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

Consulting Services for Support to the National Flood Forecasting Centre and to Improve Hydraulic Design Standards

Contract Number: GMS-FDRMMP-CS-003

INCEPTION REPORT

Prepared By:

NFFC Consultant Team of EPTISA and KCC

eptisa KEY CONSULTANTS (CAMBODIA) LTD.

Phnom Penh, CAMBODIA

May 2016

Document history

Version	Remarks	Date
Draft Report	Draft submitted for review	March 02 2016
Final Draft	Final Draft submitted for review	May 16 2016
Final	Incorporated all final comments from CPMU, PIU/DHRW, PIC and ADB	May 27 2016

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

ADB	Asian Development Bank
AusAID	Australian Agency for International Development
AWS	Automatic Weather Station
BDP	Basin Development Plan
CBDRM	Community Based Disaster Risk Management
CBOs	Community-Based Organization
CNMC	Cambodian National Mekong Committee
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
EIA	Environmental Impact Assessment
EWS	Early Warning System
GFDRR	Global Facility for Disaster Reduction and Recovery
GMS	Greater Mekong Sub-Region
GTZ	German Technical Cooperation
ICT	Information and Communications Technology
IDPs	International Development Partners
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
NFFC	National Flood Forecasting Centre
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
RGC	Royal Government of Cambodia
SEA and SSA	Strategic Environmental and Social Assessment
SOPs	Standard Operating Procedures
TA	Technical Assistance
TSA	Tonle Sap Authority
WB	World Bank
WBS	Work Breakdown Structure
WMO	World Meteorological Organization
WUAs	Water User Associations

1. Introduction

1. The Asian Development Bank (ADB) is assisting the Royal Government of Cambodia (RGC) by providing support for the National Flood Forecasting Centre and for the development of hydraulic design standards for flood protection. The support is being provided under the umbrella of the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project.

2. The Greater Mekong Sub-Region Flood and Drought Management and Mitigation Project (GMS-FDMMP) supports the Royal Government of Cambodia to prepare and undertake structural and non-structural measures for the improved management of disaster risks linked to floods and droughts. The project goals are (i) enhanced regional data and knowledge for the management of floods and droughts; (ii) upgraded or new water management infrastructure; and (iii) better prepared communities to manage disasters, such as flood and drought, and to adapt to climate change.

3. The focus of the project is to support the RGC undertake measures to better forecast floods and droughts and to better design structural and non-structural measures with the objective of reducing the negative effects that these disasters cause. The project objective is to strengthen the National Flood Forecasting Centre (NFFC) and to enhance regional data, information, and knowledge for the improved management of risks associated with floods and droughts. As well, the project is to propose climate resilient design guidelines for structural flood and drought control measures in Cambodia.

4. The Ministry of Water Resources and Meteorology (MOWRAM) is the Executing Agency (EA) and the Department of Hydrology and River Works is the Implementing Agency (IA) for the project. Although not identified as an Implementing Agency, the Department of Meteorology is a key stakeholder and will be actively engaged during the conduct of the project. The Central Project Management Unit (CPMU) and Project Implementation Consult (PIC) will be regularly consulted and advised of progress during the project. Coordination and collaboration with related projects under the Greater Mekong Sub-Region (GMS) Flood and Drought Management and Mitigation Project will be fostered through the CPMU.

5. The purpose of the consulting services being provided by EPTISA is to:

i. Assess the hydrometeorological network and data acquisition system required for flood forecasting and early warning in the major tributaries and to implement priority network and data acquisition improvement activities;
ii. Assess the current forecasting capacity and propose necessary flood and drought forecasting tools (hydrological and hydraulic models, rainfall forecasting including regional storm tracking and satellite based rainfall estimates);
iii. Assist in the preparation of specification for procurement of equipment, instruments and tools for the NFFC;
iv. Develop and pilot an operational strategy for disseminating nationwide flood forecasting and early warning at the community level;
v. Provide necessary trainings and capacity development for sustainable operation of the NFFC including recommendations of the institutional setup of the NFFC and within the Department of Hydrology and River Works (DHRW);
vi. Provide guidance to improve coordination and sharing of national forecast data in support of regional forecasting and vice-versa;
vii. Conduct a hazard and risk assessment of the impact of floods and droughts for different probabilities;
viii. Evaluate the residual risk for varying degrees of protection;
ix. Estimate of the cost of infrastructures related to flood and drought proofing for floods and droughts of different frequencies;

x. Develop design criteria for structural flood and drought control in the Mekong area (and elsewhere) in Cambodia; and

xi. Provide guidelines for climate resilient design of structures in the Mekong area (and elsewhere) of Cambodia.

6. EPTISA will provide support to the National Flood Forecasting Centre (NFFC) by installing hydrometeorological stations and by developing a flood forecasting and early warning system. The Ministry's existing flood and drought forecasting and early warning strategy will be reviewed and an updated strategy drafted and piloted at the community level through an awareness program. A mock drill will be designed and conducted to test the overall early warning and response system and to test early warning procedures, response, and coordination at the local, district, provincial, national, and regional levels. Training and capacity building support will be provided to the NFFC on the operation and maintenance of the hydrometeorological stations and the flood forecasting and early warning system.

7. In addition to strengthening the NFFC, EPTISA will assist the Department of Hydrology and River Works with the development of climate resilient design criteria and guidelines for flood and drought protection and mitigation measures.

8. As requested by MOWRAM, the area for improved flood modelling in support of forecasting and early warnings will be one tributary basin as well as the mainstream Mekong. This approach will enable the flood modelling and drought prediction approach to be expanded in the future to all major tributaries in Cambodia as resources permit. As well the scope of the study area was discussed during the ADB Review Mission of April 05 to 11, 2016. The Aide Memoir of the mission notes that a hydrodynamic simulation model with a reasonable level of accuracy will be developed for the entire reach of the Mekong River in Cambodia, Tonle Sap River, and the Pursat tributary basin.

2. Project Context

9. Cambodia (**Figure 1**) is situated in the south-western part of Indochinese peninsula, bordered by Thailand and Lao PDR to the North, Vietnam to the East and South, and the Gulf of Thailand to the West. The area of Cambodia is 181,035 km^2. About 75% of the country is located at elevations of less than 100 metres above mean sea level (msl), and its topography can be grouped into three types: (i) the low swampy region around Tonle Sap Great Lake and the rivers valleys of Mekong and Bassac River; (ii) the mountainous and highland area including a plateau region in the northeast and east of the Mekong River; and (iii) the coastal zone in the west covering the Kompot, Koh Kong, and Preah Sihanouk Provinces.

Figure 1: Location Map - Cambodia

10. Cambodia's population is predominantly rural based and most of the population is subsistence farmers or fishers. As a result, natural hazards have drastic effects on its population and pose a serious challenge for water resources management and poverty alleviation in the country.

11. Floods, droughts, and extreme weather are the dominant hazards in Cambodia and cause loss of life, damage agricultural production, and threaten livelihoods. As a result, flood and drought risk is one of the most significant factors to consider when addressing poverty reduction and economic development in Cambodia. Consequently, flood and drought proofing as well as climate adaptation strategies to reduce risks from floods and droughts are key priorities for sustainable development, ensuring the health and safety of the population, and maintaining environmental integrity.

12. The occurrence of significant flood events and periods of droughts has increased in recent years. The increase of these severe events tends to support climatic change predictions, which suggest there will be increased variability in the climate with an increase in the occurrence of more extreme weather events as the earth warms. The effect of any increase in extreme flood and drought events will directly affect vulnerable populations, exacerbate food insecurity, and result in an increase in related damages. These factors all have a direct constraining influence on poverty alleviation efforts.

13. The monsoon season for the Mekong River basin typical begins in June and persists to late October. Rainfall during this period accounts for 80 to 90% of the total annual flow of the Mekong River (MRC 2010).

14. The annual flood season plays a vital role in agriculture and in supporting environmental integrity. The annual flood pulses sustain the productivity of low-lying agricultural land as well as of the world-renowned Mekong freshwater fisheries. The average annual benefit of the flood pulse is estimate to be US$8 to US$10 billion.

15. While annual floods have significant benefits, severe flooding can cause significant damage to communities, infrastructure, and agriculture crops, disrupt economic activities, endanger human health, and result in loss of life. Examples are Typhoon Ketsana in 2009, and Typhoons Haima and Nok Teng in 2011. The average annual cost of the resulting floods in the Lower Mekong Basin is estimated to be US$60 to US$70 million.

16. An important consideration with respect to floods and droughts in Cambodia is the transboundary nature of the Mekong River basin. Much of the floodwaters in Cambodia are derived from upstream countries, including Vietnam, and in some provinces floods and droughts occur within the same season. Therefore, effective flood and drought management hinges on regional cooperation, information sharing, and the development of region-specific solutions.

17. When considering the benefits and cost of floods, the challenge of flood management and mitigation is to reduce the costs and negative impact of flooding while preserving flood benefits.

18. Unlike floods, droughts have less apparent benefits. Drought can result in food and water shortages, loss of income, and higher levels of disease. Droughts are damaging to agriculture, especially rice, and can result in a total loss of crops, livestock, and fisheries. Given the relatively high frequency of severe drought in the Lower Mekong basin, the cost of droughts is significantly higher than the cost of flooding and provide no apparent benefit. As the climate warms, the cost of droughts is expected to increase and will continue to be greater than those of flooding.

19. In response to the threat of floods and droughts, efforts are being made by the Mekong River Commission and its Member Countries to devise strategies that aim to decrease the vulnerability of people in the Mekong basin, especially in agricultural communities. As well, the Government of Cambodia has increased its effort to improve natural disaster preparedness.

20. **Figure 2** shows the major basin group in Cambodia defined with support under the ADB TA 7610-CAM: "Supporting Policy and Institutional Reforms for Capacity Development in the Water Sector Program", April 2014.

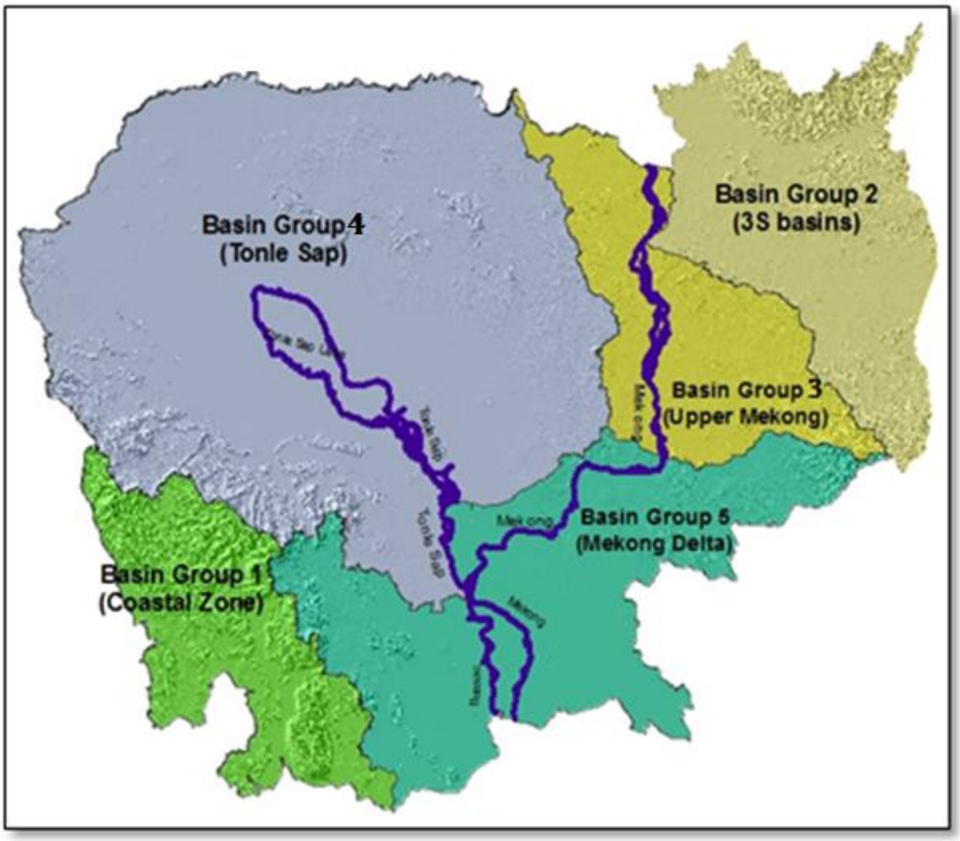


Figure 2: River Basin Groups in Cambodia. Source: ADB CDTA-CAM 7610, 2014

3. Institutional Setting

3.1 Ministry of Water Resources and Meteorology

21. The Ministry of Water Resources and Meteorology (MOWRAM) was established in 1999 based on proclamation NS/RKM/0699108, dated June 23 1999. MOWRAM is responsible for monitoring and managing all activities related to water resources and meteorology, and plays a key role in the mitigation of water-related hazards. MOWRAM has the lead role for the implementation of the Law on Water Resources Management, 2007.

22. The main objectives of MOWRAM under the Law with respect to policy and scientific issues are:

- Carry out scientific research on the potential of underground and surface water resources to establish scientific knowledge;
- Establish a roadmap for the short, medium, and long term with respect to water consumption to fulfil the needs of the country's development and to preserve the needs of urban and rural populations;
- Control and monitor all activities that consume water and to mitigate incurred risks;
- Prepare laws and regulations linked to the use of water and water control procedures;
- Raise awareness with industry, NGOs, civilian communities, and the population on the development and the exploitation of water resources; and
- Provide technical advice to all sectors on sustainable water development.

23. The following are MOWRAM's main duties and responsibilities:

- To define policy and strategy development for water resources – including business development and protection of water resources;
- To develop regulations, legislation, and other measures to ensure sustainable management;
- To research potential water resources including groundwater and weather;
- To develop plans for water development and protection of water resources that ensures alternative livelihoods for urban and rural people;
- To regulate and control the use of water resources directly and indirectly and to minimize natural disasters;
- To collect and record information on meteorology and hydrology, and to use this information to serve national and international needs;
- To prepare a plan for flood control;
- To provide support and technical advice to stakeholders such as the private sector, NGOs, and the community for sustainable water resources decision-making;
- To introduce modern technology through training and propagation;
- To lead all activities related to the Mekong River Basin, and to strengthen and promote national and international cooperation;
- To prioritize water resources management activities to the areas of most need;
- To manage river basins, sub-basins, and groundwater aquifers to protect water use areas and region; and
- To organize the farmer community for more effective participation.

24. Although MOWRAM has strategic planning, research, and monitoring duties to ensure sustainable management of the nation's water resources and to ensure hydrological and meteorological services, to date its main focus has been on irrigation development as a means of supporting the RGC's main priorities of food security and poverty alleviation.

25. Under sub-decree N58 dated June 30 1999, the Ministry of Water Resources and Meteorology was established with nine departments, which has grown to twelve. The organization structure of MOWRAM is classified into three categories as top level, central level, and support level. The top level consists of a Minister, Secretary of State, Undersecretary of State, Cabinet, and Advisors. The central level consists of the Director General of Administration Affairs, Director General of Technical Affaires, and an Internal Auditing Department. The support level consists of departments at the central headquarters as well as in the provinces. In summary, MOWRAM is comprised of six executive management levels:

- Minister;
- Secretaries of State;
- Under Secretaries of State;
- Director Generals;
- Deputy Director Generals; and
- Directors of Departments at the central and provincial government level.

26. Two authorities report to the MOWRAM Minister, the Cambodian National Mekong Committee (CNMC) and the Tonle Sap Authority (TSA).

27. The CNMC is a government body with members from seventeen line ministries and committees and is chaired by the Minister of MOWRAM, assisted by a Secretariat. CNMC plays a crucial role in coordinating activities for the effective implementation of the 1995 Mekong Agreement, and the preparation and implementation of other related projects and programmes of Mekong River Commission (MRC) in the Sustainable Development Framework of Water and related resources in the Mekong River basin. CNMC works with line Ministries, international development partners (IDPs), and international bodies to facilitate and compile information for the overall management of the Mekong River water resources. Specific tasks include facilitating the collection of water resources data, conducting water resources research, and the evaluation of the environmental effectiveness of using water resources.

28. The Tonle Sap Authority's role is to coordinate the management, conservation, and sustainable development of the Tonle Sap region and relevant area, which includes Tonle Lake and the surrounding flooded forests and floodplains. The Authority's goal is to use the economic, environmental, and social attributes of the area to support economic development and increase the standard of living of the poor in the region. Specific tasks are: to facilitate research on ecological systems, fisheries, and irrigation potential; to develop policies, strategic plans, programs and projects; to facilitate the implementation of activities of all agencies; to monitor and evaluate the implementation of projects; to collect, analyse, and update data and information; and to educate stakeholders.

29. The organizational structure of MOWRAM is shown in **Figure 3**.

30. MOWRAM's technical functions are within the Technical Affairs Directorate. In the Technical Affairs Directorate, there are seven operational departments all supported by the Department of Administration and Human Resources (DAHR). The mandates of these seven departments are summarized as follows:

- Department of Water Resource Management and Conservation (DWRMC) – Its mandate covers laws and policies, strategic planning for multi-purpose use of water, catchment planning, water allocation, efficiency of water use, regulations and standards, and research;
- Department of Hydrology and River Works (DHRW) – Its mandate covers all aspects of hydrological measurement and assessment, assessment of surface water and groundwater potential, river level and sediment monitoring, water quality monitoring, river bank protection, modelling, forecasting and warning, reporting, GIS system, and research;
- Department of Meteorology (DOM) – Its mandate covers all aspects of meteorological monitoring and assessment, atmospheric monitoring, forecasting and warning, reporting, international liaison, and research;

- Department of Irrigation and Agriculture (DIA) – Its mandate covers developing and restoring irrigation schemes, O&M of schemes and drainage works, assessing groundwater for irrigation development, saline intrusion in coastal areas, operating pumping stations, leading interventions for water related disasters, and support to FWUCs;
- Department of Engineering (DoE) – Its mandate covers design of works such as irrigation and drainage schemes and flood protection, management of equipment for construction, soil quality assessment for construction, and technological research;
- Department of Water Supply and Sanitation (DWSS) – Its mandate covers surface and groundwater source identification, planning for potable water source developments, planning for sewerage scheme development, and research; and
- Department of Farmers Water Users Committees (DFWUC) – Its mandate covers policy and legal documents, FWUC policy and strategy, irrigation system information, standards for O&M, support to establish FWUC and their operation, training, and technology development.

