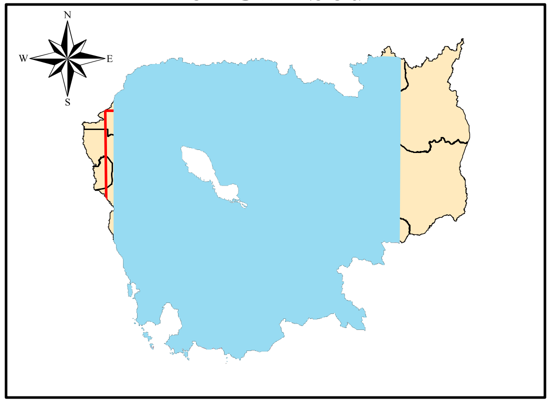
Maximum Flood Extent Map for 25 Years Return Period for Cambodia





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-19
- 20-29
- 40-48

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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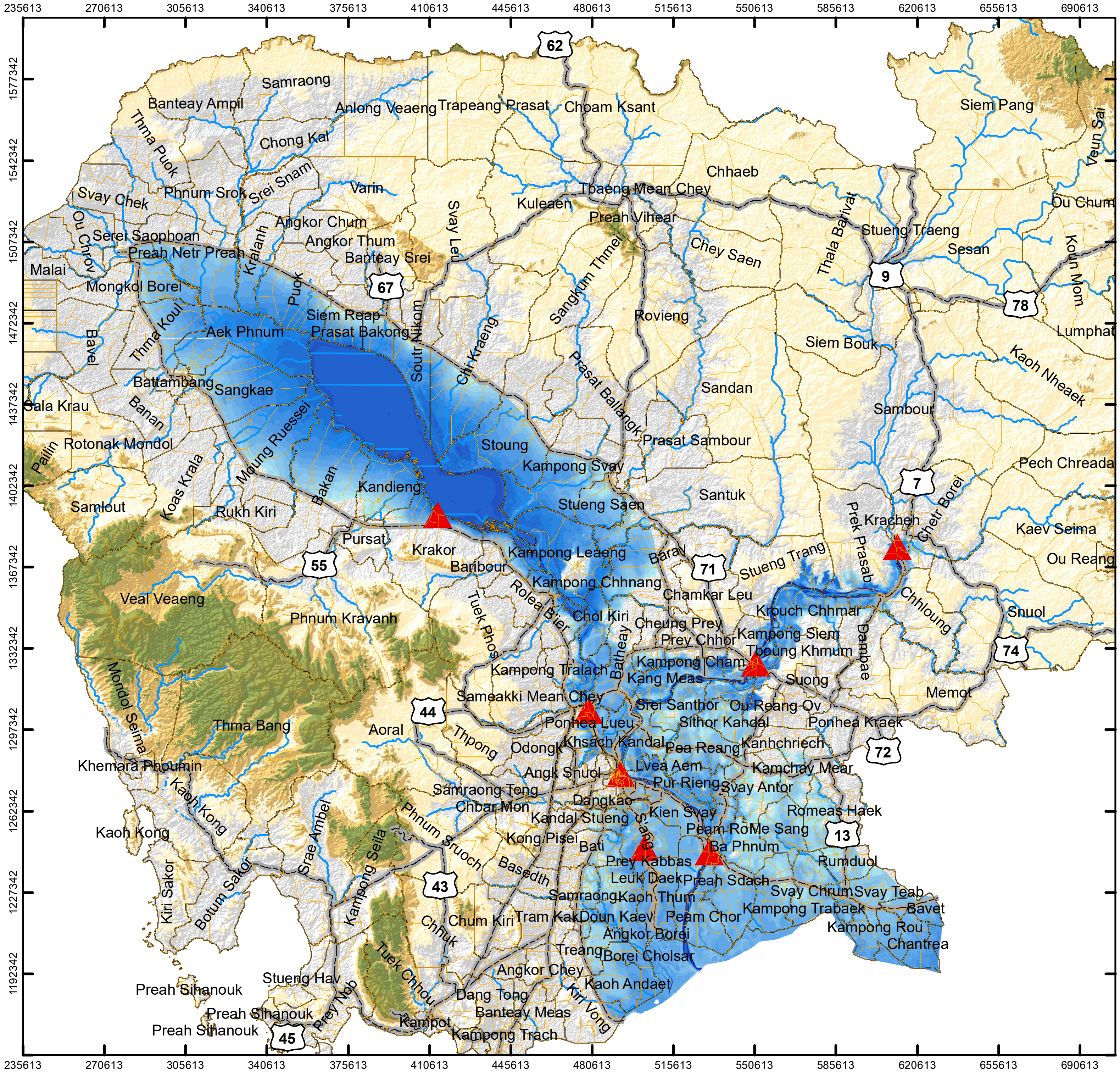
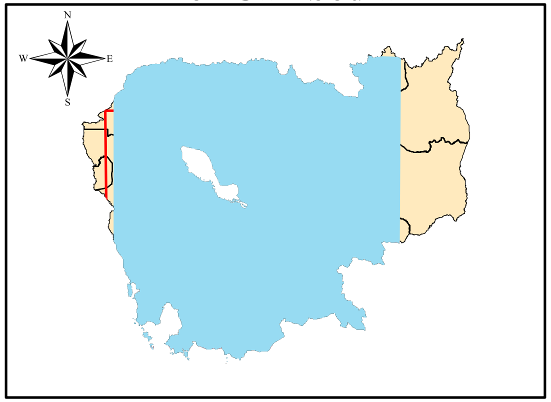
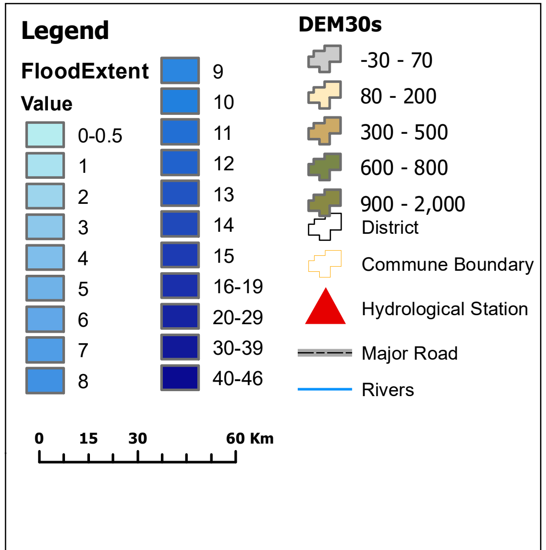
Maximum Flood Extent Map for 50 Years Return Period for Cambodia