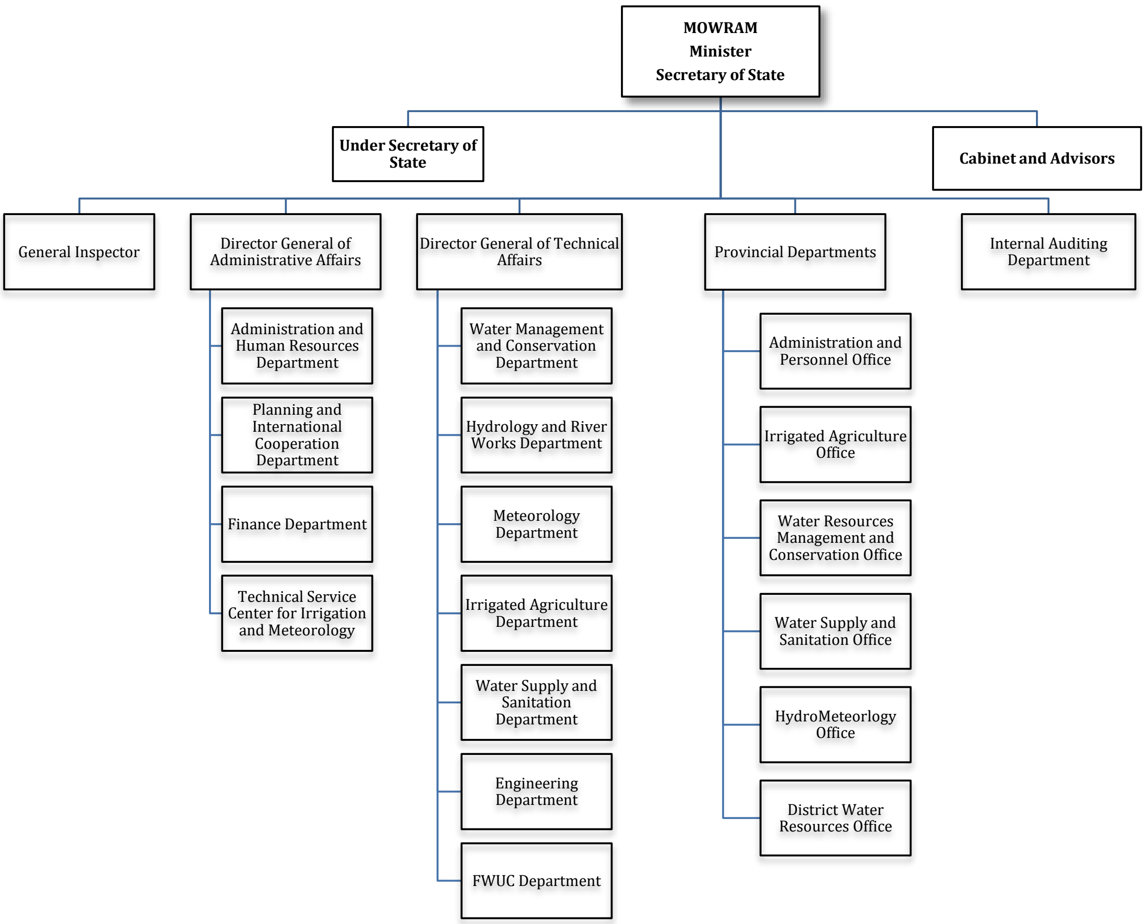


Figure 3: Organizational Structure of MOWRAM

31. The key departments involved with this component of the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project are the Department of Hydrology and River Works and the Department of Meteorology. The Department of Hydrology and River Works (DHRW) and Department of Meteorology (DOM) manage the hydrometeorological services in Cambodia. These two departments are responsible for collecting and disseminating hydrometeorological information and are mandated to provide early warning to a range of stakeholders.

32. The Department of Hydrology and River Works (DHRW) was established in 1999 under the Ministry of Water Resources and Meteorology. There are five offices within the DHRW: Office of Administration, Office of Research and Flood Forecasting, Office of Water Quality Analyses, Office of Hydrological Works, and Office of River Bank Management. The National Flood Forecasting Centre reports under the DHRW.

33. The responsibilities of DHRW include:

- To prepare plans for the installation of hydrological stations for the operation of water related structures and for water resource development;
- To prepare short, medium, and long-term strategic plans for riverbank erosion protection and the control of sedimentation;
- To conduct research and monitor surface and groundwater regimes by operating and managing a hydrological station network for the collection of water level, water discharge, and sediment data and information;
- To conduct water quality monitoring at key hydrological stations;
- To conduct studies related to hydrological phenomena for surface and ground water potential;
- To manage the generation and exchange of hydrological information;
- To issue forecasts and early warnings of flood and drought events in compliance with the national early warning strategy; and
- To maintain a geographical information system (GIS) of river basin features, hydrological networks, and the location of water resources development infrastructure.

34. **Figure 4** shows the organizational chart for DHRW.

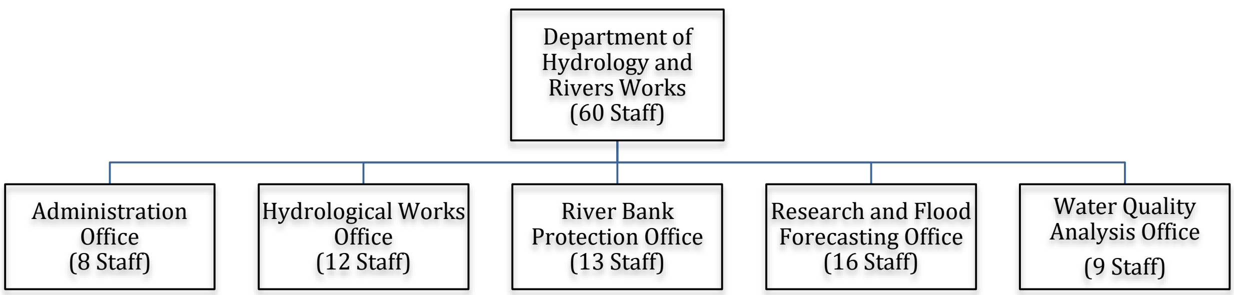


Figure 4: DHRW Organizational Chart

35. The Department of Meteorology (DOM)'s mandate is to provide meteorological services for all sectors in Cambodia and to represent Cambodia in international meteorological organization such as the World Meteorological Organization. To fulfil this mandate the DOM collects, processes, catalogues, and disseminates meteorological data and information as well as issues weather forecasts and seasonal predictions, including severe and extreme weather warnings and alerts. Specific responsibilities include:

- To establish and operate the Cambodian meteorological observing network;
- To prepare annual reports on meteorology events and conditions in the Kingdom of Cambodia;

- To provide daily and seasonal weather forecast for all sectors dependent on weather;
- To predict severe and extreme meteorological events and to issue alerts and warnings;
- To raise awareness and knowledge of weather phenomena; and
- To strengthen and broaden Cambodia's cooperation with regional meteorological organizations, United Nation agencies, and the World Meteorological Organization (WMO).

36. **Figure 5** shows the organizational chart for the DOM.

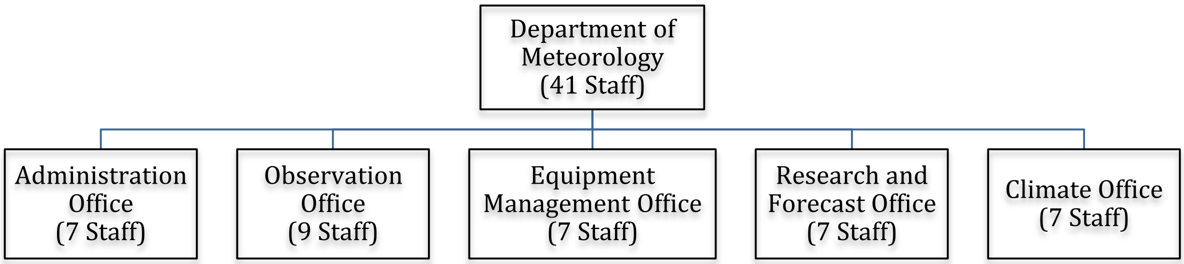


Figure 5: DOM Organizational Chart

37. MOWRAM also has a Technical Service Centre for Irrigation and Meteorology (TSC) in the General Directorate of Administrative Affairs. The TSC is responsible for studies on human resources development; training and capacity development at central, provincial, and municipal levels; research and application of new technology on the modernization of irrigation system; technical reports and information; advice to technical staff; and technical support for construction of irrigation systems.

38. MOWRAM has Departments in each Province (PDOWRAMs). The annual total budget for the PDOWRAMs is in the order of $US 25,000 per annum, which does not include special projects that may be funded. The functions of the Provincial Departments are:

- To plan and organize the programs of the Ministry at the province level;
- To operate and maintain major irrigation works;
- To manage FWUCs and other farmer bodies who are responsible for irrigation scheme operation and maintenance;
- To management the collection of ISF for the FWUCs and control expenditures from the ISF account;
- To provide oversight for construction of irrigation and flood protection works; and
- To administer minor procurement and disbursements associated with construction projects.

39. The June 2012 staff survey reports the Ministry having 1,258 staff, of which 633 (**Table 1**) are in the central office departments, and 625 are in the PDOWRAM offices (**Table 2**). Some 38% (241 staff) are with the Department of Engineering. Of the other departments, four have staff numbers of between 41 and 60 (DHRW, DAHR, DOM, and DIA), while the reminder have much lower staffing levels.

Table1: Number of MOWRAM Staff within the Central Office Departments

Department	No. Staff	Department	No. Staff
Administration and Human Resource	48	Technical Service Centre	19
FWUCs	38	Meteorology	41
Hydrology and River Works	60	Headquarter	19

Irrigated Agriculture	45	Planning and International Cooperation	30
Water Resource Management and Conservation	29	Finance	22
Engineering	241	Internal Audit	19
Water Supply and Sanitation	22		
TOTAL MOWRAM CENTRAL LEVEL STAFF: 633			

40. Staff numbers for the PDOWRAMS total 625.

Table 2: Number of MOWRAM Staff within the PDOWRAMs

City / Provinces	Female	Male	Total	City / Provinces	Female	Male	Total
Phnom Penh Municipality	6	26	32	Ratanakiri	0	9	9
Kandal	6	34	40	Mondulkiri	1	8	9
Kampot	4	17	21	Battambang	8	59	67
Sihanouk Ville	0	12	12	Kep	1	4	5
Koh Kong	0	6	6	Pursat	5	18	23
Kampong Speu	3	29	32	Siem Reap	3	39	42
Kampong Chhnang	2	24	26	Prey Veng	4	57	61
Kampong Thom	2	29	31	Takeo	5	68	73
Kampong Cham	0	26	26	Bantey Meanchey	0	20	20
Svay Rieng	3	34	37	Prah Vihear	0	10	10
Kratie	1	8	9	Pailin	0	6	6
Stung Treng	0	5	5	Uddor Meanchey	0	23	23
Total for Provinces	54	571	625				

41. The distribution of staff by PDOWRAMs is shown in **Figure 6**. The figure also shows the number of female and male staff. The average staff numbers per province is 26. Takeo Province has the most staff, which numbers 73. Battambang and Prey Veng Provinces also have staff numbers greater than the average, which is 67 and 61 staff respectively.

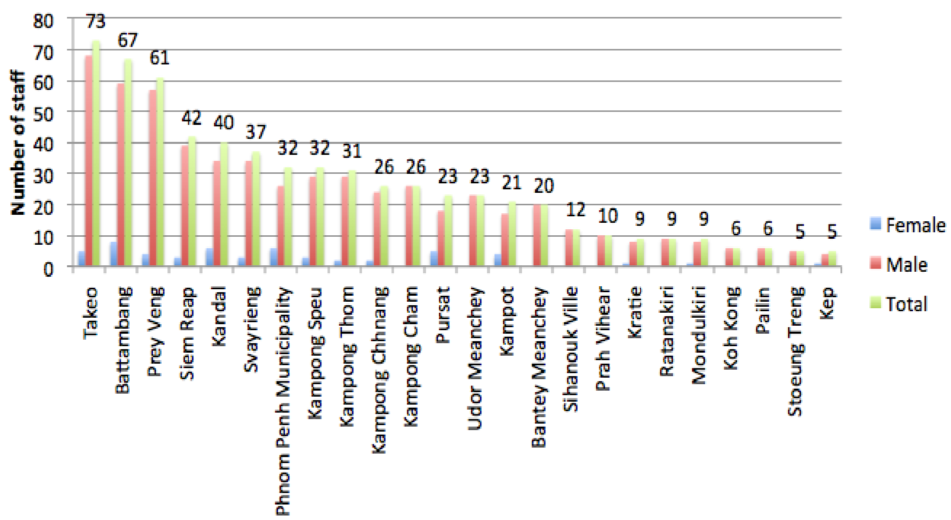


Figure 6: Distribution of Staff by PDOWRAMs

42. Expertise, experience, and budgets to support activities are limited. There has been limited training of hydrologist or meteorologists and limited recruitment of new graduates in DHRW and DOM over the past 20 years. Limited expertise, experience, and budgets have hindered the introduction of modern hydrological and meteorological methods as well as the introduction of modern flood forecasting procedures and climate change modelling. A number of basic tasks required for the operation of a hydrometeorological program have not been undertaken, such as the calibration and maintenance of field stations; the regular collection, analysis, and storage of data; and regular public reporting on the status of water resources.

43. Several national policies and strategies shape MOWRAM's activities related to flood and drought activities and actions. Article 4 of the Law on Water Resources Management of the Kingdom of Cambodia states that water and water resources shall be managed and developed based on Integrated Water Resources Management (IWRM) principles. These principles take into account all aspects of water resources, linkages between water resources and other components of the natural environments, and requirements for effective and sustainable water use consider human, environment, and economic needs.

44. Article 26 requires MOWRAM, in the event of floods and droughts, to serve as Headquarters for the RGC in the execution of required actions in close collaboration with the concerned Ministries and local authorities.

45. In the Rectangular Strategy III 2009-2013 (2nd angle: water resources management and irrigation schemes), the RGC strengthened and expanded the mechanisms for observation/monitoring as well as for forecasting and disseminating of real-time hydrological and meteorological information with an aim of ensuring crop safety and mitigating natural disaster event, especially from serious floods and droughts.

3.2 Mekong River Commission

46. The Mekong River Commission (MRC) is an important institution in the region. The Commission provides its member states with technical know-how and a basin-wide perspective. The MRC plays a key role in regional decision-making and the execution of policies that promote sustainable development and poverty alleviation. Given that a significant amount of the surface area in Cambodia is within the Mekong River basin, the Commission is a key player in the management of water resources in Cambodia.

47. The 1995 Mekong Agreement defines the scope of activities and cooperation arrangement for coordinated and joint planning of development in the Mekong River basin, while protecting the environment and maintaining ecological balance. The Agreement sets a framework for the achievement of IWRM strategic objectives, recognizes that development decisions by sector agencies in the sovereign riparian countries of the Mekong River basin may have transboundary consequences, and that the MRC as an inter-governmental river basin organization is reliant on the endorsement by the Member Countries of its activities.

48. Article 1 of the Agreement calls for "cooperation in all fields of development, utilization, management, and conservation of water and related resources to optimize the multiple use and mutual benefits and minimize the harmful effects". Article 2 charges the MRC with the responsibility of formulating a Basin Development Plan (BDP) for "the development of the full potential of the Mekong River basin waters". A core principle for the development of the Mekong River basin is the protection of the environment, natural resources, and aquatic life as well as ensuing ecological balance in the Mekong River basin (Article 3). Article 4 recognizes that any BDP should be based on respect for sovereign equality and territorial integrity, while Article 7 ensures the right of each country to develop projects, provided that they cause no harm to others.

49. The MRC Council approved the IWRM-based Basin Development Strategy in December 2010. This strategy forms the overarching strategic framework for development-oriented work of the MRC until 2016. It provides a framework for transboundary governance of the development process, including alignment of national plans and projects, basin management processes, and the identification of strategic analyses to address current knowledge gaps. The strategy is to be refined and updated every five years. The Basin

Development Strategy has major implications for Cambodia, The Cambodia National Mekong Committee coordinates activities for the effective implementation of the strategy within Cambodia.

50. The MRC Council adopted five core procedures to ensure the cooperation among the MRC member countries for the sustainable development of the Mekong River Basin, and to support the implementation of the 1995 Mekong Agreement. The core procedures are linked and supportive. The core procedures are:

- Procedures for Data and Information Exchange and Sharing (PDIES);
- Procedures for Notification, Prior Consultation, and Agreement (PNPCA);
- Procedures for Water Use Monitoring (PWUM);
- Procedures for Maintenance of Flows on the Mainstream (PMFM); and
- Procedures for Water Quality (PWQ).

51. The MRC's support for regional cooperation continues to reduce the risks of regular flooding and to promote the beneficial effects of the annual flood pulse. It's Flood Management and Mitigation Program (MRC FMMP) provides a regional context for the activities to be undertaken to strengthen the NFFC.

4. Work Breakdown Structure

52. A Work Breakdown Structure (WBS) has been developed for the NFFC project. The WBS is directly linked to the tasks shown in a Results Model developed for the project. The purpose of the WBS is to present the detail tasks and associated task activities in a logically linked framework, which is easy to understand and monitor. Hence, the WBS approach provides a concise and complete overview of all project tasks and activities as well as the expected outputs and deliverables.

53. The WBS approach is a very useful project management tool and supports the effective management of tasks and activities to be conducted during the NFFC project. In addition to facilitating systematic project management, the WBS is easy to understand and provides a solid basis for monitoring achievements, such as whether project objectives are being met, exceeded, or not achieved.

53. For each WBS a discussion of the current situation, the proposed planned interventions, and the expected improvements are presented. The key activities to be undertaken for each task are highlighted. As well, the WBS identifies the lead experts and the expected level of effort that will be used to complete the identified tasks.

54. The key elements of the WBS for the project are presented in the following sub-sections. The complete WBS is shown at the end of this section.

4.1 WBS-100 Inception Report

55. Prior to the start of the project, the Consultant organized an Orientation Meeting in Phnom Penh, on December 16, 2015. The Orientation Meeting involved the Project Director of EPTISA, the Deputy Team Leader, members of the National Team, and representatives for the Client. The purpose of the meeting was to obtain a more in-depth knowledge and to exchange views on specific issues related to the project implementation and the quality assurance system, as well as to achieve a common understanding of the project objectives and to define the next steps to guarantee successful commencement of the project.

56. During the Inception Phase a number of preliminary activities were carried out to gather information and to obtain an understanding of the project context, the capacity of the institutions involved, and the nature of other complementary projects. As well, an assessment of the ToRs, objectives, tasks, and targets was completed and a refined work program developed. An Inception Report will be prepared for presentation and approval under the Inception phase.

57. The activities carryout during the Inception Phase include:

- Engage the Ministry, NFFC and key stakeholders in orientation and project start-up meetings;
- Develop a results model and work breakdown framework for the project;
- Assess legal, regulatory, and institutional frameworks for flood and drought management;
- Assess state and capacity of staff, observational network, data management, and forecast systems at national and sub-national levels;
- Review progress and lessons learned under related projects; and
- Present Inception Report and revise the report, as required, based on feedback from the Inception Workshop.

58. During the Inception Phase, a Results Model and Work Breakdown Structure were developed for the project and presented to the Client for review, comment, and approval. The Results Model and Work Breakdown Structure guided the development of the Inception Report. The Results Model for the NFFC project is shown in **Table 3**.

59. During the Inception Phase 'in-situ' information was assembled on the organizational structure of MOWRAM, specifically DHRW and DOM. The information assembled is presented in various sections of this Inception Report.

60. As well, information on other relevant projects currently underway such as the Community Based Disaster Risk Management Project, the Pursat Irrigation Improvement Project, and other disaster risk management projects have been considered and potential collaboration and leverage opportunities identified.

61. Meetings were held with representatives of CPMU, PIC, DHRW, DOM, and with the Director General of MOWRAM to present the Results Model and WBS. The objective of the meetings was to engage key stakeholders during the Inception Phase. As well, meetings were organised by the CPMU with the Consulting Teams for the Upgrading of Water Management Infrastructure and the Community Based Disaster Risk Management sub-projects under the Greater Mekong Sub-Region (GMS) Flood and Drought Management and Mitigation Project to share information and discuss a common reporting and performance assessment approach.