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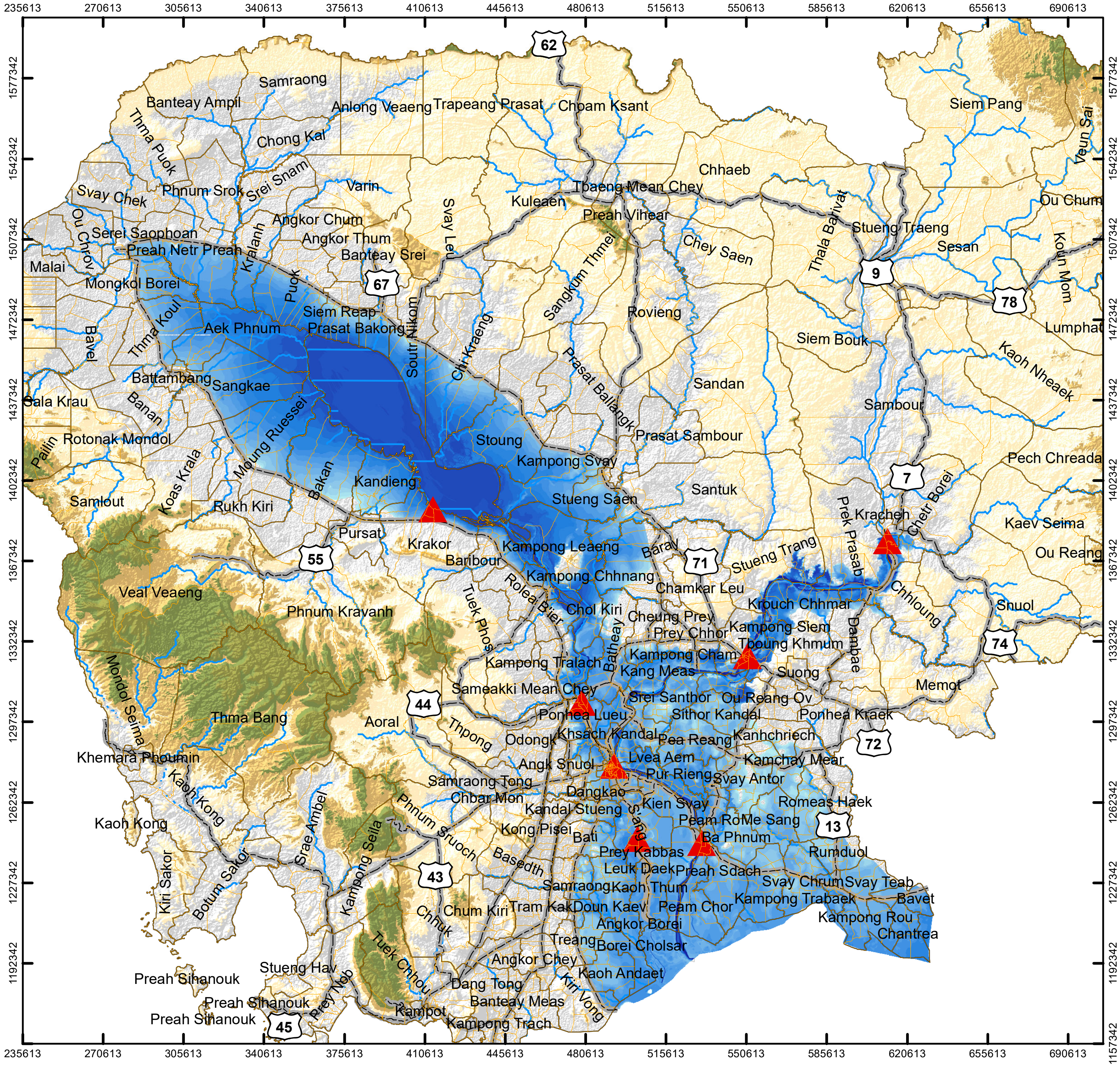
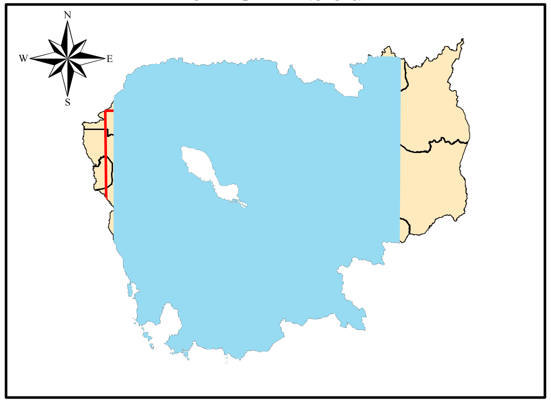
Maximum Flood Extent Map for 100 Years Return Period for Cambodia





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-19
- 20-29
- 30-39
- 40-52

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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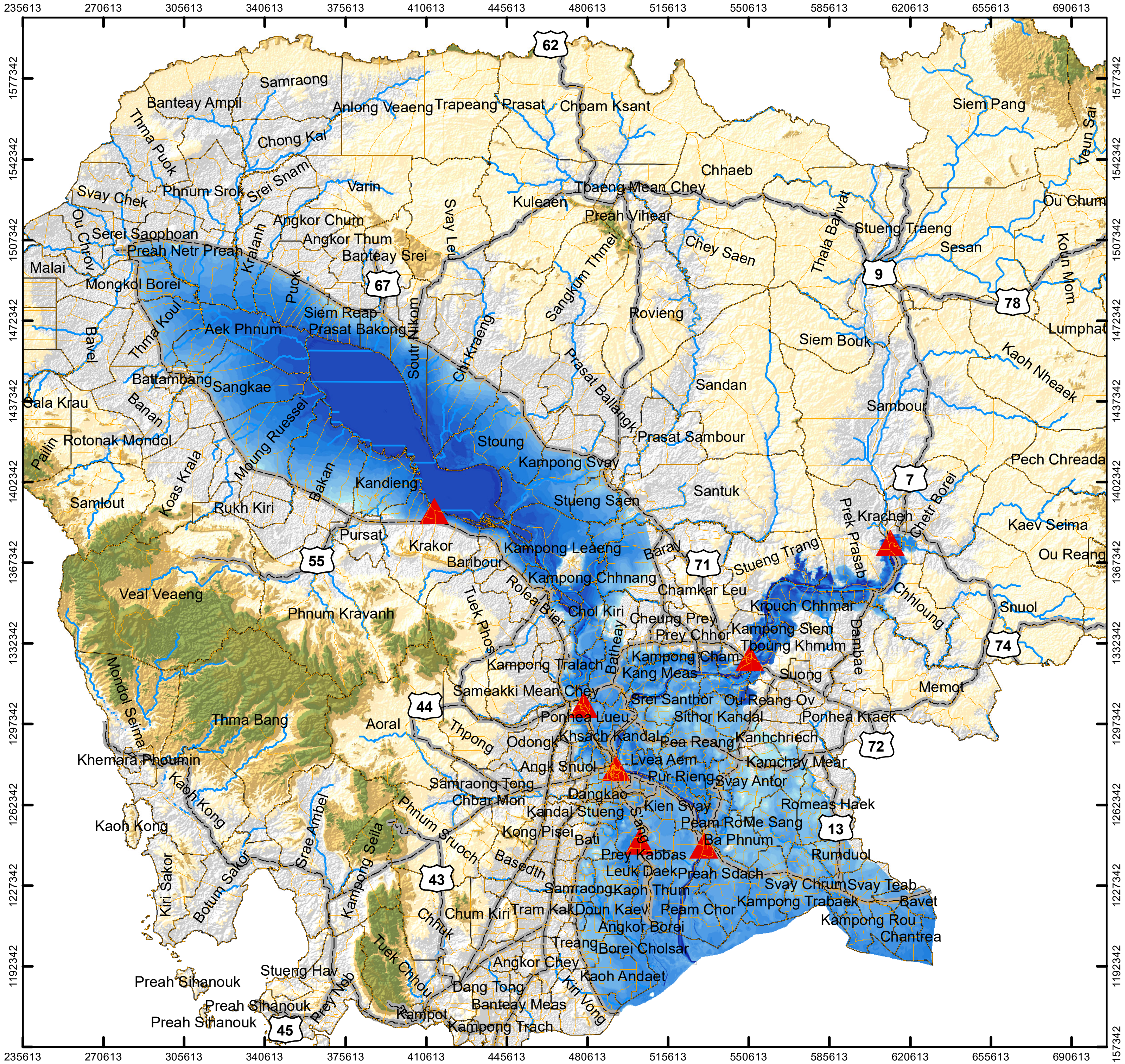
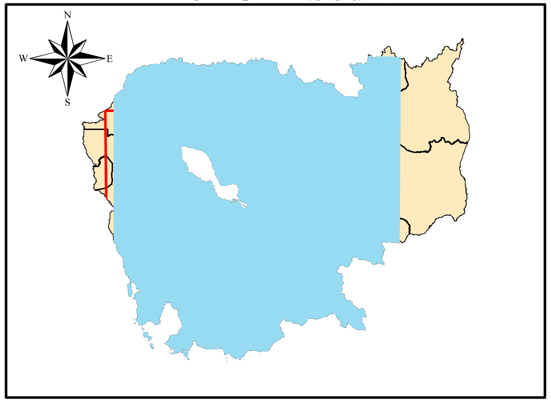
Maximum Flood Extent Map for 200 Years Return Period for Cambodia