62. The deliverable for WBS 100 is an approved Inception Report.

63. Level of Effort: The Inception Phase will involve all members of the National Team, the International Team Leader, selected inputs from Meteorologist (Meteorological Network) Meteorologist (Weather Forecast), Hydrological Modeller, Hydraulic Modeller, Forecast and Warning Dissemination and Institutional Experts of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 5.0 person months for the National Team and 2.0 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.4
Meteorologist 1 (Meteorological Network Improvement)	0.1
Meteorologist 2 (Weather Forecast)	0.1
Hydrological Modelling Expert	0.1
Hydraulic Modelling Expert	0.1
Forecast and Warning Dissemination Expert	0.1
Institutional Specialist	0.1
National	
Hydro-Meteorological Advisor/Deputy Team Leader	1.0
Meteorologist	1.0
Hydrological Modelling Specialist	0.5
Hydraulic Modelling Specialist	0.5
Forecast and Warning Dissemination Specialist	1.0
Institutional Specialist	1.0

65. Completion Date: March 2016

Table3: Results Model for the NFFC project

4.2 WBS-100a Preliminary Flood and Drought Assessment

66. As per the ToRs and discussions with the client during the Orientation Meeting in December 2015, the Project Team will conduct a Preliminary Flood and Drought Risk Assessment during the Inception Phase. The assessment will be based on available or readily derivable information, such as previous studies of flood and drought impacts. It will consider known plans for long-term developments and known Intergovernmental Panel on Climate Change (IPCC) climate change projections for the occurrence of floods and droughts.

67. The assessment will consider the following information:

- Maps showing river basins and sub-basins with topography, land use, population areas, transportation routes, geomorphological characteristics including floodplains and natural retention areas, the location of existing flood defence infrastructure, and cultural heritage sites;
- Reports and studies describing past floods and droughts; and
- Reports and studies presenting future projections of flood and drought occurrences considering the IPCC climate projections.

68. Information on the location, type of event, extent, and duration of the event as well as statistics on the impact that these past floods and droughts have had on communities, human health, economic activity such as rice production, cultural heritage, and the environment will be summarised.

69. The structure of the report and proposed table of contents for the report is as follows:

PRELIMINARY FLOOD AND DROUGHTS RISK ASSESSMENT REPORT

A. Report:

1. Introduction
2. Background
   a. Legal and Administrative framework
   b. Technical framework
3. Scope of Assessment
   a. Area of study
   b. Main priority basins and their characteristics
4. Methodology
5. Source and availability of information
6. Identification of hazard areas with the analysis of historical data and previous studies
7. Estimated damage and evaluation of current impacts
8. Risk analysis due to possible changes in the implementation of works of defence or changes in land use
9. Climate change considerations
10. Threshold definition and screening of significant risk areas (SRA)
11. Selection of significant risk areas (SRA)
12. Conclusions

B. Technical Datasheets:

The technical datasheet will include relevant information for all significant risk areas (SRA). The information to be included is location map, watershed, basin district, river, and city information; historical flood and droughts events; potential risk data for human health, cultural heritage, economic activity, infrastructures, environment, facilities, etc.

70. The original intent of the preliminary flood and droughts risk assessment was to support the selection of "two priority tributary basins" as proposed in EPTISA's response to the tender. However, discussions during the Inception Phase with MOWRAM, CPMU, ADB, and the Project Team resulted in an adjustment of the area of study to be 'one tributary' basin and the mainstream of the Mekong River in Cambodia.

4.2.1 Study Area

71. The climate of Cambodia can be characterized to be a bimodal monsoon dominate climate. The wet season is dominated by the southwest monsoon from May to November when 90% of the rainfall occurs. The remaining months are hot and less humid with high potential evapotranspiration demands in March and April. The rainfall pattern is extremely variable over the country. The maximum 24-hour rainfall is in the range of 200 mm throughout the region. The maximum rainfall is often associated with convective storms. Occasionally typhoons from the South China Sea or the Gulf of Thailand travel inland and cause widespread flooding. Usually these storms bring strong winds and torrential rain.

72. MOWRAM has defined thirty-nine river basins in its sub-decree on river basin management, which are shown in **Figure 7**.

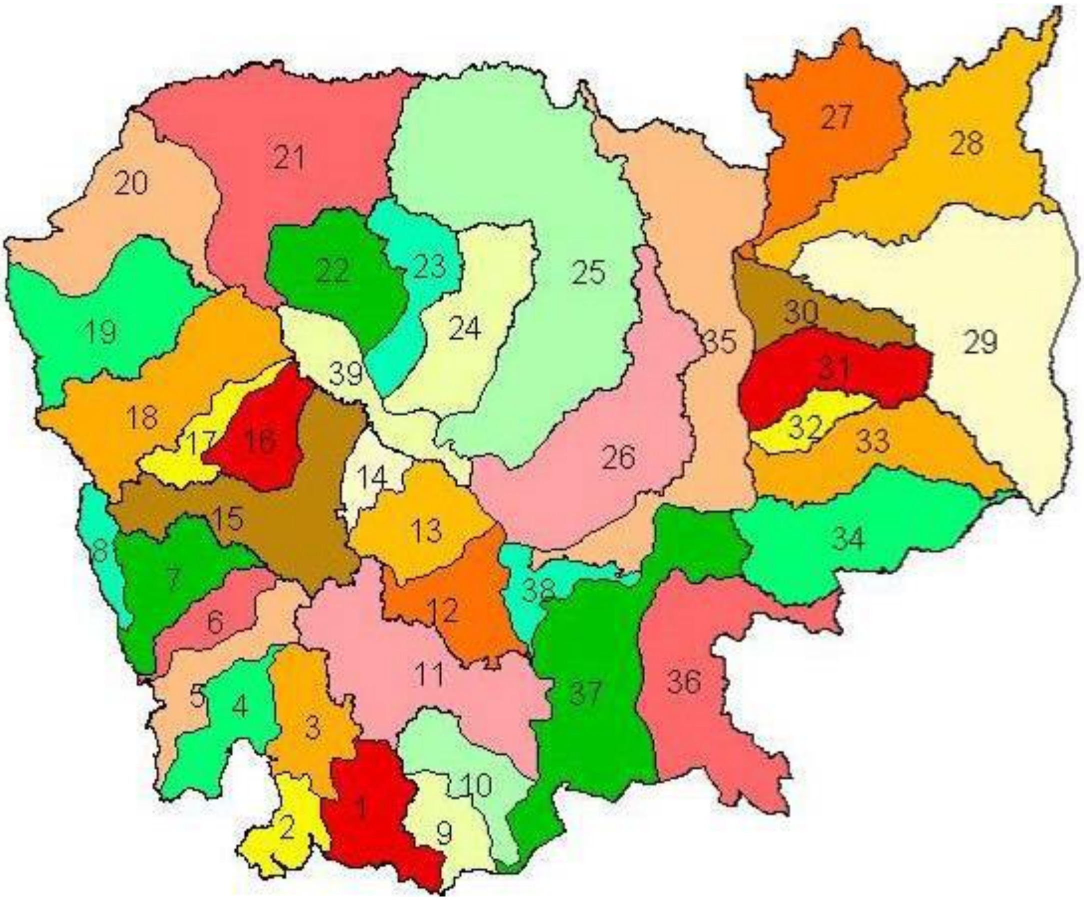


Figure 7: River Basins in Cambodia as defined by MOWRAM

73. The basin areas for these thirty-nine sub-basins are summarized in **Table 4**.

74. An initial discussion with CPMU has identified the Stung Pursat basin as one of the priority basins. The Stung Pursat basin is 5,964 km^2 in area and receives a mean annual rainfall of 1,390 mm. The maximum annual rainfall observed was 2,080 mm and the minimum was 870 mm. Rainfall amounts increase with basin elevation. The mean annual flow is 2,130 million cubic metres.

Table4: River Basins with Catchment Area [km^2]

Basin Group	Code	River basin	Area (km²)	Basin Group	Code	River basin	Area (km²)
I	1	Prek Kampong Bay	3,018	III	30	Prek Preah	2,399
	2	Prek Toek Sap	1,529		31	Prek Krieng	3,331
	3	Prek Sre Ambel	2,653		32	Prek Kampi	1,142
	4	Prek Andong Toek	2,460		33	Prek Te	4,363
	5	Prek Trapang Rung	2,615		35A	Mekong Riverine (Downstream)	8,287
	6	Prek Tatai	1,619			**Sub-Total III**	**19,522**
	7	Prek Koh Pao	3,109	IV	12	Stung Krang Ponley	3,033
	8	Stung Me Toek	1,043		13	Stung Baribour	3,003
		Sub-Total I	**18,046**		14	Stung Bamnak	1,116
II	27	Tonle Se Kong	5,564		15	Stung Pursat	5,964
	28	Tonle Se San	8,021		16	Stung Svay Don Keo	2,228
	29	Tonle Srepok	12,380		17	Stung Moung Russei (Dauntry)	1,468
		Sub-Total II	**25,965**		18	Stung Sangker	6,052
V	9	Stung Toan Han	1,765		19	Stung Mongkol Borey	5,264
	10	Stung Slakou	2,485		20	Stung Sisophon	5,593
	11	Stung Prek Thnot	7,055		21	Stung Sreng	9,931
	34	Prek Chhlong	5,599		22	Stung Siem Reap	3,619
	35B	Mekong Riverine (Upstream)	2,086		23	Stung Chikreng	2,714
	37	Mekong Delta Cambodia	8,723		24	Stung Staung	4,357
	38	Mekong TS flood plain (Spean Troas)	1,508		25	Stung Sen	16,342
	36	Tonle Vaico	6,618		26	Stung Chinit	8,236
		Sub-Total V	**35,839**		39	Boeng Tonle Sap	2,743
						Sub-Total IV	**81,663**
TOTAL = 181,035 km²							

75. The Stung Pursat basin (Figure 8) flows into the Tonle Sap Great Lake. The basin ranges in elevation from 6 m to 1,717 m above msl. More than 75% of the basin consists of hilly terrain with an elevation above 30 m above msl. Forest covers some 74% of the area and agriculture production utilizes some 13% of the land area. The hydrology of the Stung Pursat basin consists of three main branches: Stung Pursat, Stung Peam, and Stung Santre. A number of dams and diversion have been constructed in the basin to support irrigated rice protection as well as to provide flood protection.

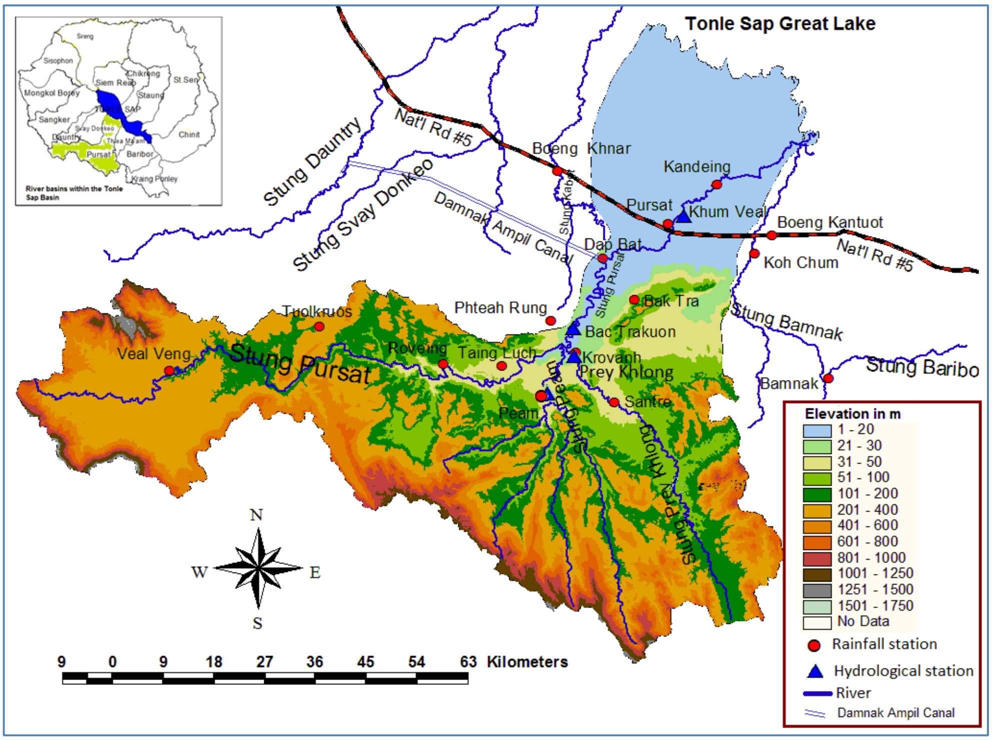


Figure 8: Location Map, Topography, and Hydromet Network - Pursat River Basin

77. As well, MOWRAM suggested that improvements to the existing flood forecasting model, which covers the mainstream Mekong, Bassac, and Tonle Sap Rivers in Cambodia, be selected as the second priority area. The reason for selecting the mainstream Mekong is driven from MOWRAM's desire to enhance flood forecasts for the mainstream Mekong in both accuracy and the forecast horizon. EPTISA is in agreement with the selection of the mainstream Mekong as one of the priority areas.

78. The Mekong River flows through Cambodia for a total length of about 500 km before discharging into the Vietnamese Mekong delta. At the Phnom Penh-Chaktomuk junction (Quatre Bras), the Mekong River is hydraulically connected to the Tonle Sap Great Lake by the 120 km long Tonle Sap River. Downstream of Phnom Penh, the Mekong splits into two rivers, namely the Lower Mekong River, which flows into the South China Sea after crossing the Vietnamese Mekong delta, and the Bassac River, which also flows to the South China Sea. About 86% of Cambodia's land surface area is within the Mekong River basin (**Figure 9**), including the catchments of the Bassac River, the Tonle Sap River, the Tonle Sap Great Lake, and the tributaries to the Great Lake.

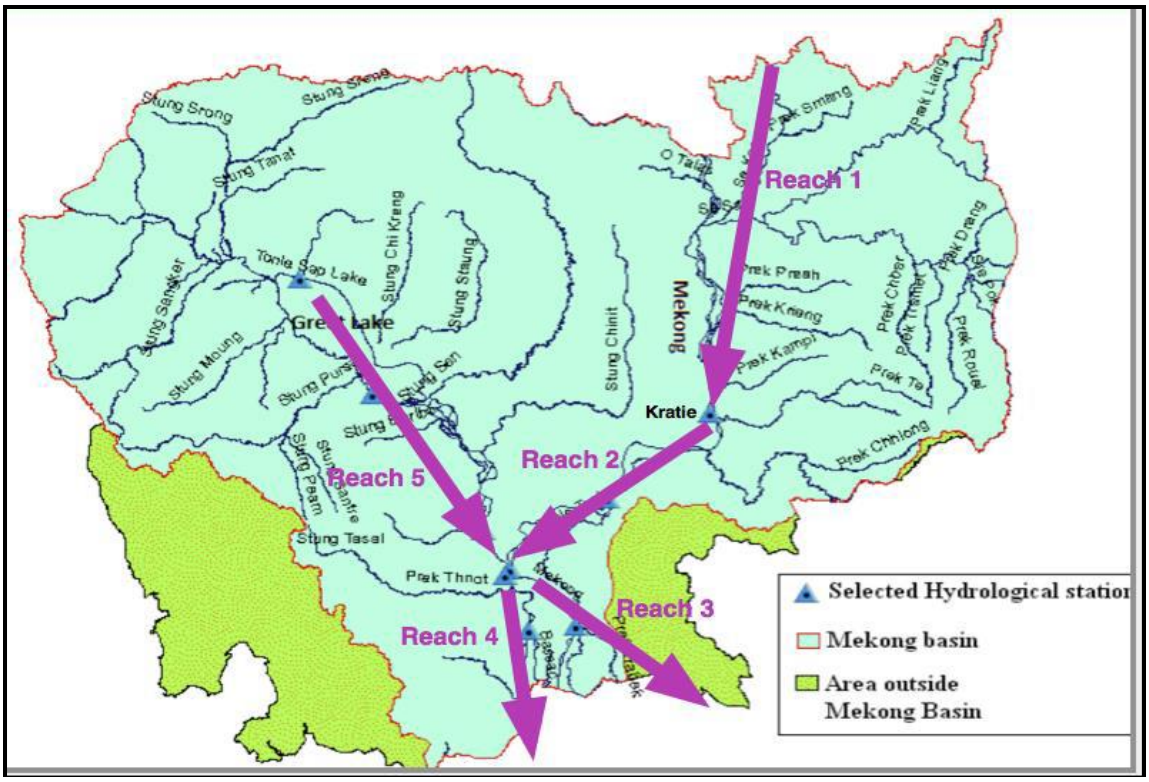


Figure 9: Mainstream Mekong, Bassac, and Tonle Sap Rivers in Cambodia. Source: ADB CDTA 2014

79. The Mekong River can be divided into a number mainstream reaches (**Figure 9**). Reach 1 is the Mekong River from the Laos-Cambodian border to the town of Kratie. The major flow contributions to the Mekong mainstream in this reach come from the transboundary Se Kong, Se San, and Sre Pok catchments, which discharge at Stung Treng. In total, over 25 % of the mean annual flow volume of the mainstream Mekong River at Kratie comes from these three transboundary basins. There are two river gauging stations in this reach, one at Stung Treng and the other at Kratie.

80. Reach 2 is the Mekong River from Kratie to Chroy Changvar (Phnom Penh), just upstream of the Chaktomuk Junction, where the Tonle Sap River joins the Mekong and the Bassac Rivers. The flow pattern in this reach is very complex during the flood season as hydraulic conditions define the flow distribution. The complexity includes downstream backwater effects that reverse the flow system of the Tonle Sap River, overbank and overland flow, temporary water storage on the floodplain, colmatage systems, and infrastructure controls.

81. Reach 3 is defined as the Mekong River from Phnom Penh to the border of Cambodia and Viet Nam, with river gauging stations at Koh Norea and Neak Luong.

82. Reach 4 includes the Bassac River from Chaktomouk Junction to the Cambodia–Viet Nam border with a river length of about 94 km. Downstream of the Chaktomouk junction, at about 9 km, the Bassac River receives water from the Prek Thnot basin. River gauging stations are located at Chaktomouk and Koh Khel.

83. Reach 5 is defined by the Tonle Sap River and the Tonle Sap Great Lake. A river gauging station is located at Prek Kdam. At the beginning of the flood season, in late May, Mekong floodwater flows into the Great Lake via the Tonle Sap River. This reverse flow into the Great Lake from the Mekong River continues to early October until the water level in the Great Lake measured at Kampong Luong exceeds the level at Phnom Penh. At that time, the flow in the Tonle Sap River changes direction and discharges water from the Great Lake to the Mekong and Bassac Rivers.

84. Upstream of Kratie (Reach 1), the Mekong River generally flows within the well-defined mainstream channel. In all but the most extreme flood years, the channel has the capacity to contain the full discharge with only limited local over-bank flow to natural storage areas. The Stung Treng, Kratie, Kampong Cham, and Phnom Penh are the key river gauging stations, which monitor upstream flows before the Mekong River is join by the Tonle Sap River.

85. From Kratie to the sea (Reach 2 and onward), the Mekong River is affected by downstream hydraulic conditions during the flood season. During the dry season, tidal effects up to Kampong Cham influence the Mekong River. Seasonal natural floodplain storage dominates the annual flow regime. There is significant redistribution of water between channels, as the result of overland flooding and natural storage, the seasonal refilling of the Great Lake, and the flow reversal in the Tonle Sap River. Hence, water levels and hydraulic conditions determine the movement of water in these lower reaches of the Mekong basin and over the landscape.