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-19
- 20-29
- 30-39
- 40-53

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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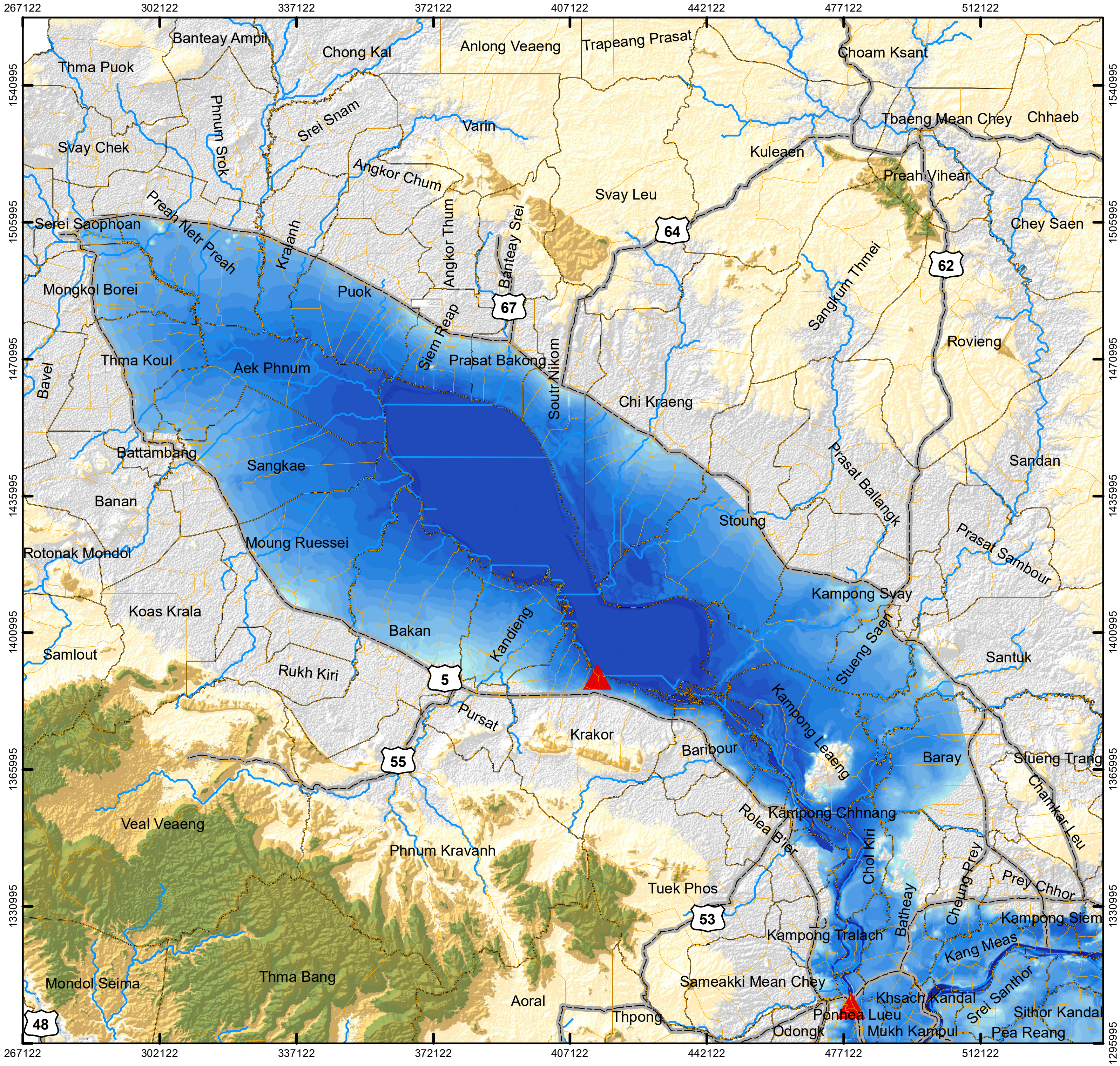
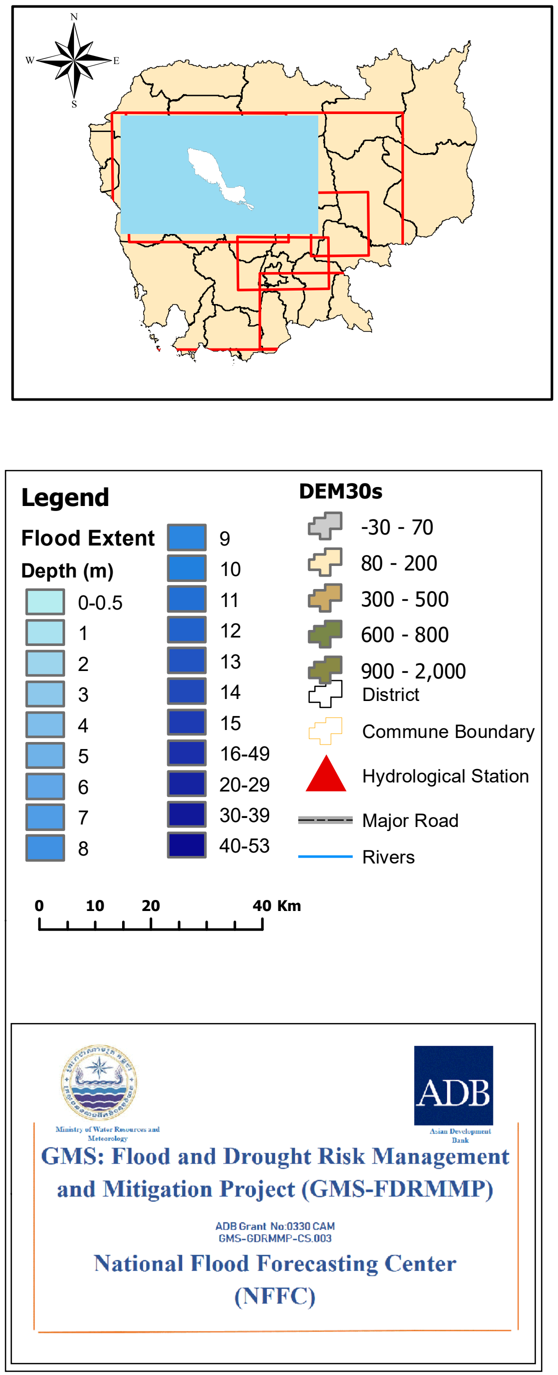
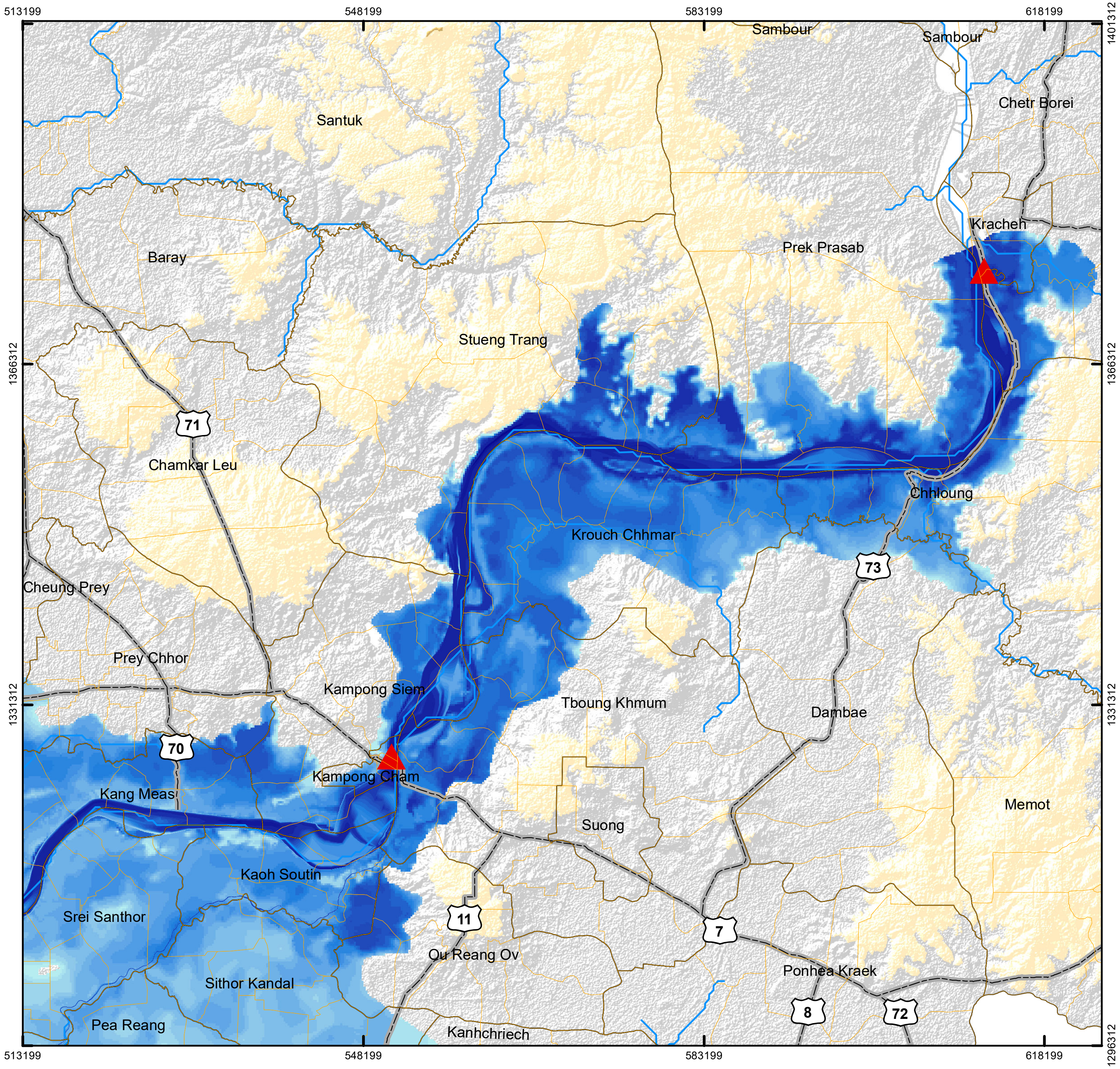
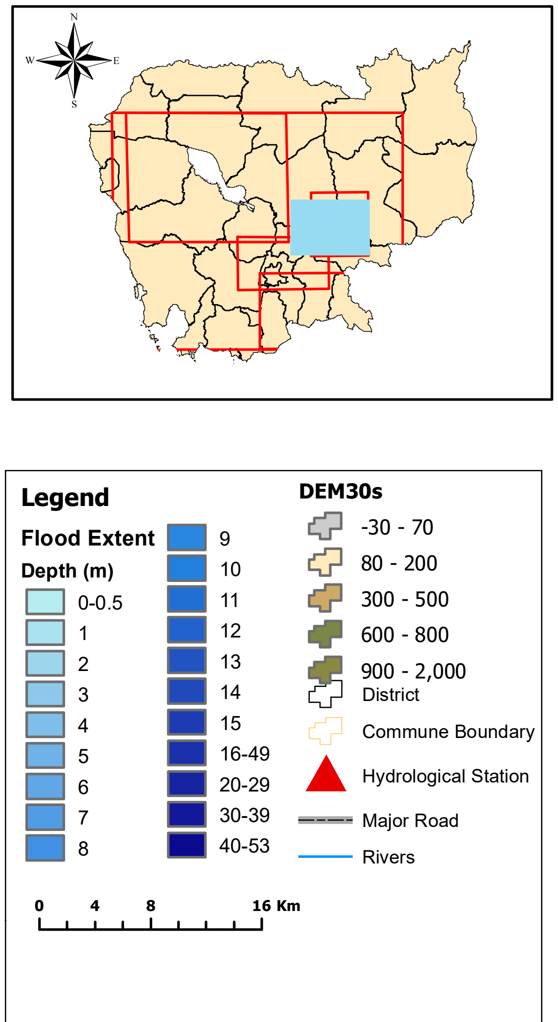
Maximum Flood Extent Map in 2000 for Tonlesap Area





Maximum Flood Extent Map in 2000 for Upper Mekong Area





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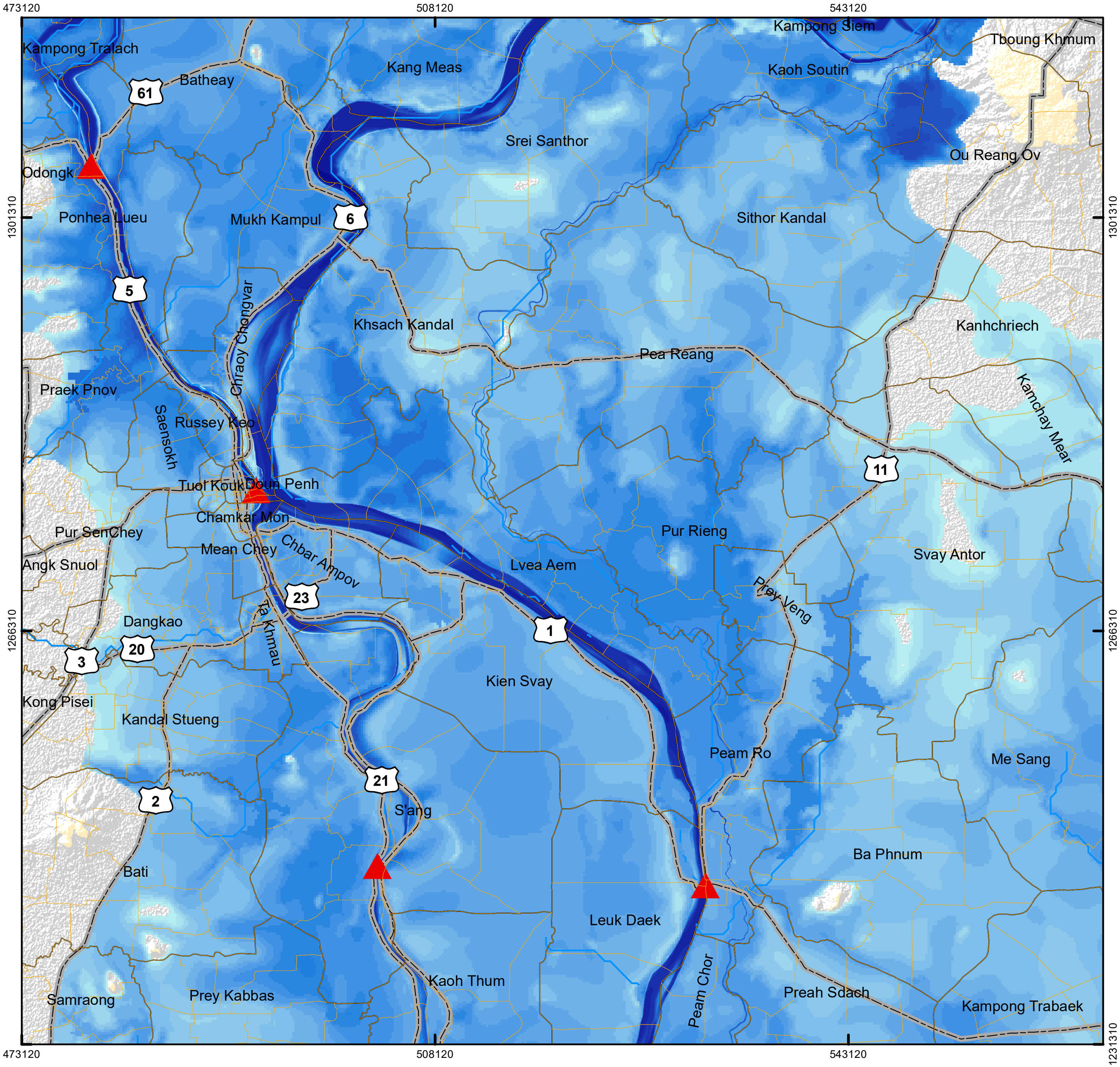
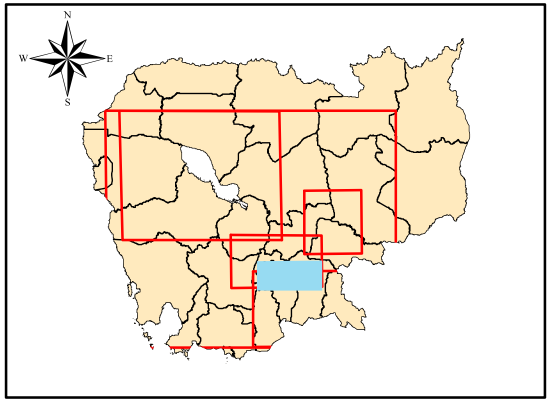
Maximum Flood Extent Map in 2000 for Phnom Penh Area