86. During the flood season, floodwaters of the Mekong or the Bassac Rivers are diverted naturally at upper locations by a number of overflow branches, which return floodwaters to the Mekong or the Bassac Rivers further downstream. In Reach 2, at about 15 km downstream of Kampong Cham on the left bank, part of the Mekong flow is diverted into the Tonle Toch river, which then discharges back into the Mekong downstream at 4 km north of Neal Leung in Reach 3.

87. During the flood season when the flow of the Mekong River at Kampong Cham exceeds about 25,000 m^3/s, water spills over the banks of the Mekong River between Kampong Cham and Phnom Penh. Part of the spill on the right bank reaches the Tonle Sap Great Lake as overland flow and as such is not measured at Prek Kdam. The overland flow component contributing to the Tonle Sap Lake inflow varies from year to year depending on the flood magnitude. DHRW estimates that the overland flow varies from 2 % to 12 % of the total Tonle Sap Great Lake inflow volume.

88. The two main branches on the eastern part of the Mekong floodplain in Reach 3 are the Stung Slot and Prek Kampong Trabaek. These two branches divert flow from the Mekong River via the floodplain and discharge into the Soha-Caico River in Viet Nam, which later flows back to the Mekong River or is further diverted to the Plain of Reeds in Viet Nam. Flow measurements on these two branches are made along National Road #1, at the Stung Slot and Kampong Trabaek gauging stations.

89. The main tributaries in Reach 4 are the Prek Thnot and the Stung Slakou (Stung Takeo). The Prek Ambel branch on the right bank near Koh Khel of the Bassac River diverts flow from the Bassac River, which is later returned to the Bassac River upstream of the Stung Takeo river confluence near the Cambodian-Vietnamese border. Flow measurements on the Prek Ambel branch are made at Angkor Borey. Flow measurements on the Stung Takeo are taken at Kampong Ampil (Borey Chulsa).

90. The Tonle Sap River and the Tonle Sap Great Lake System functions as a natural storage reservoir for Mekong floodwaters. The area of the Great Lake increases from a dry season area of 2,500 km^2 to a typical flood season area of 15,000 km^2. During a typical flood season that average depth of the lake increases from 1 m to 6 – 9metres. The volume of water held in the Great Lake is between 60 to 70 km^3 during the wet season and may be reduced to 1.5 km^3 during the dry season.

91. In summary, the activities under WBS100a will include:

- Review reports and studies on the occurrence and severity of past floods and droughts;
- Categorize the severity and occurrence of floods and droughts by major sub-basins;
- Consult with the Ministry on possible governmental priority sub-basins;
- Prepare and present draft report for feedback and comment;
- Collaborate with the Ministry on the selection of two priority basins; and
- Submit Final Report on Flood and Drought Assessment.

92. The deliverable for WBS 100a is a report on the Preliminary Risk Assessment of Floods and Droughts.

93. Level of Effort: The Preliminary Risk Assessment of Floods and Droughts report will involve all members of the National Team, the International Team Leader, and backstopping support from the home office in Madrid. The total level of effort is estimated at 3.0 person months for the National Team and 0.5 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	0.5
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0
Hydrological Modelling Expert	0
Hydraulic Modelling Expert	0
Forecast and Warning Dissemination Expert	0
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	1.5
Meteorologist	0.3
Hydrological Modelling Specialist	0.3
Hydraulic Modelling Specialist	0.3
Forecast and Warning Dissemination Specialist	0.3
Institutional Specialist	0.3

94. Completion Date: March 2016

4.3 WBS-200 HydroMeteorological Network and Data Management Assessment

95. The Department of Hydrology and River Works (DHRW) has established about 123[1] hydrometric stations with funding from the government budget as well as with financial support under a number of international projects. However, DHRW reports that due to insufficient operational budgets about 40[2] of the 123 hydrometric stations are operational. Most of the hydrometric stations provide only water level observations. Some discharge measurements are made at stations on the mainstream, however discharge measurements are not conducted at stations on the tributaries.

96. As reported by DHRW twelve of the 40 operational hydrometric stations are equipped with automatic data recorders with real-time data transmission capability under the Mekong HYCOS project (**Figure 10**). Of the twelve auto-stations, four stations are located on the Mekong mainstream and Tonle Sap Rivers. The remaining eight stations are located on the main tributaries of the Mekong River and Tonle Sap Great Lake.

97. With support under the Flood Management and Mitigation Program (FMMP), improvements to data collection at15 hydrometric stations have been made. Observations are made at 07:00 and 19:00 and the data are transmitted by 07:00 to the HYDMET data system at DHRW in Phnom Penh and shared with the Mekong River Commission riparian countries.

98. Data collection and transmission are reliant on telephone calls from DHRW in Phnom Penh to observers except for the telemetry equipped HYCOS stations. Staff of the Office of River Flood Forecast (ORFF) telephone observers at 07:00. In total fifteen observers along the mainstream and main tributaries are called. Rainfall data is collected once per day. As well, DHRW in Phnom Penh receives water level data for upstream stations from the Mekong River Commission.

99. In 2015, JICA supported the installation of six hydrometric auto-stations with telemetry under the River Basin Water Resources Utilization Study Project of Tonle Sap Great Lake. The project also established a number of manual hydrometric stations, where data is sent using SMS messaging. The six JICA supported stations are at Bak Trakuon, Andeuk Haeb, Bassac Reservoir, Prek Am, and Ta Des.

100. Parallel to the manual data collection from the noted 15 stations, real-time water level data from 18 telemetry stations, twelve under HYCOS and six under the JICA's River Basin Water Resources Utilization Study Project on Tonle Sap Great Lake.

101. All water level data for the fifteen stations, seven on the mainstreams, six stations on the Tonle Sap River and Tonle Sap Great Lake tributaries, and two stations on the Se San and Sre Pok, are entry into an Excel spreadsheet, DHRW's flood forecasting model interface, and at the same time these data are stored in the operational flood forecasting database, called HYDMET. The data is then sent via 'FTP' to the Regional Flood Management and Mitigation Centre (RFMMC) of the Mekong River Commission. The data is used by MRC's flood forecasting system.

102. HYDMET is custom designed database software for operational flood forecasting at RFMMC. It is used to collect and distribute rainfall and water level data from the involved national line agencies in all Mekong riparian countries. HYDMET has tools to manage data transmission from stations as well retransmit data to the national line agencies by SMS, to access data using a graphical interface, and the ability to export data in a number of formats to MRC's flood forecasting system.

103. Hydrological data observed from other stations are sent to DHRW at year end or every six months in a hard copy paper format. All daily data are later archived to the HYMOS database several times per week by staff of ORFF.

[1]Confirmed by officers of ORFF of DHRW on 12 May 2016

[2]Confirmed by officers of ORFF of DHRW on 12 May 2016

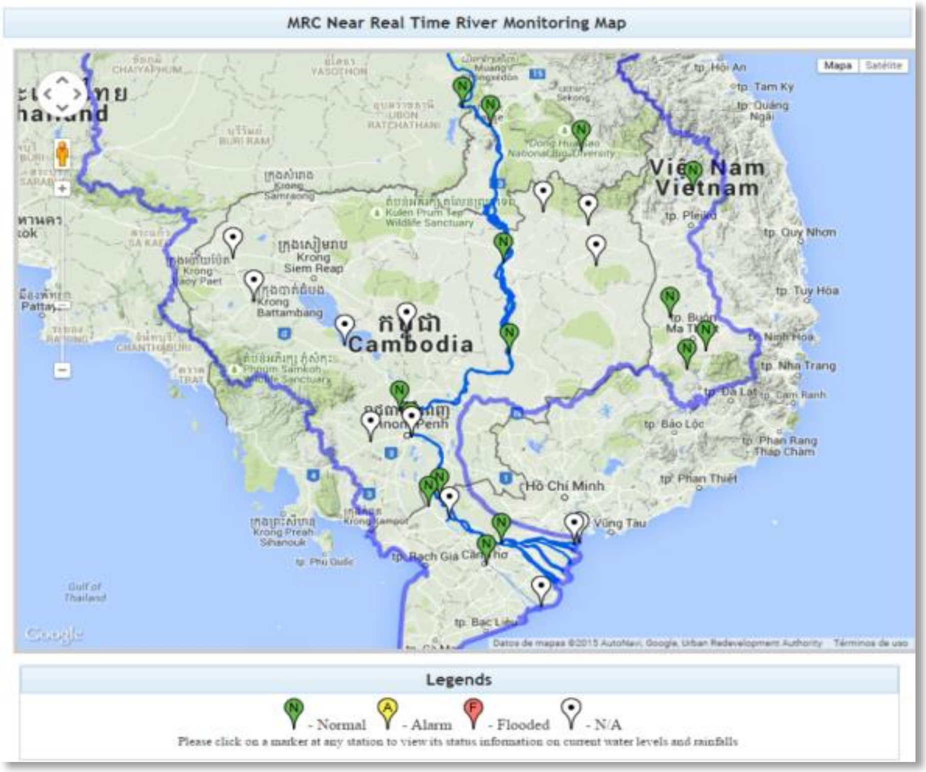


Figure 10: Near Real-time River Monitoring Stations supported by MRC

104. The ADB CDTA 7610-CAMreport on “Institutional Arrangements for the Management of Water Resources in Cambodia”, (February 2015) noted that within the total complement of DHRW’s 60 staff members, the professional staff complement was composed often irrigation engineers and three hydrologists (two with M.Sc. in Hydrology/Water Resource, one with a B.Sc. in Hydrology), two technician hydrologists Class 3, three technician hydrologists, and three assistant hydrologists Class 4. The remaining staff members graduated from construction engineering, chemistry, agriculture, oceanography, commerce, accounting, management, IT, and English language undergraduate programs. The professionally trained hydrologists graduated in the early 1990s from Russia, where as the technician hydrologists graduated from Viet Nam and the Prek Leap Technical School in Cambodia. Over the last two decades no professionally trained hydrologists have been recruited.

105. The above-mentioned report of ADB CDTA 7610-CAM noted that DHRW suffers from lack of technical manpower to operate, maintain, or expand the hydrometric station network. This shortage of skilled staff is problematic as there are no institutions in Cambodia providing courses in hydrology, meteorology, and earth science at the postgraduate levels.

106. DOM reported[3] that its observing network is composed of 35 weather stations providing coverage for all 25 provinces of Cambodia. Of the 35 stations, 26 are Manual Weather Stations (MWS) installed in the main towns of each province including Phnom Penh. As well, 26 Automatic Weather Stations (AWS) have been installed: 17 AWSs are located with the MWS and the remaining 9 AWSs are installed in the main district centres located in the Tonle Sap Great Lake basin. The manual stations observe meteorological parameters twice per day at 07:00 and 19:00. The manual stations have incomplete and obsolete equipment, with only mean, maximum, and minimum air temperatures and rainfall data being observed.

[3]Confirmed by Mr. Sam Oeun Soknara, Chief Administrative Office of DOM through communication on 07 April 2016

107. Under ADB's "Flood Damage Emergency Reconstruction" project, eight AWSs have been installed. In addition, MOWRAM has installed 12 AWSs. Both DHRW and DOM can assess the observation data from those 20 AWS stations.

108. The DOM reported that in 2015 there are 193 rain gauges installed throughout Cambodia. However, many of the rain gauges lack maintenance and are non-operational. A recent data availability assessment (ADB CDTA 7610-CAM, 2014) determined that of the existing 193 rainfall stations, only 87 have a continuous time series of more than 10 years (1990 to 2008 with gaps). As well, the density of the rain gauge network is considered to be well below the minimum requirements proposed by the World Meteorological Organization (WMO).

109. ADB CDTA 7610-CAM concluded that the meteorological network is in need of a complete review. Most stations that make up the meteorological network are located along major roads. As a result, the headwater areas of most river basins are not monitored due to difficult access. International standards are not always respected.

110. In February 2012, a Doppler Weather Radar (Meteo 650C) was installed in Phnom Penh at MOWRAM headquarters. The radar is equipped with three ranges: 80 km, 240 km, and 450 km, which can cover the entire Cambodian territory. The radar can be used to assess the spatial development of storms, which contributes to improve weather forecasts. The Doppler radar has been calibrated, however further ground-truthing for rainfall is required. As well, local capacity to support the provision of reliable radar information for weather and flood forecasting needs to be strengthened.

111. A MTSAT ground satellite receiving system is also located at DOM in Phnom Penh, however in November 2015 Japan's Meteorological Administrative (JMA) replaced the MTSAT satellite with the Himawari 8 satellite. Hence, DOM is no longer receiving weather related satellite images.

112. Since June 14, 2010, DOM has been connected to Bangkok via WMO's GTS network and DOM uses the GTS network to receive and transmit meteorological data as per WMO's international requirements.

113. Meteorological data is transmitted from each manual station using HF radio communications and telephone calls from DOM to the observers. Weather data for each station are sent to DOM once per day after the 07:00 observations are taken and in paper form at the end of the year.

114. Hardcopies of the daily rainfall data collected at the manual rain gauge stations are sent to DOM at the end of the year or every six months. However, with support from MRC under its flood management program, rainfall data for some 30 stations are sent daily to DOM via mobile SMS.

115. DOM staff of the Climatology Office enter the manual data for further analysis and archiving. DOM does not have a structured database and uses MS Excel for their data storage, which limits further data checking, processing, and collating.

116. Data from the DOM's AWS are received by the MRC's Regional Flood and Mitigation Centre using the HYDMET software. These data are then made available to DOM through Centre's 'FTP' server.

117. DOM has a total complement of 41[4] staff working in five offices: Administration Office, Meteorological Observation Office, Meteorological Equipment Management Office, Weather Forecasting Office, and Office of Climatology. The Weather Forecasting Office (WFO) has seven staff, who are assigned monitoring and forecasting tasks. DOM noted that it is neither adequately staffed nor funded to operate, maintain, or expand the meteorological station network.

[4] Confirmed by Mr. Sam Oeun Soknara, Chief Administrative Office of DOM through communication on 07 April 2016

118. At the provincial level, meteorological services are conducted by the Provincial Department of Water Resource and Meteorology (PDOWRAM). Each PDOWRAM has a HydroMet Service that is in charge of the provincial meteorological station, located within the provincial office compound, and rainfall stations within the province.

119. In summary, DHWR and DOM have stated that their institutional capacity and observational networks must be significantly strengthened to enable them to carry out their mandated functions and to support forecasting needs.

120. It is important to note that there are a number of projects either underway, or proposed, to improve the hydrometeorological network in Cambodia. The known interventions are:

- The "Uplands Irrigation and Water Resources Management Sector" plans to install 15 hydrometric and 15 AWS stations in the upper parts of the Tonle Sap Great Lake basin. As well, eight meteorological stations will be upgraded to AWS stations;
- It is expected that improvements in the hydrometeorological network will be implemented under the UNDP/GEF-LDCF project (2015 to 2018) - "Strengthening climate information and early warning systems in Cambodia to support climate resilient development and adaptation to climate change". Some 55 hydrometric stations with rain gauges and 25 AWSs are expected to be installed under the UNDP/GEF-LDCF project; and
- The Mekong-IWRM APL2 project, supported by the World Bank, will improve the hydrometeorological network within the 3S and 4P River basins in the north-east of the country. Some ten hydrometric stations with rain gauges, four AWSs, and ten automatic rain gauges are expected to be either upgraded or installed.

121. Given this background information, the Project Team will undertake two critical activities in support of this WBS. The first will be to develop a conceptual design outlining key issues and a future vision for the hydrometeorological observing networks and data management architecture in Cambodia. The conceptual design will consider the existing technologies used in Cambodia as well as those supported by MRC's hydrometeorological network.

122. The objective of the conceptual design is to ensure consistency and compatibility in field technologies used to observe hydrometeorological data as well as to support a common data management structure for hydrometeorological data. Developing a common hydrometeorological observing and data management system is often a challenge, given the various donor supported projects in the region, each with a unique tendering and procurement process resulting in a wide range of field technologies and data management system being implemented. However, it is hoped that the comprehensive design provided under this project will guide future procurement activities for the upgrade of the hydrometeorological network in Cambodia and that it will facilitate a common data management structure for DHRW and DOM.

123. The primary guide for the design of the hydrometeorological system will be the international standards and practices developed by the World Meteorological Organization (WMO). WMO provides a basic level of standardization for hydrometeorological observations, data management and forecasting functions, and services worldwide. The conceptual design and technical design will be guided by a number of of these WMO standards, which include:

- WMO No. 8 "Guide to Meteorological Instruments and Methods of Observation", while WMO No. 8 is primarily for conventional manual stations, its guidelines also apply to automatic weather stations;
- WMO No. 49 "Technical Regulations – Volumes I, II, III, and IV";
- WMO No. 168 "Hydrological Practices" - covers precipitation and evaporation as well as stream gauging;
- WMO No. 386 "Manual on Global Telecommunications System";
- WMO No. 485 "Manual on Global Data Processing and Forecast Systems";

- WMO No. 544 “Manual on Global Observing System”;
- WMO No. 1004 “Manual on Stream Gauging – Volume 1 – Field Work”;
- WMO No. 1004 “Manual on Stream Gauging - Volume II – Computation of Discharge”;
- WMO No. 1060 “Manual on the WMO Information System”;
- WMO No. 1083 “Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology”;
- Guide No. 8 “Meteorological Instruments and Methods of Observations”;
- Guide No. 100 “Guide to Climatological Practices”;
- Guide No. 134 “Guide to Agricultural Meteorological Practices”;
- Guide No. 168 “Guide to Hydrological Practices;
- Guide No. 305 “Guide to Global Data-Processing Systems (GDPS)”;
- Guide No. 488 “Guide to Global Observing System”;
- Guide No. 636 “Guide to the Automation of Data-Processing Centres”;
- Guide No. 834 “Guide to Public Weather Services Practices”; and
- Guide No. 1061 “Guide to WMO Information System”.

124. As well, a high-level data model for the hydrometeorological system will be used. The data model identifies functions and activities specifically required to support each element of the data model. The data model will be used to develop the conceptual design for the data acquisition, data processing, and data reporting system. The high-level data model is shown in the following schematic (**Figure 11**).