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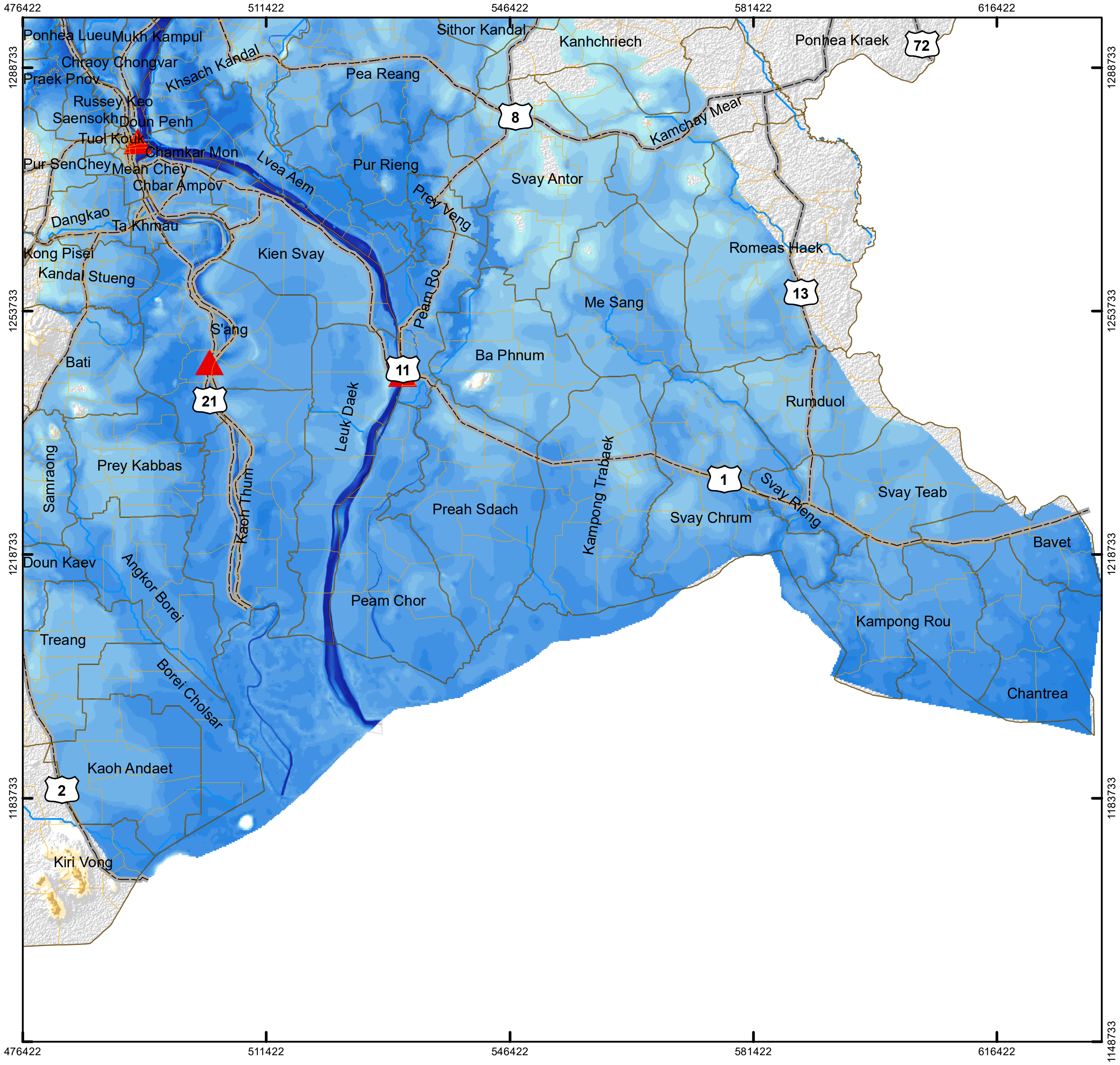
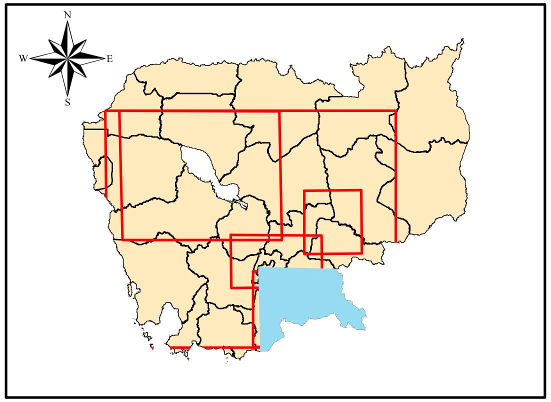
National Flood Forecasting Center (NFFC)

Maximum Flood Extent Map in 2000 for Lower Mekong Area





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-49
- 20-29
- 30-39
- 40-53

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 5 10 20 Km

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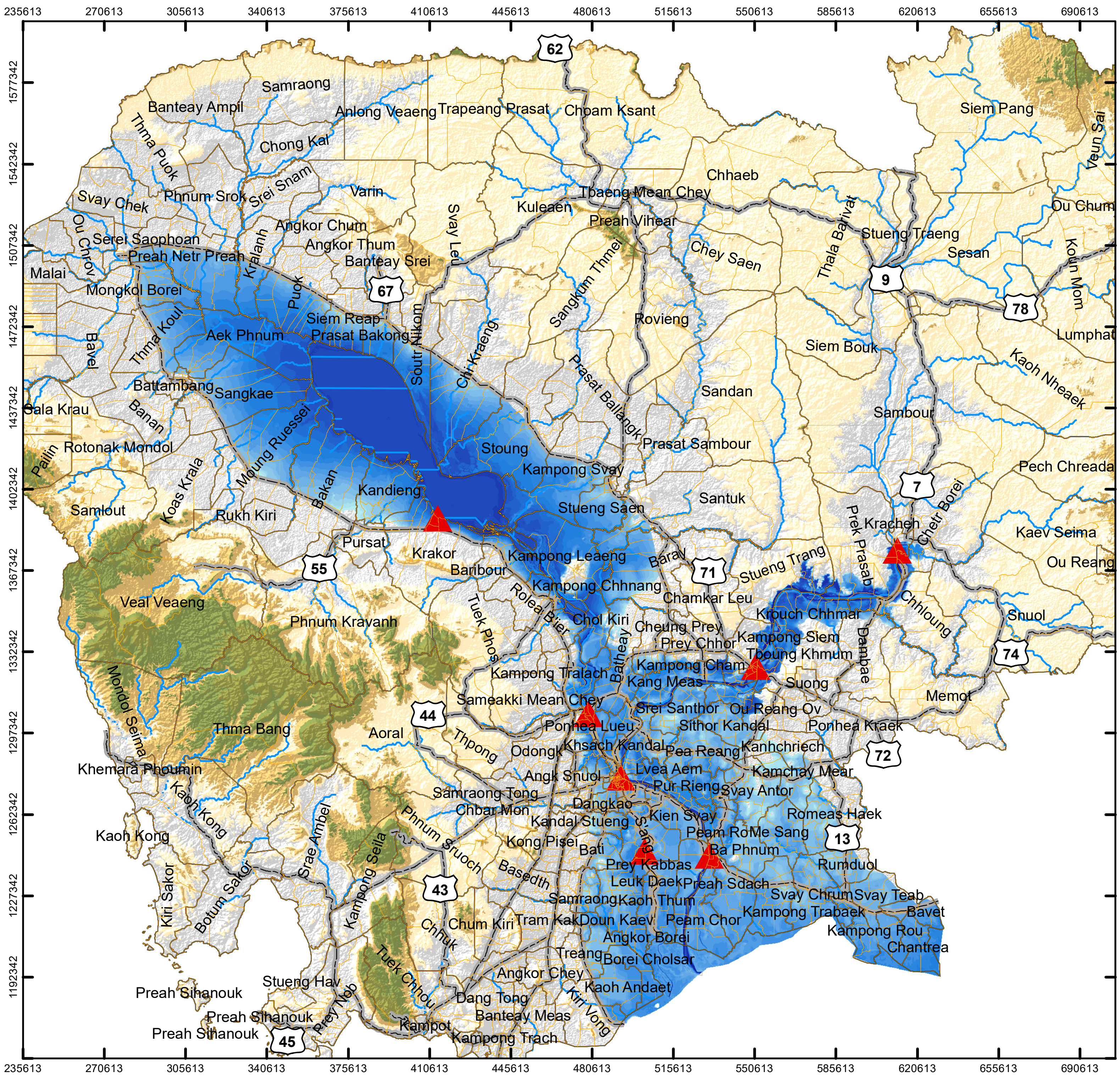
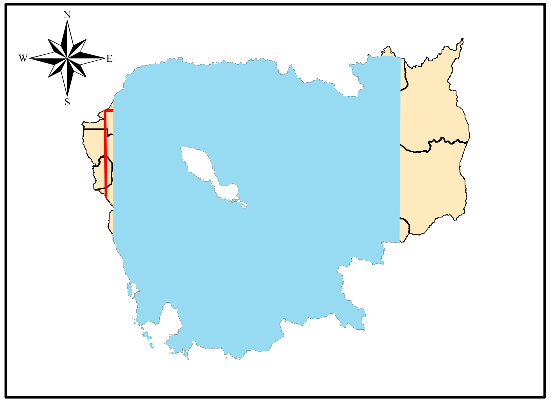
Maximum Flood Extent Map in 2000 for Cambodia