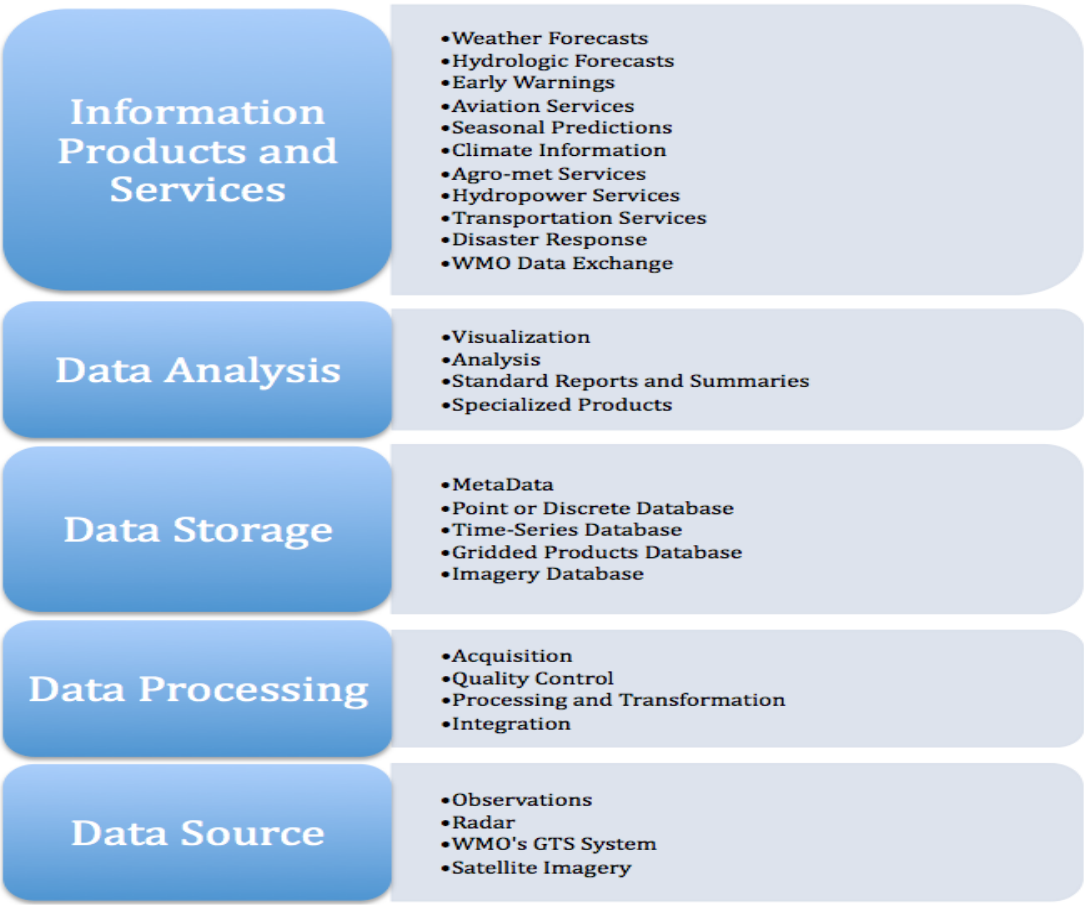


Figure 11: Data Model for the Hydrometeorological System

125. The second critical activity is to design a suitable hydrometeorological station network for the study area, which supports flood forecasting and drought prediction for an early warning system in the Pursat tributary basin and the mainstream Mekong. The network designed for the Pursat basin will follow a standard methodology and will be used as a pilot demonstration for the design of networks in other sub-basins. The need for additional key hydrometeorological stations, which improve the reliability of the forecast, will be identified during the review and enhancement of the existing flood forecasting system for the mainstream Mekong.

126. For the network design, the Project Team intends to use a number of standard GIS tools to display the basin's topography and hydrography, land use, the existing hydrometeorological network. GIS tools will be used to provide catchment delineations within the basin and to analyse variability in the hydrological response of the basin considering topography and stream hydrography. Field visits to the priority basin are proposed to conduct an assessment of the existing gauging infrastructure and to complete a detailed site survey for proposed new sites.

127. The proposed strategy for the hydrometeorological station network is to place an adequate number of rainfall stations in the headwater areas of the basin with hydrometric stations located further downstream on key tributaries and the mainstream. The location and density of the hydrometeorological station network will consider the need to calibrate and validate the catchment response to rainfall events and to provide adequate lead times for issuing early warnings to affected communities.

128. A conceptual design, with technical specifications for upgrading the hydrometeorology field network, will be developed. The conceptual design will consider station rehabilitation and modernization requirements, data communication options, operational requirements, staff capacity, and compatibility with the existing technologies and data management systems. The conceptual design will contain details of the hydrometeorological network, equipment, and data acquisition system as well as present a data processing and management approach. The conceptual design will include a training plan for the field and data management functions.

129. In summary, the activities under this WBS 200 will include:

- Develop Conceptual Design for a comprehensive "end to end" system outlining key issues and a future vision for the hydrometeorological observing network and data management architecture;
- Develop estimates of operating and maintenance budgets required for sustaining the proposed system in the study area;
- Prepare a draft report summarizing key findings and recommendations for review and comment; and
- Submit final report with revisions, as required.

130. The deliverable for WBS 200 is a Conceptual Design Report for Hydrometeorological Observing and Data Management System with a hydrometeorological station network design for the study area.

131. Level of Effort: The activities under WBS 200 will involve the Deputy Team Leader as well as the Meteorologist, Hydrological Modelling Specialist, Hydraulic Modelling Specialist and the Institutional Specialist of the National Team, the International Team Leader, and backstopping support from the home office in Madrid. The total level of effort is estimated at 3.3 person months for the National Team and 0.5 person months for the International Team.

Expert	**Input (Person- Months)**
International	
International Hydro-Meteorological Advisor/Team Leader	0.5
Meteorologist 1 (Meteorological Network Improvement)	0

Expert	Input (Person- Months)
Meteorologist 2 (Weather Forecast)	0
Hydrological Modelling Expert	0
Hydraulic Modelling Expert	0
Forecast and Warning Dissemination Expert	0
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	1.0
Meteorologist	1.0
Hydrological Modelling Specialist	0.5
Hydraulic Modelling Specialist	0.5
Forecast and Warning Dissemination Specialist	0
Institutional Specialist	0.3

132. Completion Date: March 2016

4.4 WBS-300 Forecast Approach and Operational Capacity

133. A successful flood forecasts system has a number of key requirements. The first is access to reliable and timely weather forecast, especially for severe weather events. The second is reliable and timely data on current hydrological conditions in the basin. The third is the availability of calibrated hydrological and hydrodynamic operational models for the basin.

134. The following schematic (**Figure 12**) presents the general model layout for an operational water level and flood forecast system. It is expected that the flood forecasting system developed under the NFFC project will be a basic flood forecasting system, however the structure will lay a solid foundation for the evolution to a more advanced system using more sophisticated and powerful weather prediction and data assimilation techniques.

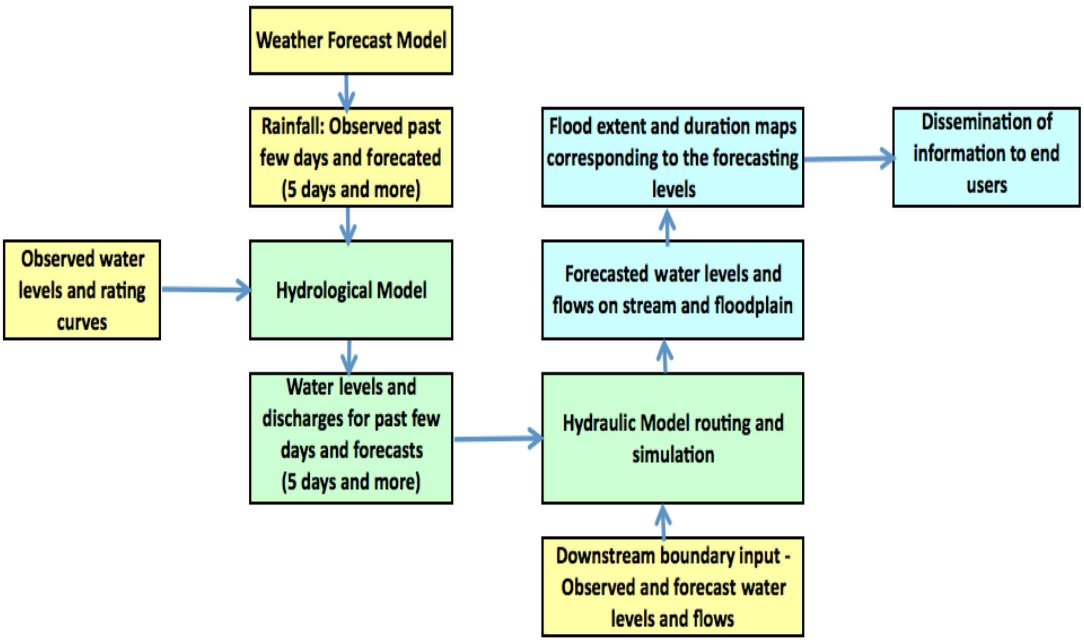


Figure 12: General Model for an Operational Flood Forecast System

135. It is important to note that the flood forecast system must provide a projection of the area that will be inundated for a forecasted flood level. Given the predominance of large flood plains in the lower Mekong region, the flood forecasting system must have a hydraulic model capability, supported by a reliable Digital Elevation Model (DEM), to route and simulate water levels over a large flood plain and produce useful flood inundation maps.

136. At present the flood forecasting system is based on a regression model, and is only calibrated to forecast water level on the mainstream Mekong, Bassac, and Tonle Sap rivers. These multi and single regression models have been applied by DHRW to compute the daily 3-day water level forecasts at seven mainstream Mekong, Bassac, and Tonle Sap stations. The interface has been developed using an Excel spreadsheet and the model uses only water level data as input. However, the effect of local rainfall is subjectively considered for adjusting the model output and forecasted water levels. The Mekong mainstream model has been calibrated using available records to 2009. The models have not been updated with more recent data. Furthermore, model verification is a manual process and is carried out only at the end of the flooding season.

137. Forecasts of water levels is carried out in the flooding season from June 1st to November 30th. During the flood season, one to three forecasts are issued daily for the seven mainstream stations on the Mekong, Tonle Sap, and Bassac rivers. DHRW does not provide water level forecasting for the tributaries, which are subject to flash floods caused by tropical storms.

138. Two flood related products are issued, a water level bulletin containing observations is issued daily shortly after 07:00 to senior Ministry officials, and a flood bulletin containing information on the current 07:00 observations and the forecast for the next 3-days is issued at 08:30.

139. MRC's RFMMC has adopted the Flood Early Warning System (FEWS), which comprises a FEWS engine, models, post-processing tools, and a database. Three models are used in the FEWS - the URBS (hydrological), ISIS (hydrodynamic), and a Multi-regression model. FEWS was developed by Delft University of the Netherlands. It is a fully scalable system that can run as a self-contained manually driven forecasting system operating on a normal desktop computer, and it can be deployed as a fully automated distributed client-server application. The FEWS river flood forecast system at the time of preparing this report can provide a 5 to 7-day forecast of water level using daily observed water level from hydrometric stations, satellite rainfall estimate (SRE), and satellite rainfall forecast (GFAS) downloaded from the NOAA web site.

140. The rainfall-runoff model, "URBS - Unified River Basin Simulator", was developed Mr. Don Caroll, a Senior Modeller in Australia. DHRW staff have received training from MRC on using the model as a flood-forecasting tool.

141. With support of the Mekong River Commission, DHRW has been introduced to the Flash Flood Guidance System (FFGS - called MRC-FFG system) developed by the U.S. Hydrologic Research Center (HRC) under a USAID/OFDA funded program. Using the MRC-FFG system, DHRW staff can access real-time information related to flash flood guidance (FFG), flash flood threats (FFT), mean areal precipitation (MAP), satellite rainfall estimate (Hydroestimator), and average soil moisture (ASM) for 1, 3, 6, and 24 hours on a small basin scale for Cambodia. The MRC-FFG system has been operational and providing information to the MRC web site since August 2010.

142. The information available on the MRC-FFG system is updated every 6 hours at 00:00, 06:00, 12:00, and 18:00 UTC. Hydroestimator and MAP are updated every hour.

143. In December 2009, FMMP developed a GIS software tool for processing information from the FFG system to identify flash flood risk areas at the district and village level in Cambodia. The system has been able to detected flash flood risk areas at the village level in Cambodia. To date DHRW has not taken advantage of the MRC-FFG system.

144. DOM issues a 1 to 3-day weather forecast using global Numerical Weather Prediction products from ECMWF, Hong Kong Observatory, CMA, KMA, and JMA, as well as products from SWFDP-WMO (WMO's Severe Weather Forecast Demonstration Project). DOM also uses seasonal and long-term forecast products from ECMWF. These global products are accessed via DOM's Synergie system. DOM does not run a Numerical Weather Prediction (NWP) model[5] due to its lack of technical and human resource capacity.

145. The daily weather forecast bulletin issued by DOM is sent each day to key agencies including the National Committee for Disaster Management (NCDM), Cambodian Red Cross (CRC), and media outlets. Television and radio media broadcast the weather forecast to the public. Information on weather forecasts and warnings are also disseminated through the DOM website.

146. The daily weather forecast bulletin is comprised of two parts - a general weather outlook for three topographic relief zones and a 3-day forecast for cities and provincial towns. The forecast includes rainfall, air temperature, humidity, wind direction, and wind speed. For the coastal cities, sea wave information is included.

147. DOM conducts non-stop 24 hour monitoring and reporting when there is tropical cyclone activity in the vicinity of the Indochina peninsula. During this period DOM continuously monitors its meteorological observation network, satellite images, and weather charts to track the cyclone. The Typhoon forecast considers weather maps and weather reports from surrounding countries including marine weather forecasts issued by the Royal Observatory of Hong Kong.

148. The Project Team will review and assess the current weather, hydrological, and hydrodynamic models as well as forecasting procedures and systems used by DOM and DHRW as well as those used at the regional level by the Mekong River Commission (MRC-FMMP). The review will include an assessment of the current human resource capacity and available computer applications and hardware. In the context of the NFFC project the term 'forecast' is used when future conditions are based on initial or known present and immediate past conditions, and the term 'prediction' is without consideration of an initial condition.

149. A conceptual design for improving NFFC's analytical and modelling capability and for improved flood forecasts and drought predictions will be prepared. The conceptual design will provide a plan for improvements to weather forecast operations including the selection of appropriate weather forecast models and seasonal climate prediction models. The conceptual design will propose procedures for forecasting rainfall including satellite based rainfall estimates and appropriate hydrological and hydrodynamic models to forecast flood level, extent, and duration. The conceptual design will identify regional available weather products and forecast services based on Operational Numerical Weather Prediction Models and WMO's network of regional centres, such as the Japanese Meteorological Agency as well as regional storm tracking services available from the Regional Typhoon Centre. The selection of models and modelling approach will consider the regional models used by MRC-FMMP. The conceptual design will detail the required staff, expertise, and training as well as operational budgets to operate, maintain, and enhance the forecast systems.

150. In summary, the activities under this WBS 300 will include:

- Develop Conceptual Design for a comprehensive "end to end" system outlining key issues and a future vision for improving NFFC's analytical and modelling capability and for improved flood forecasts and drought predictions for Cambodia;
- Develop estimates of operating and maintenance budgets required for sustaining the proposed system;
- Prepare draft report summarizing key findings and recommendations for review and comment; and

[5]Confirmed by Mr. OUM Ryna, DOM Director, through personal communication on 04 May 2016.

- Submit final report with revisions, as required.

151. The deliverable for WBS 300 is a Conceptual Design Report for Forecast Production and Dissemination

152. Level of Effort: The activities under WBS 300 will involve the Deputy Team Leader as well as the Meteorologist, Hydrological Modelling Specialist, and Hydraulic Modelling Specialist of the National Team, the International Team Leader, selected inputs from the Meteorologist (Weather Forecast), Hydrological Modeller, Hydraulic Modeller, and Forecast and Warning Dissemination Experts of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 4.5 person months for the National Team and 1.90 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	0.5
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0.5
Hydrological Modelling Expert	0.25
Hydraulic Modelling Expert	0.25
Forecast and Warning Dissemination Expert	0.4
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	1.0
Meteorologist	2.0
Hydrological Modelling Specialist	0.5
Hydraulic Modelling Specialist	0.5
Forecast and Warning Dissemination Specialist	0.1
Institutional Specialist	0.4

153. Completion Date: June 2016

4.5 WBS-400 Technical Specifications for Improvements to Hydrometeorological Network and Forecast System

154. The Project Team will use the results and findings from the work conducted under WBS 200 and 300 to assist CPMU develop a procurement plan and to detail the technical specifications for the proposed improvements to the hydrometeorological network in the study area. As well, technical specifications will be prepared for the procurement of a commercially supported data management system at NFFC, for the IT hardware and systems software to support the data management and forecast applications, for improvements to weather forecasts and climate prediction capability at DOM, and for improvements to flood forecast capability at DHRW.

155. In addition, assistance will be provided to CPMU during the biding process through participation in pre-tender conferences and drafting answers to bidder’s questions, as required.

156. As well, assistance will be provided to CPMU during the evaluation and preparation of bid evaluation reports. The bid evaluation reports may require an expert assessment of proposed technical solutions to

ensure conformity with the technical requirements of the project and bidding documents. As required, assistance will be provided to support contract negotiations with bid winners.

157. The Project Team expects that technical supervision of the contractor's work will be required for specialized elements of the contract. The support will include technical and troubleshooting assistance as well as assistance with any change order proposals during the contract delivery phase.

158. The Project Team recommends that an acceptance protocol be developed for delivery, installation, and operational assurance of the procured systems. If agreed to by CPMU, the Project Team will develop the completion and operational acceptance process for each goods and services contract. The objective is to verify the consistency and compatibility of the goods and services provided by contractors and to ensure interoperability of all the system's components.

159. In summary, the activities under this WBS 400 will include:

- Draft technical design and specifications documents as required for improvements to the hydrometeorological network in the priority basin, data management system and the modelling and forecast system;
- Assist the CPMU with the preparation of procurement documents and during the bid process with pretender meetings and bidders questions;
- Assist CPMU with the technical evaluation and assessment of bids;
- Assist CPMU with supervision of the supply and installation contract execution and delivery; and

160. The deliverable for WBS 400 are a series of Technical Specification documents.

161. Level of Effort: The activities under WBS 400 will involve the Deputy Team Leader of the National Team, the International Team Leader, selected inputs from the Meteorologist (Weather Forecast) Expert of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 3.0 person months for the National Team and 1.75 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.5
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0.25
Hydrological Modelling Expert	0
Hydraulic Modelling Expert	0
Forecast and Warning Dissemination Expert	0
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	3.0
Meteorologist	0
Hydrological Modelling Specialist	0
Hydraulic Modelling Specialist	0
Forecast and Warning Dissemination Specialist	0
Institutional Specialist	0

162. Completion Date: June 2016

4.6 WBS-500 Flooding and Drought Hazard and Risk Assessment for Different Probabilities

163. Cambodians are particularly vulnerable to floods and droughts events as much of the population depends upon subsistence agriculture for their livelihood. As a result, they frequently suffer hunger, increased poverty, or even the loss of life when such disasters occur. This vulnerability has increased in recent years due to a series of consecutive natural disasters, which have not allowed the rural population the opportunity to recover from previous floods or droughts.

164. The National Committee for Disaster Management estimates the exposure to flood risks in terms of GDP in Cambodia is at 14%, which is the highest among the Lower Mekong Basin countries. Cambodia also has the highest loss of life per flood event, 87 people on average. The average number of people affected per flood event is 733,355, highest among the four riparian countries of Lower Mekong Basin countries.

165. Comprehensive statistics on drought impacts is limited in Cambodia. However it is widely acknowledged that drought is one of Cambodia's most significant and widespread natural hazards. For example, within the past 25 years, there have been a significant number of distinct drought events: 1986-87, I994, 1997-98, 2002, 2004, 2005, 2012, and 2014. The 2004 drought event affected 2 million people in 14 provinces with a total damage estimated at USD 21 million, according to the National Committee for Disaster Management's Flood and Drought Bulletin (2004).

166. Meteorological droughts, due to low rainfall over the monsoon season (May-November), reduce yields of rain-fed rice and other crops. Similarly, the agricultural impacts of hydrological droughts in the dry season, due to less than normal water levels, reduce irrigation water supply and adversely affects dry season production.

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

168. The Project Team plans to undertake a flood and drought hazard and risk assessment for the selected study area. However, the mainstream Mekong does not lend itself to the detailed assessment of flood and drought hazards and the associated assessment of risks within the twenty-four month duration of the contract, given the significant complexity of modelling the mainstream rivers and the large area covered by flood and drought events. Therefore, the detailed investigation for the development of design guidelines for climate resilient structures will be limited to the Pursat basin. It is suggested that using the Pursat basin will not constrain nor limit the development, scope, and application of the proposed design guidelines.