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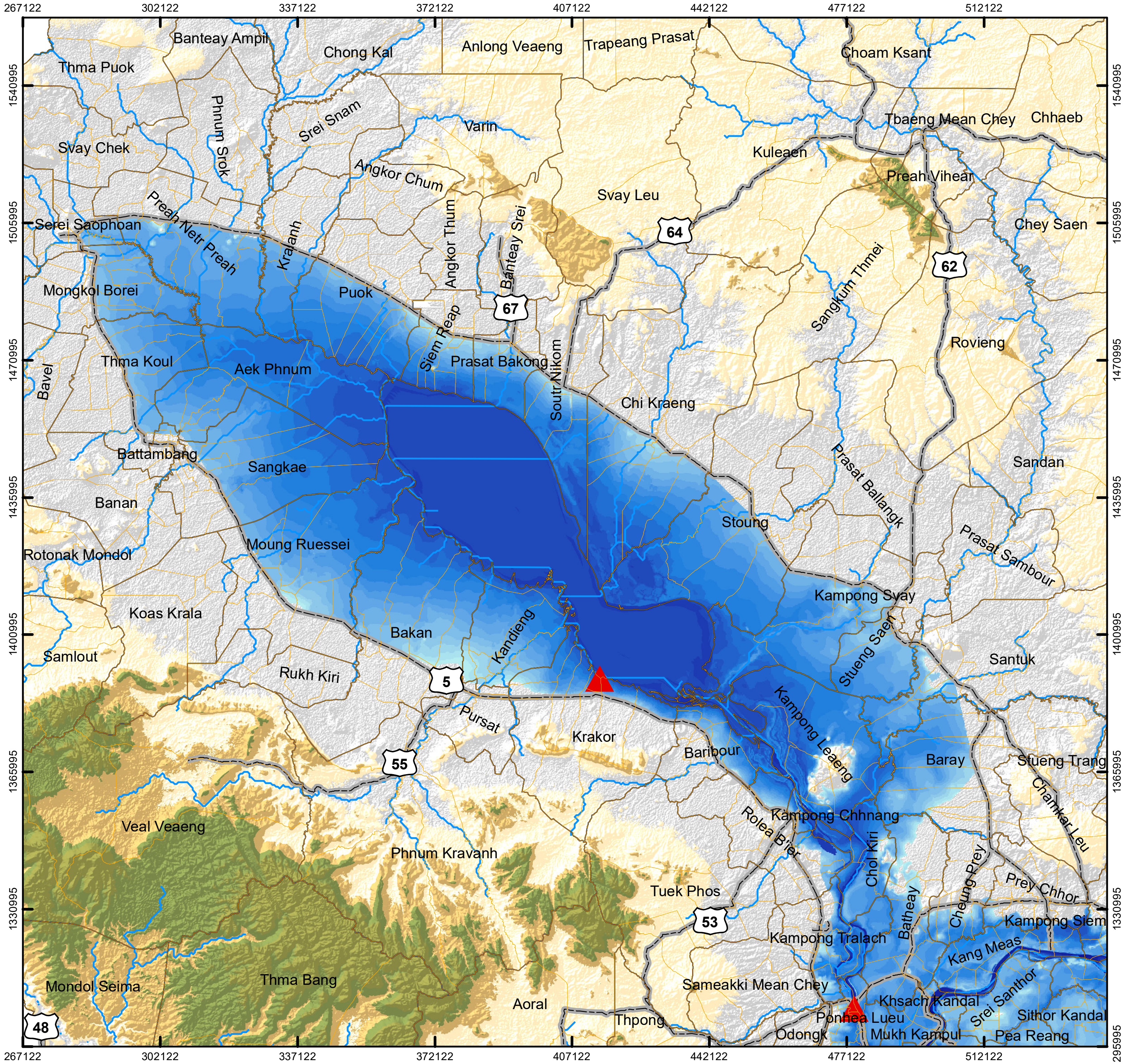
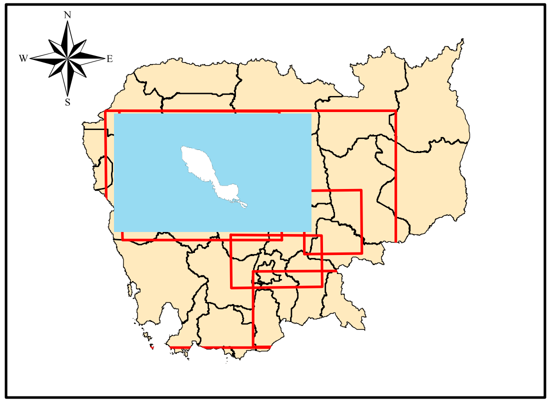
ANNEX 2 Details Flood Extent Maps NFFC for the Baseline Year 2000

Maximum Flood Extent Map in 2000 for Tonlesap Area





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-49
- 20-29
- 30-39
- 40-53

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 10 20 40 Km

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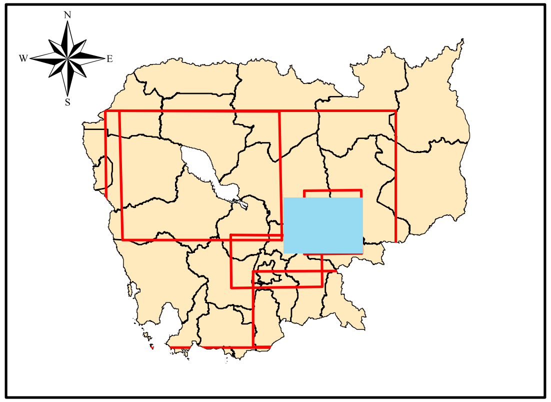
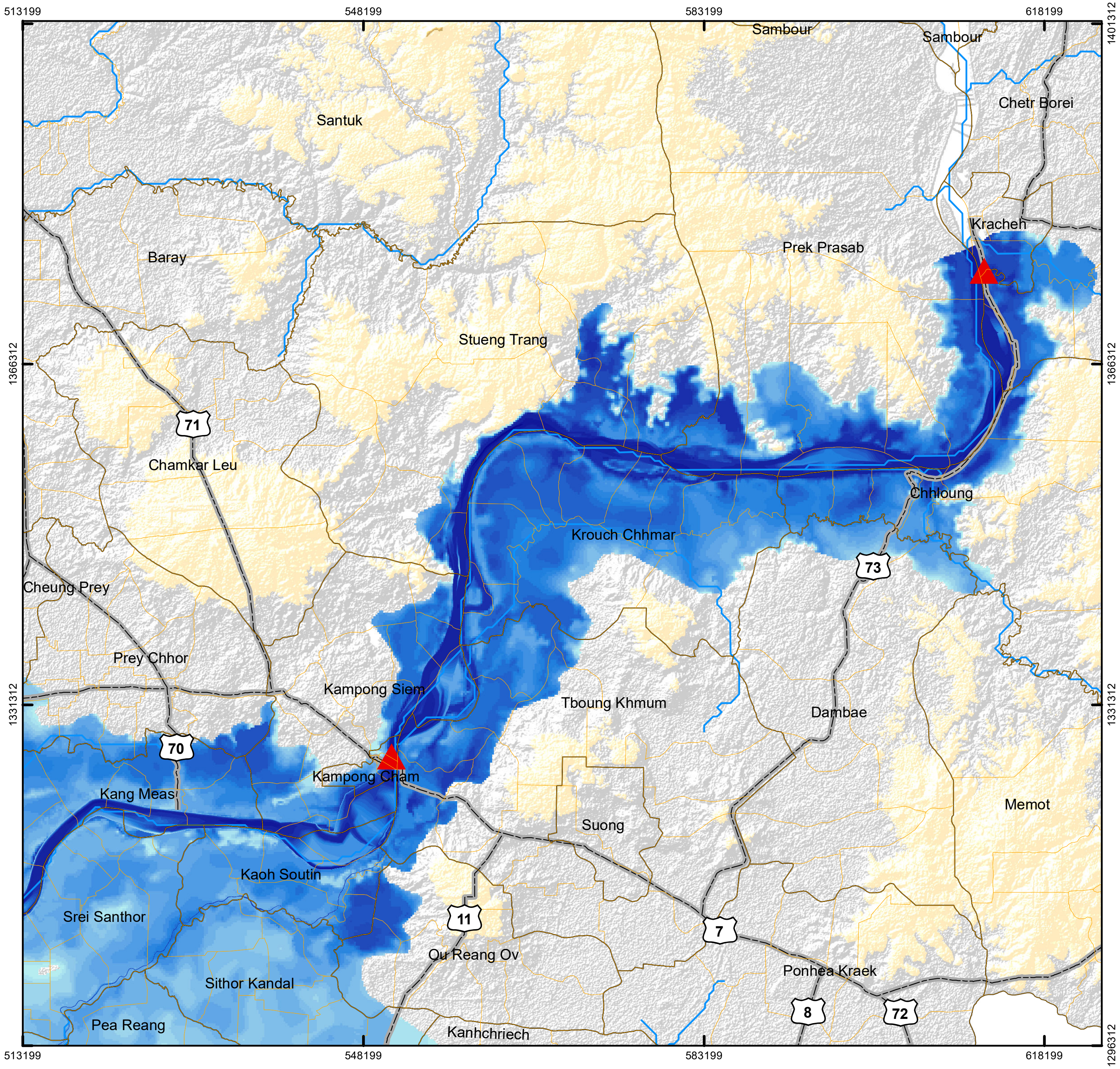
Maximum Flood Extent Map in 2000 for Upper Mekong Area





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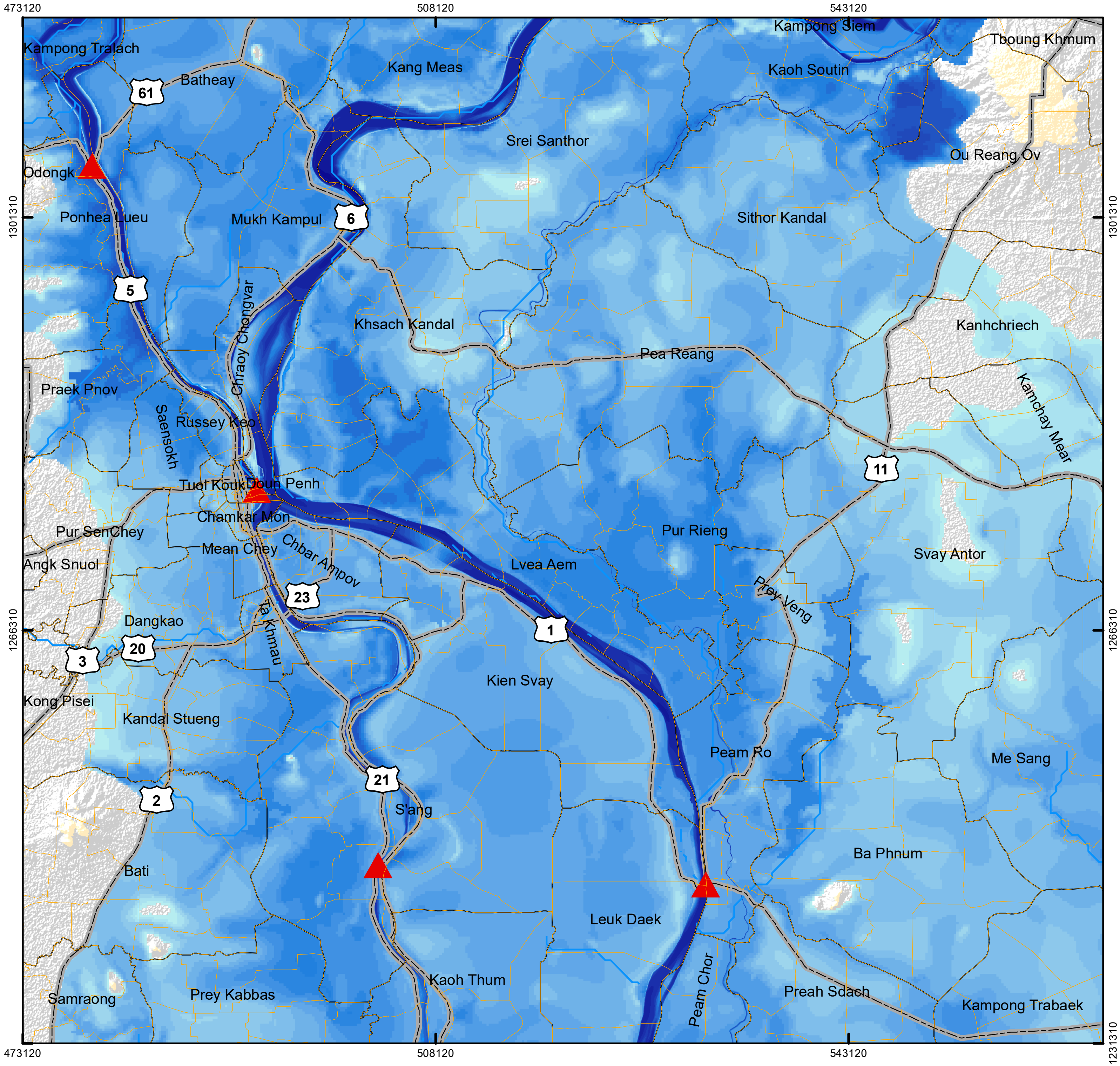
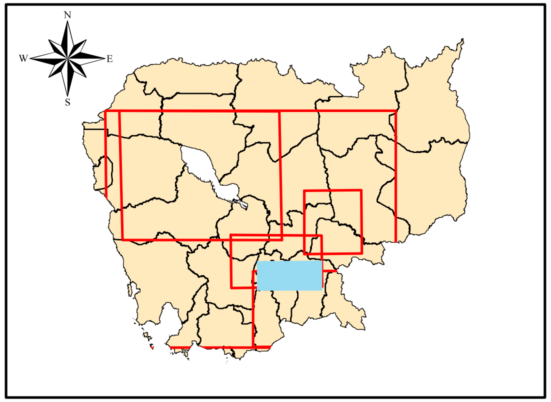
Maximum Flood Extent Map in 2000 for Phnom Penh Area





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-49
- 20-29
- 30-39
- 40-53

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000
- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 3.25 6.5 13 Km