169. The Project Team will use a statistical analysis and a modelling strategy to assign a risk associated with different frequencies of flood occurrence. Drought events are more difficult to model given their regional scale and long duration. As such, the Project Team will consider the development of a drought severity index based on established international approaches. The drought severity index will be adapted for conditions in Cambodia.

4.6.1 Floods

170. Floods have repeatedly occurred in Cambodia over the past decade with the country experiencing three types of flood events:

i. Mainstream flooding in provinces located on the banks of Mekong, Bassac, and Tonle Sap rivers;
ii. Tributary flooding, which occurs in the Kompong Chnang, Kampong Thom, Pursat, and Seam Reap Provinces; and
iii. Flash floods from the steep rivers of Pursat, Battambang, Banteay Meanchey, and Siem Reap Provinces.

171. The proposed modelling strategy is based on the United States Army Corp of Engineers HEC suite of models. It is believed that using the HEC suite of models will build additional modelling capacity in Cambodia and provide future options for modelling of hydrological and hydraulic events.

172. The following features make the HEC suite of models a good choice for this activity:

- The models are available free of charge and are actively maintained, supported, and under regular development by the U.S. Army Corps of Engineers' Hydrologic Engineering Center (HEC) in Davis, California;
- The models are widely used in the engineering community, including applications around the world by consultants and counterpart teams. Software support, including regularly scheduled training courses, is readily accessible;
- The models facilitate processing of geospatial data within a GIS framework, simplifying model development;
- The models provide map-based representations of drainage basins and stream networks;
- The models offer a user-friendly graphical interface, which makes model updating, scenario testing, sensitivity analysis, and reporting more efficient; and
- The HEC models read and write hydrometric data stored in a common and easily accessible database format such as HEC-DSS. HEC-DSS is the Corps of Engineers' data storage system for hydrometric data. However the read-write functionality and database interface format can be easily configured for other database structures.

173. The Project Team proposes to use the most recent version of the HEC hydrological numerical model software, which is HEC-HMS. HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic watershed systems. It is applicable to a broad range of geographic areas. The model can be used to support large river basin water supply and flood hydrology investigations as well as small urban or natural watershed runoff. Hydrographs produced by the program can be used directly, or in conjunction with other software fora range of studies including water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.

174. HEC-HMS features a completely integrated work environment including a database, data entry utilities, computation engine, and results reporting tools. A graphical user interface allows the seamless movement between the different parts of the program. Program functionality and appearance are the same across all supported platforms. As well, the power and speed of the program makes it possible to represent watersheds with hundreds of hydrological elements.

175. The Project Team proposes to use annual maximum daily precipitation as a basis for calculating annual instantaneous peak flows. Annual exceedance probabilities of 50% 10%, 2%, 1%, and 0.2% are suggested for the probability analysis. Maximum precipitation for durations shorter than a day will be considered depending on the 'time of concentration" for the selected tributary basin and the availability of rainfall data for the required duration.

176. The output from the hydrological modelling for the various annual maximum daily precipitation probabilities will be used as input to the numerical hydrodynamic models, either 1D or 2D models, to simulate flood level for selected reaches. The numerical hydrodynamic models with a reliable DEM will enable the area of flood extent to be defined for each of the probabilities. The Project Team proposes to use the HEC-RAS software V5.0.1 with the GIS extension GeoRAS for the 1D and 2D simulations of the Stung Pursat basin. A full description of the features of HEC-HMS and HEC-RAS is found in Appendix 2.

177. The Project Team plans to also consider the application of the ISIS 2D hydrodynamic model under the Flood Modeller Suite. ISIS is a generic modelling system for the simulation of unsteady flow in channel

networks. The United Kingdom companies of Halcrow and Wallingford Software jointly developed ISIS. Consequently, ISIS is a commercially available hydrodynamic modelling system, which provides an implicit numerical solver for the de Saint Venant equations. ISIS can be applied for a wide range of hydraulic problems, such as flood propagation, tidal flow, and channel drainage. At selected intervals the model computes water levels and discharges on a non-staggered grid. There is some knowledge of the ISIS model in the region given that it is part of the Mekong River Commission's decision support framework (DSF), which has been upgraded and is now known as MRC-Toolbox.

178. The most significant challenge for the modelling work is the availability of suitable digital elevation models (DEM) and digital terrain models (DTM) representative of the study area.

179. A DEM provides information on land surface elevations of the watershed. The DEM is combined with a land use model to derive hydrological characteristics for the watershed. The accuracy and scale of the DEM directly governs the confidence in the hydrological model parameters derived and the calibration of the hydrological model.

180. A DTM, or digital surface model, provides details of buildings and infrastructure on the landscape necessary for the conduct of hydrodynamic modelling.

181. It is expected that reliable DEMs and DTMs at an appropriate scale are limited for the study area. As well, it is expected that the low density of the hydrometeorological data network coupled with gaps in the data record will be a challenge for the models to generate reliable results. These challenges will be addressed once the available hydrometeorological and digital elevation data for the study area have been assembled. The modelling strategy may require adjustment as well as a number of modelling assumptions may be required in order for the work to proceed. All assumptions will be fully documented.

4.6.2 Droughts

182. Drought is classified as a slow onset natural hazard, which occurs because of deficiency of rainfall over an extended period-of-time, such as a season, a year, and/or several years as the result of climatic variability. Drought affects can cover a wide area and impacts agriculture, water resource, livestock, human health, and the environment. In severe events, drought can last for many years and can have a devastating effect on socio-economic and environmental sectors.

183. In general, communities are able to respond to and cope with one or two successive droughts, which results in crop and livestock losses. However, a prolong drought can cause widespread consequences for water supplies for humans and animals, result in significant crop failures and impairment of water quality leading to malnutrition, and degrade landscape quality as the result of loss of biodiversity, forest, fisheries, plants, and animal species.

184. Droughts can be classified into three broad categories as follows:

i. Meteorological drought - occurs when rainfall over a prescribed period is significantly less than the long-term average;
ii. Hydrological drought - occurs when water resources are significantly depleted because of a meteorological drought, which results in water level over a prescribed period being significantly less than the long-term average; and
iii. Agricultural drought - occurs when meteorological and hydrological droughts reduce crop yields as well as livestock and fisheries production. An agricultural drought occurs when soil moisture is insufficient to meet crop water requirements for food and fodder.

185. The drought hazard assessment will take a regional approach as the occurrence, extent, and duration of droughts are driven by regional weather and climate patterns. Accordingly, the Project Team will review past drought events and available climate studies for the region. The results of coupled ocean-atmosphere models and studies, which have considered anomalous circulation patterns in the ocean and atmosphere,

will be reviewed. The purpose of the review is to determine if there are any relationships between these regional circulation patterns and the occurrence and duration of drought.

186. For example, El Niño events have been known to cause drought-like conditions in the Mekong region. The 2015-2016 El Niño event is one of the strongest to date. El Niño events are caused by warmer-than-average temperatures in the Pacific Ocean causing changes in weather patterns that can lead to flooding and droughts in the Mekong region.

187. The Project Team is also aware of work being done for the Mekong region by Columbia University to improve the seasonal forecast of drought events considering sea temperatures in the South China Sea. The Project Team plans to follow-up with the lead researcher, who is conducting the investigation, to determine the availability of historical information on droughts.

188. The Project Team will use information and data on past drought events to assess a recurrence frequency for various droughts and the affect that these drought have had in the study area.

189. The proposed approach will be to review existing drought severity index methods used in the international community, such as the Standardized Precipitation Index (SPI). As well, a water level indicator will be investigated. The water level indicator would consider monthly and seasonal percentiles of water level for key sites. A preferred approach for Cambodia will be recommended, based on criteria such as robustness, tractability, transparency, sophistication, extendibility, and dimensionality. Case studies using the 2002, 2004-05, and 2012 droughts and application of drought indices, such as the SPI, will be used to assess the reliability of the selected drought and water level index to predict the onset of a drought, its duration, and effect on water availability.

190. The Project Team will prepare a series of flood and drought hazard and risk maps at the most appropriate scale for the selected study area, using the information generated by the modelling and drought studies. A detailed report presenting the results of the flood and drought risk assessment will be prepared. All data, graphs and charts, as well as the files used for the 1D and 2D hydrodynamic runs will be shown as appendices.

191. The experience and lessons learned during the model calibration, verification, and application activities conducted under this WBS will be used to improve the flood forecast operational system for the National Flood Forecasting Centre under WBS 800.

192. In summary, the activities under this WBS 500 will include:

- Compile hydrological, land use, social economic, and related spatial data and flood and drought information for the selected study area;
- Select a suitable digital terrain model for the selected study area;
- Define modelling methodology and present to the Ministry for comment and approval;
- Conduct hydrological and hydraulic modelling for the selected study area;
- Conduct probability analysis based on the modelled results;
- Assess drought prediction approaches and severity indices, which consider seasonal and historical patterns;
- Prepare flood hazard and risk maps and draft report summarizing key findings and recommendations for review and comment; and
- Submit final report with revisions, as required.

193. The deliverable for WBS 500 is a Detailed Flood and Drought Hazard and Risk Assessment Report for the selected study area.

194. Level of Effort: The activities under WBS 500 will involve the Deputy Team Leader as well as the Meteorologist, Hydrological Modelling Specialist, and Hydraulic Modelling Specialist of the National Team, the International Team Leader, selected inputs from the Meteorologist (Weather Forecast), Hydrological Modeller, Hydraulic Modeller, and Forecast and Warning Dissemination Experts of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 8.5 person months for the National Team and 4.0 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.5
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0.75
Hydrological Modelling Expert	0.75
Hydraulic Modelling Expert	0.75
Forecast and Warning Dissemination Expert	0.25
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	3.0
Meteorologist	1.5
Hydrological Modelling Specialist	2.0
Hydraulic Modelling Specialist	2.0
Forecast and Warning Dissemination Specialist	0
Institutional Specialist	0

195. Completion Date: December 2016

4.7 WBS-600 Residual Risk Associated with Protection Measures

196. The most effective flood mitigation methods in Cambodia are relocation and elevation. However when these methods are not feasible, structural flood proofing and mitigation methods may be an alternative.

197. 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.

198. Structural measures aim to reduce flood risk by controlling the flow of water. Non-structural measures are actions taken to mitigate flood loss and damages through better planning and management of watershed development.

199. 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.

200. Non-structural measures manage risk by building the capacity of people to cope with flood and droughts. Non-structural measures, such as an early warning system, are a key component of a flood and drought mitigation and risk reduction strategy. 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 themes (**Figure 13**):

i. **Risk Knowledge** - Risks arise from flood and drought events and the communities' vulnerabilities at a particular location. 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;

ii. **Monitoring and Warning Service** - 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 event parameters is essential to generate accurate warnings in a timely fashion. Warning services for flood events must be coordinated and benefit from existing institutional, procedural, and communication networks. Droughts are more seasonal and offer a longer warning period;

iii. **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 occurs; and

iv. **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 be 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.

Figure 13: Non-Structural Flood Management Components

(Source: Platform for Promotion of Early Warnings – PPEW, Bonn, Germany)

201. A recent concept in flood and drought management is one of Integrated Flood Management (IFM) or Sustainable Flood Management. Sustainable Flood Management integrates land and water resources development in a river basin, within the context of an Integrated Water Resources Management (IWRM) approach, with a view to maximizing the efficient use of flood plains and minimizing loss to life and livelihoods.

202. For flood and drought management to be carried out within the context of IWRM, river basins should be considered as systems. As well socio-economic activities, land-use patterns, hydro-morphological processes, structural and non-structural approaches, and institutional capacity development needs must be recognized.

203. Under a Sustainable Flood Management approach, land use planning and water management is combined in a comprehensive plan developed and coordinated amongst land management and water management authorities to achieve consistency. The rationale for this integrated approach is that land use affects both water quantity and quality. As well, upstream changes in land use can drastically change the characteristics of a flood and associated water quality and sediment transport. Water quantity, water quality, and the processes of erosion and deposition are inherently linked and are the primary reasons for adopting a river basin-based approach under a Sustainable Flood Management framework.

204. Although the Sustainable Flood Management approach is beyond the scope of work being conducted under this project, it is presented here (**Figure 14**) for completeness and may offer an interface point for linkage to other activities under the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project.

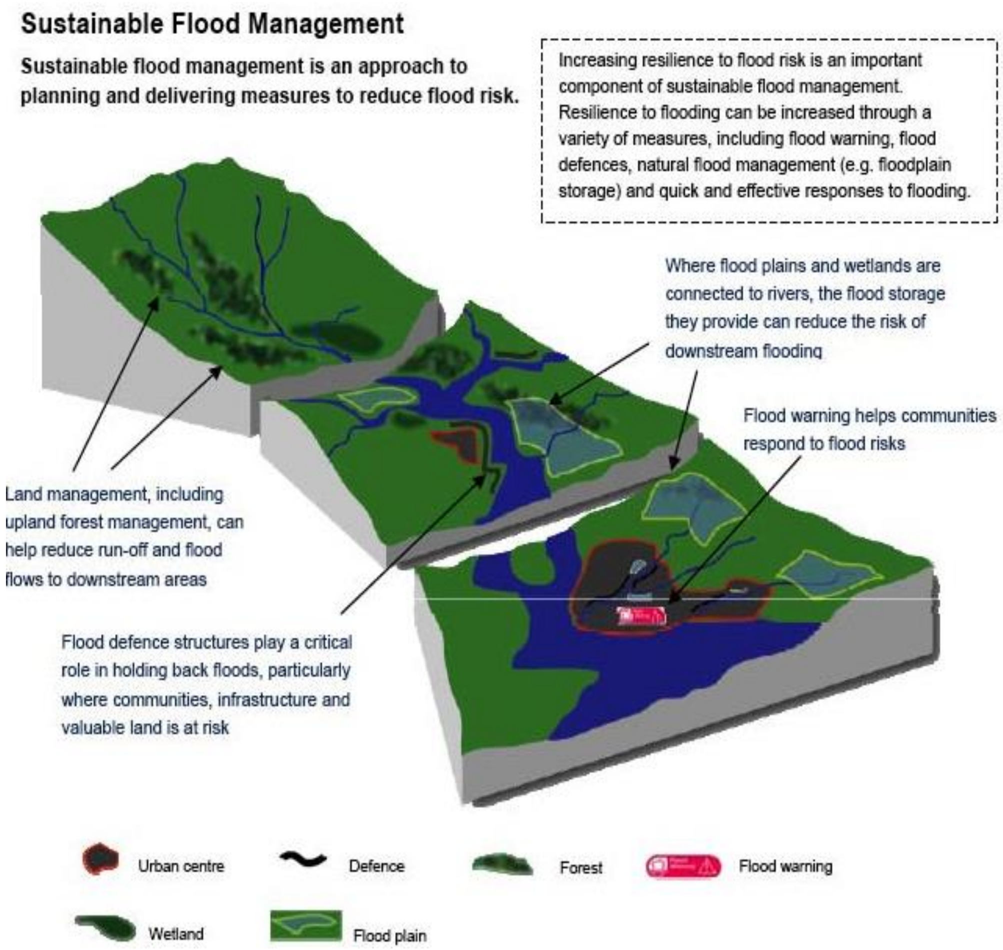


Figure 14: Sustainable Flood Management Concepts

205. The Project Team will propose a number of structural flood and drought protection measures taking into account a Sustainable Flood Management approach and will assess the residual risk and costs associated with the proposed protection measures. The flood and drought strategies and options that will be considered include:

Strategy	Options
Reduce Flooding	Dams and reservoirs Dikes, levees, and flood embankments High flow diversions Catchment management Channel improvements
Reduce Flood and Drought Susceptibility	Flood plain regulation Development and redevelopment policies Design and location of facilities Housing and building codes Flood and drought proofing 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 Drought Strategy	Coordination between governments and non-government organizations at national, provincial, and local levels

206. The Project Team will develop a cost-benefit analysis for structural and other measures proposed to mitigate flood and drought risks in the priority basin. Hazard and risk maps will be generated for the various options and improvement in benefits determined for various options or levels of options. Regular consultations will be required with key stakeholders during this process.

207. In summary, the activities under this WBS 600 will include:

- Prepare background discussion document on flood protection and drought mitigation measures;
- Review and assess existing RGC national flood and drought response and mitigation strategies;
- Assist the Ministry define and develop an updated flood and drought risk mitigation strategy, as required;
- Develop a cost and benefit analysis using cost of infrastructure for various protection measures for the priority basin;
- Prepare draft report summarizing key findings and recommendations for review and comment; and
- Submit final report with revisions, as required.

208. The deliverable for WBS 600 is a Cost Benefit Analysis Report on Residual Risk Associated with Various Protection Measures for the selected study area.

209. Level of Effort: The activities under WBS 600 will involve the Deputy Team Leader as well as the Meteorologist, Hydrological Modelling Specialist, and Hydraulic Modelling Specialist of the National Team, the International Team Leader, selected inputs from the Meteorologist (Weather Forecast), Hydrological Modeller, and Hydraulic Modeller of the International Team, and backstopping support from the home office

in Madrid. The total level of effort is estimated at 7.0 person months for the National Team and 2.0 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.0
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0.5
Hydrological Modelling Expert	0.25
Hydraulic Modelling Expert	0.25
Forecast and Warning Dissemination Expert	0
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	2.0
Meteorologist	1.0
Hydrological Modelling Specialist	2.0
Hydraulic Modelling Specialist	2.0
Forecast and Warning Dissemination Specialist	0
Institutional Specialist	0

210. Completion Date: June 2017

4.8 WBS-700 Climate Resilient Design Criteria for Structural Flood and Drought Control

211. The Project Team will develop guidelines for climate resilient design of structures for flood and drought mitigation. The design guidelines will consider the results of the work conducted under WBS 500 and WBS 600. As well, the design guidelines will consider the implications of climate change over the design life of the various structural mitigation options. It is expected that the guidelines will include a discussion of regulatory requirements, design standards, construction codes, and other guidance documents.

212. In summary, the activities under this WBS 700 will include:

- Prepare discussion document on flood and drought proofing and mitigation measures considering the cost benefit analysis;
- Assess probable climate scenarios to be considerate for the region;
- Develop design criteria for structural flood and drought mitigation measures;
- Prepare draft report summarizing key findings and recommendations for review and comment; and
- Submit final report with revisions, as required.

213. The deliverable for WBS 700 is a report on Climate Resilient Design Guidelines for Structural Flood and Drought Control Measures.

214. Level of Effort: The activities under WBS 700 will involve the Deputy Team Leader and Hydraulic Modeller of the National Team, the International Team Leader, and support from the home office in Madrid. The total level of effort is estimated at 2.5 person months for the National Team and 1.0 person month for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.0
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0
Hydrological Modelling Expert	0
Hydraulic Modelling Expert	0
Forecast and Warning Dissemination Expert	0
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	2.0
Meteorologist	0
Hydrological Modelling Specialist	0
Hydraulic Modelling Specialist	0.5
Forecast and Warning Dissemination Specialist	0
Institutional Specialist	0

215. Completion Date: August 2017

4.9 WBS-800 Improved Flood Forecasts and Drought Predictions

216. The Project Team will spend considerable effort under WBS 800 to enhance the capacity of the National Flood Forecasting Centre within the Department of Hydrology and River Works and the capacity of the Weather Forecast Centre in the Department of Meteorology. The plan for the improvement of flood forecasts and drought predictions and strengthening of the forecast centres will be developed under WBS 200 and WBS 300 and procurement will occur under WBS 400. Most of the training under WBS 900 is directed at the National Flood Forecasting Centre. However, significant support will be provided under this WBS to implement improvements to NFFC's operational flood forecast and early warning dissemination system for the study area. However, the expectations must be in-line with the available resources and timeline of the project. As well, the calibration and verification of the forecasting models will be highly dependent on the availability of reliable and representative meteorological, hydrological, river geomorphology, and digital elevation data for the study area.