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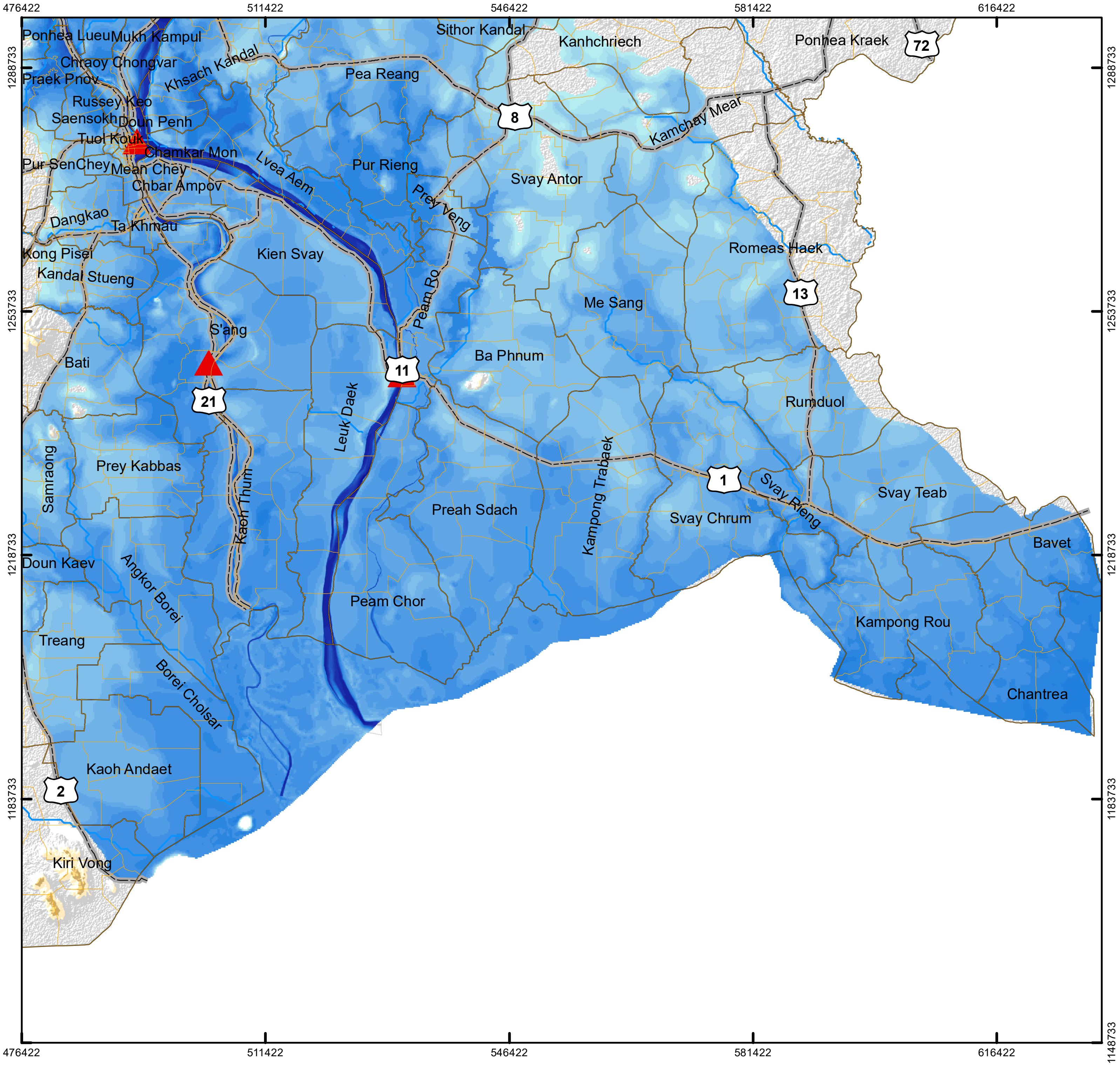
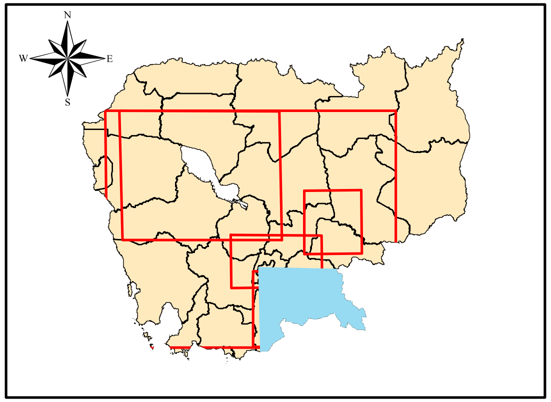
Maximum Flood Extent Map in 2000 for Lower Mekong Area





Legend

Flood Extent

Depth (m)

0-0.5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16-49
20-29
30-39
40-53

DEM30s

-30 - 70
80 - 200
300 - 500
600 - 800
900 - 2,000
District
Commune Boundary
Hydrological Station
Major Road
Rivers

0 5 10 20 Km

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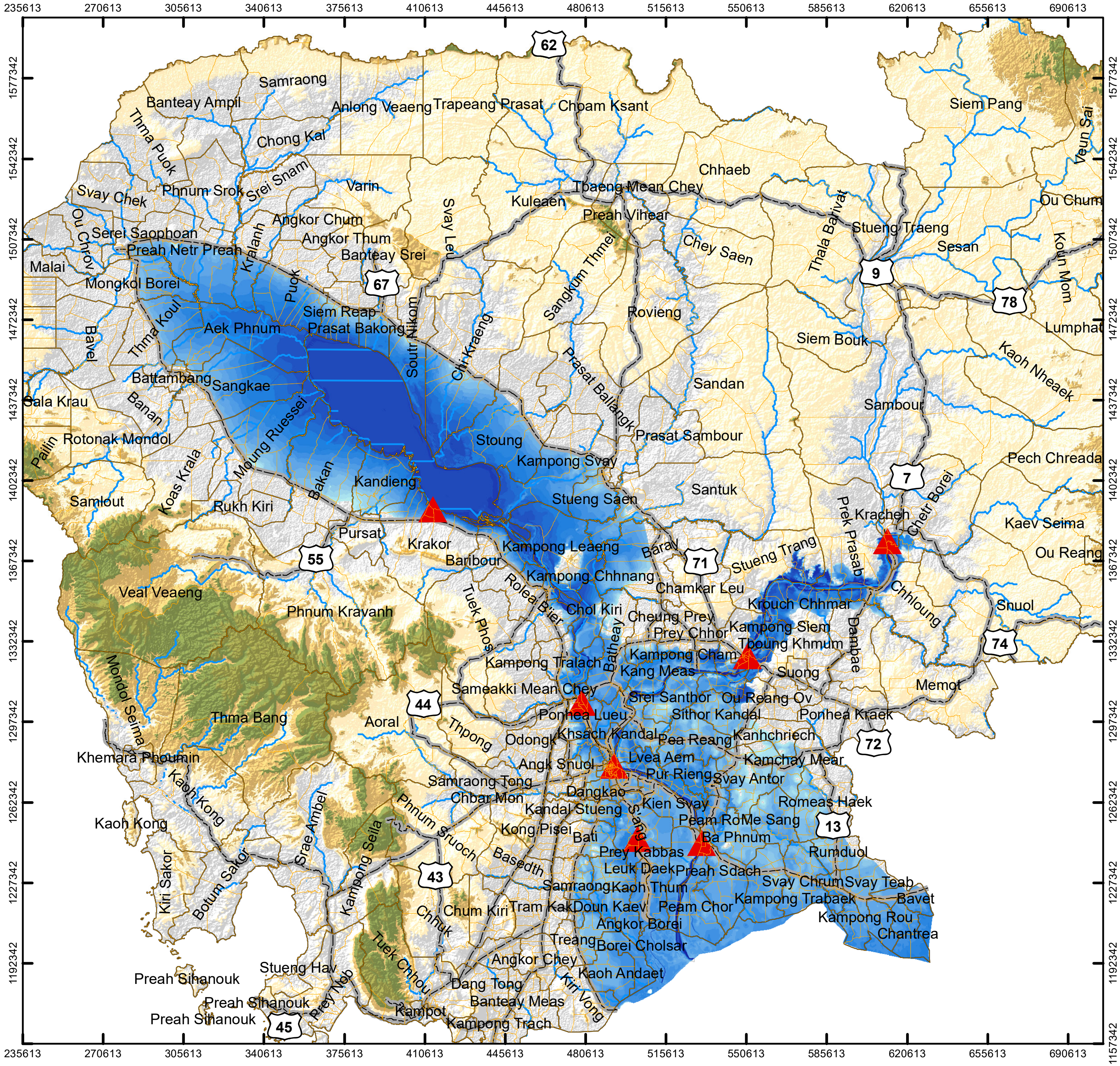
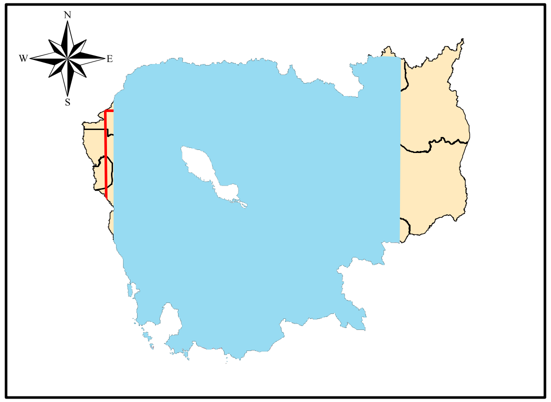
Maximum Flood Extent Map in 2000 for Cambodia





Legend

Flood Extent

Depth (m)

- 0-0.5
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16-49
- 20-29
- 30-39
- 40-53

DEM30s

- -30 - 70
- 80 - 200
- 300 - 500
- 600 - 800
- 900 - 2,000

- District
- Commune Boundary
- Hydrological Station
- Major Road
- Rivers

0 15 30 60 Km

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