217. It should be noted that the river system in the Lower Mekong is hydraulically controlled and requires 1D and 2D modelling approaches in order to forecast flood levels. As such, it will be a significant undertaking to improve the water level forecast in the Lower Mekong mainstream given the complexity of the interconnecting channels and overland flow. Furthermore, the reliable of hydraulic models to represent the flood extent is directly linked to the availability of recent and appropriately scaled DEMs and DTMs. It is believed that the required detailed DEM and DTM are not available at this time. However, the Project Team will apply 2D modelling in the mainstream Mekong in Cambodia and as required in the Pursat tributary basin.

218. Simulations using a 2D hydrodynamic model are required to analyse flood zones where the flow does not have a clearly marked direction in the axial flow direction and has a transverse component. This is the case for side branches, bifurcations, or confluences, and urban areas. The analysis of the flood zone is required to generate flood inundation maps.

219. Simulations using a 2D hydrodynamic model require a Digital Terrain Model, hydrological data as input, and roughness characterization for the flooded area using Manning coefficient polygons. The 2D hydrodynamic model determines the depth and velocity of water at each grid point of the study area. The detailed grid cell information supports the analysis of the flood wave as it evolves and its subsequent recession.

220. As previous described under WBS 300, the Project Team will consider the forecast approach used at the Mekong River Commission's RFMMC. The Flood Early Warning System (FEWS) will be assessed in consultation with DHRW and key stakeholders to determine its acceptance and potential for implementation at NFFC. As well, the Project Team will consider the Info Works ICM (Integrated Catchment Modelling) Commercial Software and HEC-HMS/RAS for the simulations.

218. Info Works ICM is an integrated modelling platform for modelling both urban and river catchments. Info Works ICM enables the hydraulics and hydrology of natural and manmade environments to be incorporated into a single model. Info Works ICM enables unique man-made features such as small inlets, bridges, sluices, weirs, and pumping stations to be accounted for and combined with natural features to support more precise modelling of flows through complex geometries. Furthermore, Info Works ICM supports the presentation of data as geographical views, sections, longitudinal profiles, temporary tables, and graphs. Data can be presented in animated form using geographic, longitudinal, or transverse views, including fully dynamic flood maps.

219. A further enhancement will be to provide information on the effect that the forecasted flood levels will have with respect to flood extent and duration. This enhanced information is in keeping with WMO's goal to have national forecast centres provide information on the impact of forecasted events. Therefore, the Project Team proposes to investigate and implement the coupling of the water level forecast to a projection of the flood extent and duration for selected reaches of the mainstream Mekong using available DTM information.

220. Under the existing system the impact of local rainfall is subjectively considered in adjusting the flood level forecasts. Given the effect that local rainfall events may have on the mainstream water levels, the Project Team proposes to investigate and incorporate a more science-based approach to considering these local rainfall events on the forecasted flood parameters such as peak water levels, timing of the flood, and duration of the flood. This may involve improvements to the rainfall observing network, greater use of remote sensing products, enhanced ability to assimilate rainfall forecasts provided by numerical global models, and improvements to the forecast capabilities within DOM and the forecast models used in the NFFC.

221. As discussed under WBS 500, the Project Team will build upon the drought prediction approach selected for Cambodia with respect to the application of drought indices to predict the onset of a drought, its duration, and effect on water availability.

222. Accordingly, the activities to be conducted under WBS 800 include:

- Develop NFFC's flood forecast system and capacity for the study area as per the agreed to strategy under WBS 300;
- Enhance DOM's capacity to provide rainfall forecasts as required by NFFC;
- Enhance DOM's capacity to provide seasonal drought predictions;
- Test the flood forecast, drought prediction, and early warning SOP in the priority areas during the 2017 monsoon season;
- Review and update the flood forecast, drought prediction, and early warning SOP considering lessons learned during 2017 monsoon season; and
- Prepare a report on the recommendations and next steps required to further enhance NFFC's and DOM's capacity for medium-term flood forecasts and drought prediction.

223. The deliverable for WBS 800 is an improved DOM capacity for rainfall forecasts and drought predictions and an improved NFFC flood forecast system.

224. Level of Effort: The activities under WBS 800 will involve the Deputy Team Leader as well as the Meteorologist, Hydrological Modelling Specialist, Hydraulic Modelling Specialist, Forecast and Warning Dissemination Specialist, and Institutional Specialist of the National Team, the International Team Leader, selected inputs from the Meteorologist (Weather Expert), Hydrological Modeller, Hydraulic Modeller, and Forecast and Warning Dissemination Experts of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 18.6 person months for the National Team and 5.3 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.6
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0.9
Hydrological Modelling Expert	1.15
Hydraulic Modelling Expert	1.15
Forecast and Warning Dissemination Expert	0.5
Institutional Specialist	0
National	
Hydro-Meteorological Advisor/Deputy Team Leader	4.5
Meteorologist	3.2
Hydrological Modelling Specialist	4.7
Hydraulic Modelling Specialist	4.7
Forecast and Warning Dissemination Specialist	1.0
Institutional Specialist	0.5

225. Completion Date: April 2017 for the DOM and NFFC's forecast systems and October 2017 for updates to the SOP and report on next steps.

4.10 WBS-900 National Flood Forecasting Centre (NFFC) Training and Capacity Development

226. Sustainability of the National flood Forecasting Centre is directly dependent on the NFFC's capacity to maintain and operate the data acquisition, forecast, and early warning systems provided under the project. In the context of sustainability, the capacity dimension includes the available of a reasonable annual budgetary provision to meet the cost of operational and service needs and an adequately skilled human resources capacity to operate, maintain and enhance the tools provided. Hence, the Project Team will provide appropriate training to develop the available human resources. The training requirements and themes will be derived from the training needs assessment conducted under WBS 200 and WBS 300.

227. The training and transfer of knowledge and expertise to local personnel will be implemented through a combination of formal training, including workshops, thematic seminars, roundtable meetings, and on-the-job training.

228. Workshops will be organized prior to the implementation of specific tasks and during the course of the project. Workshops or refresher courses are intended to provide basic skills and knowledge on matters related to the general topics or project tasks. Workshops will generally be one day in duration. Lecturers in the workshop will include members of the Project Team, national or regional known experts, and invited speakers from other components.

229. Thematic seminars will be organized for specific subjects related to project tasks. Seminar topics will be targeted to a small group and technical in nature. Seminars will normally be a few hours in duration.

230. Roundtable meetings will be organized by the Project Team to discuss and exchange views and experiences with counterpart staff on different aspects of component tasks and sub-tasks.

231. On-the-job Training (OJT) will be the primary training methodology for achieving technical transfer. The OJT strategy is based on the principle of teamwork in which the Project Team works closely with the local counterpart personnel to implement or accomplish specific tasks. Self study guides and user guides will be developed to support the OJT activities.

232. The training plan, which will be developed, will cover:

- Hydrometeorological field operations and data management functions;
- Weather forecast and seasonal climate prediction models, operations, and model calibration;
- Hydrologic model use, model calibration, and application;
- Hydraulic model use, model calibration, and application;
- Forecast operations and model refinements; and
- Forecast presentation and dissemination.

233. Each training session will culminate in a feedback session to reflect on the training session and to measure the participant's understanding of the subject presented. As well, regular assessment of NFFC's capacity development will be conducted to measure the effectiveness of the training being offered and to provide feedback for improving future training.

234. The Project Team will review the organizational structured and make recommendations to institutional strengthen the NFFC. The recommendations on organizational structure are expected to ensure:

- Clarification of operating responsibilities to ensure all functions are clearly assigned;
- Systematic and structured information flow;
- Appropriate and timely decision making; and
- A work environment that supports innovation and continuous improvement.

235. In summary, the activities under this WBS 900 will include:

- Conduct a training assessment;
- Develop a training plan for hydrometeorological field operations and data management functions; for the weather forecast operations and models; for hydrological forecasting and calibration of models; for the hydraulic model operations; and for forecast presentation and dissemination;
- Provide training using formal and on-the-job training approaches;
- Provide regular and on-going mentoring to NFFC staff during the project;
- Prepare training and self study guides for NFFC; and
- Conduct regular assessments of NFFC capacity development.

236. The deliverable for WBS 900 is a needs assessment, training plan, and a series of workshops, seminars, and on-the-job training supported with self-study modules and user guides.

237. Level of Effort: The activities under WBS 900 will involve the Deputy Team Leader Meteorologist, Hydrological Modelling Specialist, Hydraulic Modelling Specialist, Forecast and Warning Dissemination Specialist, and Institutional Specialist of the National Team, the International Team Leader, selected inputs from the Meteorologist (Network Improvements), Meteorologist (Weather Expert), Hydrological Modeller, Hydraulic Modeller, Forecast and Warning Dissemination, and Institutional Experts of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 6.5 person months for the National Team and 5.55 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	0.5
Meteorologist 1 (Meteorological Network Improvement)	1.9
Meteorologist 2 (Weather Forecast)	1.0
Hydrological Modelling Expert	0.5
Hydraulic Modelling Expert	0.5
Forecast and Warning Dissemination Expert	0.75
Institutional Specialist	0.4
National	
Hydro-Meteorological Advisor/Deputy Team Leader	2.0
Meteorologist	1.0
Hydrological Modelling Specialist	0.5
Hydraulic Modelling Specialist	1.0
Forecast and Warning Dissemination Specialist	1.0
Institutional Specialist	1.0

238. Completion Date: October 2017

4.11 WBS-1000 An Early Warning Strategy at the Community Level with Improved Regional Coordination and Cooperation

239. The scope of activities under WBS 1000 is several fold. The first will involve the development or improvement of an operational flood forecast and early warning dissemination strategy. The scope of strategy will cover the national to community level. The strategy will build upon the work of the Community Based Disaster Risk Management and Famers Water Users Community sub-project of the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project.

240. The operational flood forecast and early warning dissemination strategy will be built upon the flood and drought mitigation elements presented under WBS 600 of risk knowledge, monitoring and warning service, dissemination and communications, and response capability. As such, the strategy will develop actions that consider the following:

- Assessment of risk requires the systematic collection and analysis of data and considers the dynamic nature of flood and drought events and vulnerabilities that arise. Risk assessments and risk maps are used to prioritize flood and drought needs and to guide preparations for prevention, mitigation, and response.

- Monitoring and warning services lie at the core of the system. Continuous monitoring of flood and drought event parameters and the generation of accurate forecasts and warnings in a timely fashion is essential.
- Dissemination and communication of clear messages that contain simple and useful information is critical in enabling proper responses from those at risk as well as the agencies responsible for flood and drought response and relief. Regional, national, and community level institutions must be pre-identified and appropriate roles and responsibilities established.
- Response capability at the community level is key. Communities must understand the 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 be in place, well practiced, and tested.

241. The operational flood forecast and early warning dissemination strategy will consider the structure and function of the MRC's Regional Flood Management and Mitigation Centre, who also issue daily flood forecasts and warnings. As well, it will consider existing strategies and Standard Operating Procedures (SOPs) for flood and drought early warning and disaster management.

242. The piloting of the strategy and SOPs will be undertaken from the national to community level through an awareness campaign. The awareness campaign will be in collaboration with the activities and plans of the Community Based Disaster Risk Management and Famers Water Users Community sub-project.

243. The second activity is the conduct of a mock drill of the early warning system to test the 'end to end' performance and functionality of the flood forecasting and drought prediction system, including the interface at the community level. The mock drill will be designed to assess interconnections with the regional and national disaster emergency organizations as well as community-based organizations. The mock drill will be as comprehensive as possible, and include testing of the early warning systems, evacuation drills, and response activities.

244. A comprehensive report on the results of the drill will be prepared. The report will highlight strengths and weaknesses of the system and include recommendations for improvements to the early warning system and on opportunities to improve national-regional coordination and corporation.

245. The third activity is to identify avenues for improvements in the sharing and exchange of data as well as flood and drought information within a regional context. The sharing of information will also consider knowledge exchange on technologies and experiences. The Project Team recommends that the Mekong River Commission, with donor support, host a regional workshop to showcase the enhancements and approach used to strengthen the NFFC and to exchange experiences with other flood forecasting centres in the Mekong basin. It is believed that a 'community of practice' could be established as the result of the Regional workshop. The annual regional flood-forecasting meeting may serve as a suitable forum for this activity.

246. In summary, the activities under this WBS 1000 will include:

- Review existing early warning dissemination policies, strategies, and institutional arrangements and prepare discussion document;
- Revise as required the early warning dissemination strategy and SOPs in collaboration with CBDRM sub-project;
- Design and pilot a mock drill of the NFFC's early warning system to increase awareness and to assess the system's effectiveness at the community level;
- Identify avenues for the exchange and sharing of information and knowledge and experiences with respect to forecasting floods and droughts;
- Prepare a report on the results of the mock drill with recommendations to improve NFFC's early warning SOPs and regional information exchange; and
- Submit final report with revisions, as required

244. The deliverable for WBS 1000 is a Community Based Flood Forecast and Early Warning Dissemination SOPs and a Guidance Report on National and Regional Coordination and Cooperation Improvements.

245. Level of Effort: The activities under WBS 1000 will involve the Deputy Team Leader as well the Meteorologist, Hydrologic Modeller, Forecast and Warning Dissemination Specialist, and Institutional Specialist of the National Team, the International Team Leader, selected inputs from the Institutional Expert of the International Team, and backstopping support from the home office in Madrid. The total level of effort is estimated at 4.1 person months for the National Team and 2.0 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	0.5
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0
Hydrological Modelling Expert	0
Hydraulic Modelling Expert	0
Forecast and Warning Dissemination Expert	0
Institutional Specialist	1.5
National	
Hydro-Meteorological Advisor/Deputy Team Leader	1.0
Meteorologist	1.0
Hydrological Modelling Specialist	1.0
Hydraulic Modelling Specialist	0
Forecast and Warning Dissemination Specialist	0.6
Institutional Specialist	0.5

246. Completion Date: October 2017

4.12 WBS-1100 Project Management and Reporting

247. The consulting services will be provided over a period of 24 months and will follow the Work Breakdown Structure (WBS) presented in this Inception report. Quarterly assessments of progress according to the WBS and the detailed schedule of deliverables will be conducted. The performance assessments will be used to determine adjustments to the work plan, scheduling of experts, and refinements to the modularity of the work required to complete the activities outlined.

248. The Team Leader will be responsible for overall project management. In his absence, the Deputy Team Leader will assume the project management responsibilities, or with the approval of the Client the responsibility may be assigned to another senior member of the Team on an acting bases. Under the overall direction of the Team Leader and his Deputy, the local project team will form a project management team together with relevant international specialists, as required. The International Team will be comprised of two Meteorologists specialized in meteorological network improvement and weather forecasting; a Hydrological Modelling Expert and a Hydraulic Modelling Expert, who will be in charge of preparing forecast plans, developing hydrological and hydraulic models, providing training, and preparing flood risk maps; a Forecast and Warning Dissemination Expert, who will develop and implement a plan for public awareness;

and an Institutional Specialist, who will prepare a plan for institutional strengthening. The members of the Project Team are shown in Appendix 3.

249. Monthly coordination meetings with the other Team Leaders of the Greater Mekong Sub-Region Flood and Drought Risk Management and Mitigation Project will be organized by the CPMU to exchange and share information.

250. Project reporting will be as per the requirements of the contract and needs of CPMU. Progress reporting activities will include quarterly and annual progress reports, mid-term report at the end of month 12, mid-term workshop for disseminating the mid-term report, draft final report at end of month 22, final workshop for disseminating the draft final report, and the final report at end of month 24.

251. In summary, the activities under this WBS 1100 will include:

- Manage staff and coordinate project activities as per the approved work plan;
- Attend CPMU and PIU meetings and maintain regular contact with Project Authority via meetings, email, and conference calls;
- Prepare progress reports and hold progress meetings and workshops as required;
- Participate in monthly coordination meetings with Team Leaders of related ADB projects;
- Ensure adherence to EPTISA's Project Management and Quality Assurance policies; and
- Notify Project Authority of concerns or project issues and suggest corrective actions, as required.

252. The deliverables will be:

i. Inception report, at end of month 3;
ii. Inception Workshop to disseminate Inception Report;
iii. Quarterly and Annual Progress Reports;
iv. Mid Term Report, at end of month 12;
v. Mid Term Workshop for disseminating Mid Term Report;
vi. Draft Final Report, at end of month 22;
vii. Workshop for disseminating Draft Final Report; and
viii. Final Report, at end of month 24.

253. Level of Effort: The activities under WBS 1100 will involve the Deputy Team Leader and the International Team Leader, and backstopping support from the home office in Madrid. The total level of effort is estimated at 2.0 person months for the National Team and 1.5 person months for the International Team.

Expert	Input (Person- Months)
International	
International Hydro-Meteorological Advisor/Team Leader	1.5
Meteorologist 1 (Meteorological Network Improvement)	0
Meteorologist 2 (Weather Forecast)	0
Hydrological Modelling Expert	0
Hydraulic Modelling Expert	0
Forecast and Warning Dissemination Expert	0
Institutional Specialist	0
National	

Hydro-Meteorological Advisor/Deputy Team Leader	2.0
Meteorologist	0
Hydrological Modelling Specialist	0
Hydraulic Modelling Specialist	0
Forecast and Warning Dissemination Specialist	0
Institutional Specialist	0

254. Completion Date: December 2017

Work Breakdown Structure

6. Project Schedule

255. The activity schedule with deliverables is shown in the following figure. It is coordinated with the Schedule of Experts shown in Appendix 1.

Proposed Work Plan and Schedule

Task	Work Component	2016												2017											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Task 1	WBS 100 - Inception Report	■	■	■																					
Task 1a	WBS 100a - Preliminary Flood and Drought Assessment	■	■	■																					
Task 2	WBS 200 - Hydrometeorological Network and Data Management System	■	■	■																					
Task 3	WBS 300 - Forecasting Approach and Operational Capacity	■	■	■	■	■	■																		
Task 4	WBS 400 - Technical Specifications for Improvements to Hydrometeorological Network and Forecast System	■	■	■	■	■		■			■	■	■									■			
Task 5	WBS 500 - Flooding and Drought Hazard and Risk Assessment for Different Probabilities					■	■	■	■	■	■	■	■												
Task 6	WBS 600 - Residual Risk Associated with Protection Measures										■	■	■	■	■	■	■	■	■						
Task 7	WBS 700 - Climate Resilient Design Criteria for Structural Flood and Drought Control																	■	■	■	■				
Task 8	WBS 800 - Improved Flood Forecasts and Drought Predictions							■	■	■	■	■	■	■	■	■	■					■	■		
Task 9	WBS 900 - NFFC Training and Capacity Development							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Task 10	WBS 1000 - An Early Warning Strategy at the Community Level with Improved Regional Coordination and Cooperation																			■	■	■	■		
Task 11	WBS 1100 - Project Management and Reporting	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

7. Project Deliverables

256. The deliverables as per the Work Breakdown Structure are:

WBS	Deliverable	Timeline
WBS 100	Approved Inception Report	March 2016
WBS 100a	Report - Preliminary Risk Assessment of Floods and Droughts.	March 2016
WBS 200	Conceptual Design Report for Hydrometeorological Observing and Data Management System	March 2016
WBS 300	Conceptual Design Report for Forecast Production and Dissemination	June 2016
WBS 400	A series of Technical Specification: • Hydromet Equipment and Data Management • Forecast and Information Dissemination • Hydromet Stations- Civil Works	 March 2016 July 2016 July 2016
WBS 500	Detailed Flood and Drought Hazard and Risk Assessment Report for the selected study area.	December 2016
WBS 600	Cost Benefit Analysis Report on Residual Risk Associated with Various Protection Measures for the selected study area	June 2017
WBS 700	Climate Resilient Design Guidelines for Structural Flood and Drought Control Measures.	August 2017
WBS 800	Improved NFFC flood forecast system Improved DOM capacity for rainfall forecasts and drought predictions Updates to the SOPs and report on next steps.	April 2017 October 2017
WBS 900	Needs assessment and training plan Series of workshops, seminars, and on-the-job training supported with self-study modules and user guides.	June 2016 Ongoing from July 2016 to October 2017
WBS 1000	Community Based Flood Forecast and Early Warning Dissemination SOPs Guidance Report on National and Regional Coordination and Cooperation Improvements.	October 2017 October 2017
WBS 1100	As per Terms of Reference	January 2016 to December 2017

The deliverables as per the Terms of Reference are:

- Inception report, at end of month 3;
- Inception Workshop to disseminate Inception Report;
- Quarterly and Annual Progress Reports;
- Mid Term Report, at end of month 12;
- Mid Term Workshop for disseminating Mid Term Report;
- Draft Final Report, at end of month 22;
- Workshop for disseminating Draft Final Report; and
- Final Report, at end of month 24.

8. References

1. MOWRAM / ADB CDTA7610-CAM: "National Water Resources Status Report", 2014.

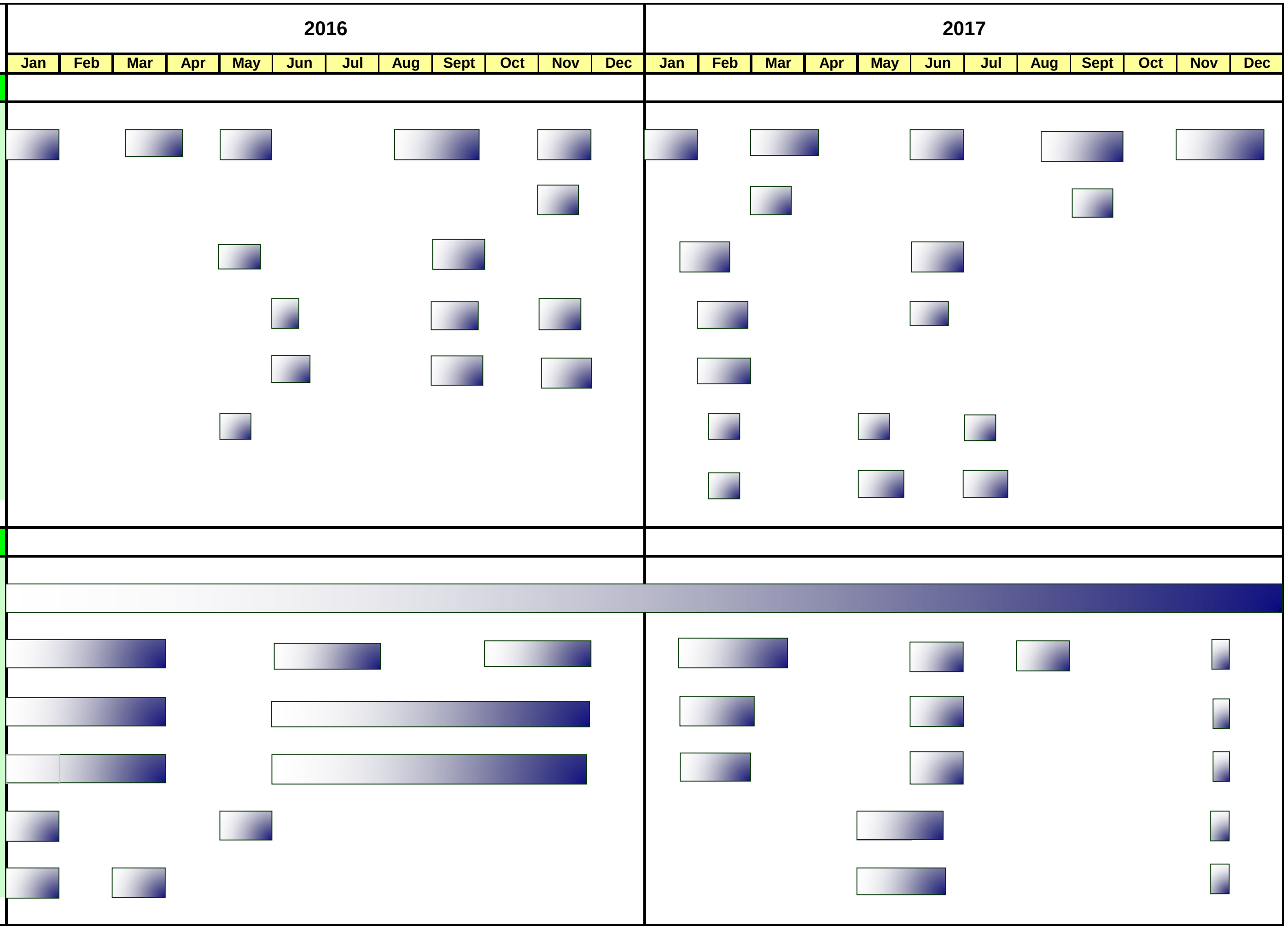
2. MOWRAM / ADB CDTA7610-CAM: "Cambodia Water Resources Profile", April 2014.

3. MOWRAM / ADB CDTA7610-CAM: "Report on Institutional Arrangements For The Management Of Water Resources In Cambodia", February 2015.

Appendix 1: Schedule of Experts

Consultant Schedule

Consulting Team	
International Experts	**28**
Team Leader/ HydroMet Advisor	12
Meteorologist 1 - Network Improvements	2
Meteorlogist 2 - Weather Forecast	4
Hydrologic Modeller	3
Hydraulic Modeller	3
Forecasting and Warning Dissemination	2
Institutional	2
National Team	**68**
Deputy Team Leader/ HydroMet Advisor	24
Meteorologist	12
Hydrologic Modeller	12
Hydraulic Modeller	12
Forecasting and Warning Dissemination	4
Institutional	4



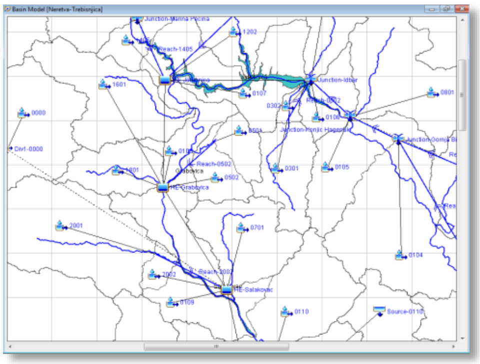
Appendix 2: HEC-HMS and HEC-RAS Features

HEC-HMS FEATURES

Watershed Physical Description

256. The physical representation of a watershed is accomplished considering a basin-wide model. Hydrologic elements are connected in a dendritic network to simulate runoff processes. Model elements include sub-basins, reaches, junctions, reservoirs, and diversions. Computation proceeds from upstream elements in a downstream direction.

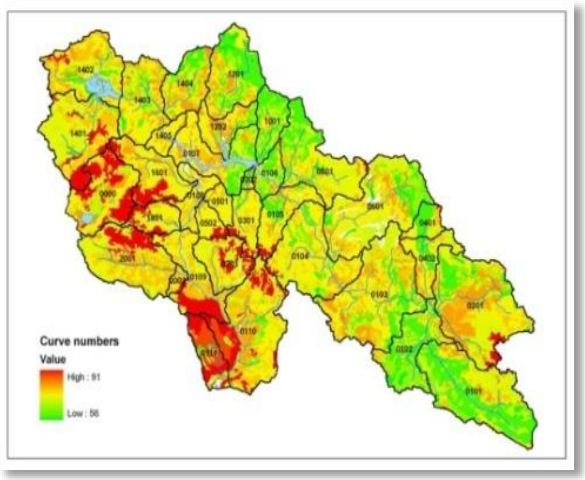
257. An assortment of different methods is available to simulate infiltration losses. Options for event modelling include initial constant deficit, SCS curve number, gridded SCS curve number, exponential relations, and Green Ampt method. The one-layer deficit constant method can be used for simple continuous modelling. The five-layer soil moisture accounting method can be used for continuous modelling of complex infiltration and evapotranspiration environments. Gridded methods are available for both the deficit constant and soil moisture accounting methods.



258. Several methods are included for transforming excess precipitation into surface runoff. Unit hydrograph methods include the Clark, Snyder, and SCS techniques. User-specified unit hydrograph or S-graph ordinates can also be used. The modified Clark method, Mod Clark, is a linear quasi-distributed unit hydrograph method that can be used with gridded meteorological data. An implementation of the kinematic wave method with multiple planes and channels is also included.

259. Multiple methods are included for representing baseflow contributions to sub-basin outflow. The recession method gives an exponentially decreasing baseflow from a single event or multiple sequential events. The constant monthly method can work well for continuous simulation. The linear reservoir method conserves mass by routing infiltrated precipitation to the channel.

260. A variety of hydrological routing methods are included for simulating flow in open channels. Routing with no attenuation can be modelled with the lag method. The traditional Muskingum method is included along with the Straddle Stagger method for simple approximations of attenuation. The modified Puls method can be used to model a reach as a series of cascading, level pools with a user-specified storage-discharge relationship. Channels with trapezoidal, rectangular, triangular, or circular cross sections can be modelled with the kinematic wave or Muskingum-Cunge methods. Channels with overbank areas can be modelled with the Muskingum-Cunge method and an eight-point cross-section.



261. Water impoundments can also be represented. Lakes are usually described by a user-entered storage-discharge relationship. Reservoirs can be simulated by describing the storage-capacity curve, spillway, and outlet structures of the reservoir. Pumps can also be included, as necessary. Control of the pumps can be linked to water depth in the collection pond and, optionally, the stage in the main channel.

Meteorology Description

262. Meteorological data analysis is performed by the meteorological model and includes precipitation and evapotranspiration. Six different historical and synthetic precipitation methods are included. Two evapotranspiration methods are currently available.

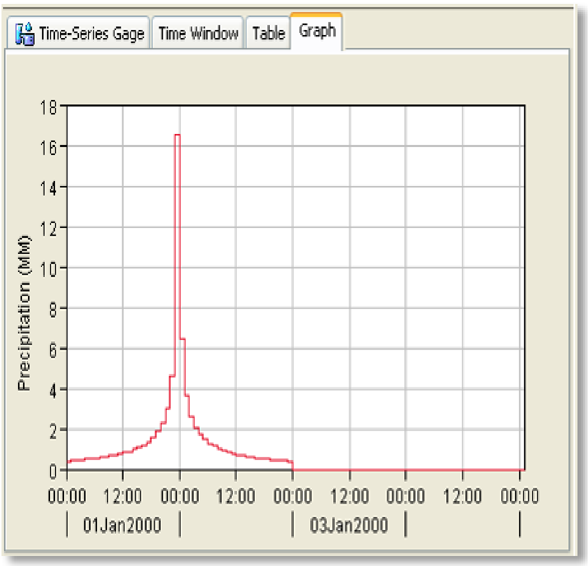
263. Four different methods for analysing historical precipitation are included. The user-specified hyetograph method is for precipitation data analysed outside the program. The raingauge weight method uses an unlimited number of recording and non-recording gages. The Thiessen technique is one possibility for determining the weights. The inverse distance method addresses dynamic data problems. An unlimited number of recording and non-recording gauges can be used to automatically proceed when missing data is encountered. The gridded precipitation method uses radar rainfall data.

264. Four different methods for producing synthetic precipitation are included. The frequency storm method uses statistical data to produce balanced storms with a specific exceedance probability. The standard project storm method implements the regulations for precipitation when estimating a standard project flood. The SCS hypothetical storm method implements primary precipitation distributions for design analysis. The user-specified hyetograph method can be used with a synthetic hyetograph resulting from analysis conducted outside the program.

265. Potential evapotranspiration can be computed using monthly average values. A gridded version of the Priestley-Taylor method that includes a crop coefficient is also available.

Hydrologic Simulation

266. User set specifications controls the time span of a simulation. Control specifications include a starting date and time, ending date and time, and a time interval.



267. Combining a basin model with a meteorological model and providing a series of control specifications creates a simulation run. Run options include setting a precipitation or flow ratio, ability to save all basin state information at a point in time, and the ability to begin a simulation run from previously saved state information.

268. Simulation results can be viewed using a basin map. Global and element summary tables include information on peak flow and total volume. A time-series table and graph are available. Results from multiple elements and multiple simulation runs can also be viewed. All graphs and tables can be printed.

Parameter Estimation

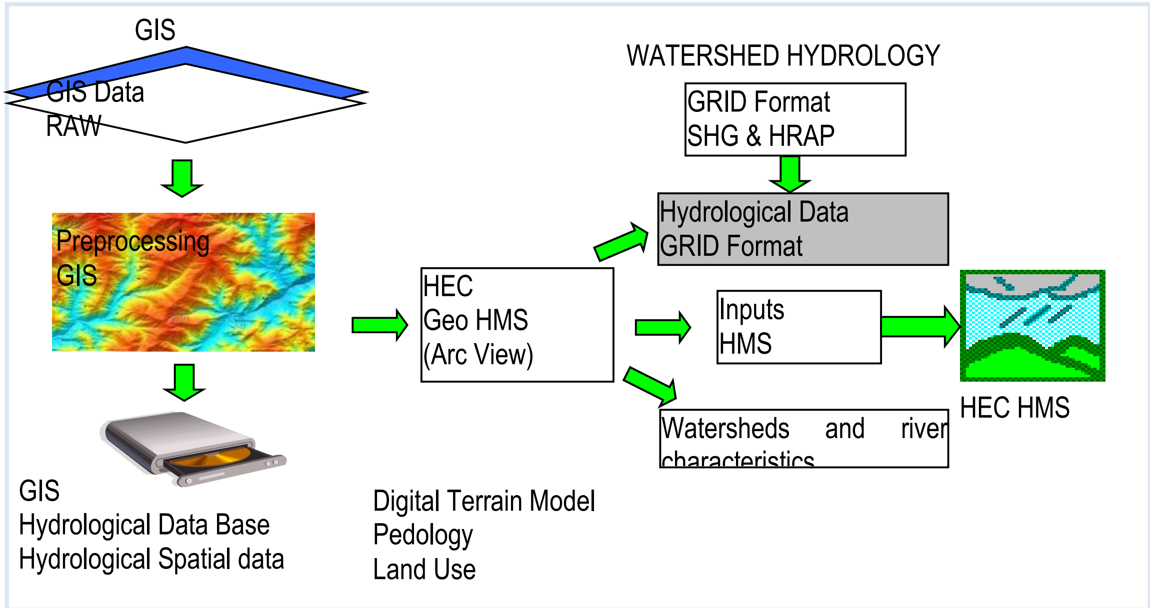
269. Most parameters for the sub-basin and reach elements can be automatically estimated using optimization trials. Observed discharge must be available for at least one element before optimization can begin. Parameters at any element upstream of the observed flow location can be estimated. Six different objective functions are available to estimate the goodness-of-fit between the computed results and observed discharge. Two different search methods can be used to minimize the objective function. Constraints can be imposed to restrict the parameter space of the search method.

Analysing Simulations

270. Analysis tools are designed to work with simulation runs and to provide additional information or processing. Currently, the only tool is the depth-area analysis tool. It works with simulation runs that have a meteorological model using the frequency storm method. Given a selection of elements, the tool automatically adjusts the storm area and generates peak flows represented by the correct storm areas.

GIS Connection

271. A GIS companion product has been developed to aid in the creation of basin models. The GIS product is called the Geospatial Hydrologic Modelling Extension (HEC-GeoHMS) and can be used to create basin and meteorological models for use with HEC-HMS.



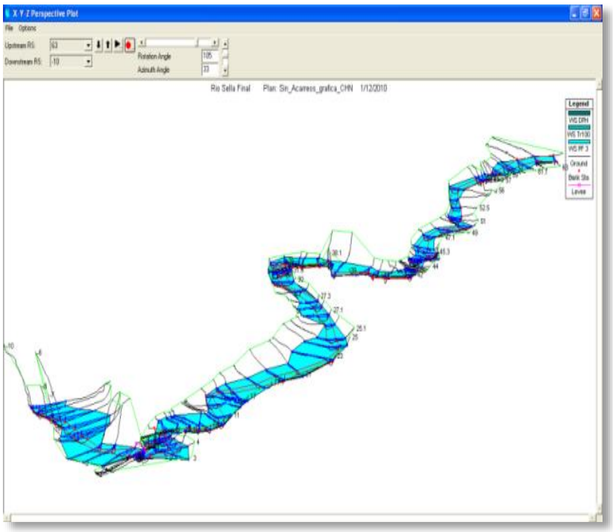
HEC-RAS 5.0.1 FEATURES

272. HEC-RAS is designed to perform one and two-dimensional hydraulic calculations for a full network of natural and constructed channels.

Hydraulic Analysis Components

273. The HEC-RAS system contains several river analysis components for: (1) steady flow water surface profile computations; (2) one- and two-dimensional unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis. A key element is, that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to these river analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed.

Steady Flow Water Surface Profiles



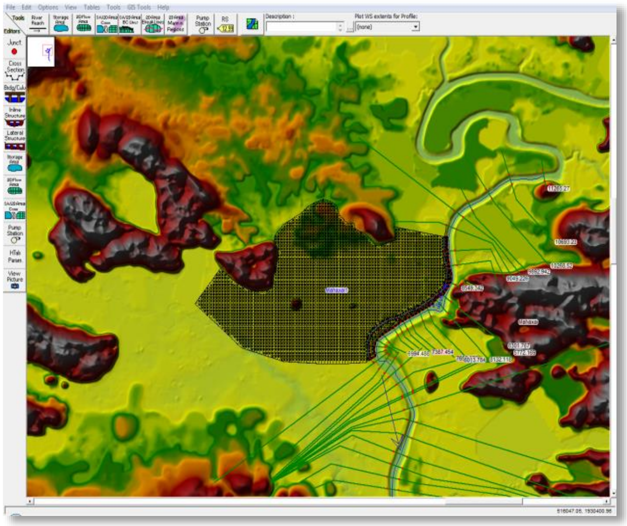
274. This component of the modelling system is intended for calculating water surface profiles for steady gradually varied flow. The system can handle a full network of channels, a dendritic system, or a single river reach. The steady flow component is capable of modelling subcritical, supercritical, and mixed flow regimes water surface profiles.

275. The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation may be used in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions).

One- and Two-Dimensional Unsteady Flow Simulation

276. This component of the HEC-RAS modelling system is capable of simulating one-dimensional; two-dimensional; and combined one/two-dimensional unsteady flow through a full network of open channels, floodplains, and alluvial fans. The unsteady flow component can be used to performed subcritical, supercritical, and mixed flow regime (subcritical, supercritical, hydraulic jumps, and draw downs) calculations in the unsteady flow computations module.

277. The hydraulic calculations for cross-sections, bridges, culverts, and other hydraulic structures that were developed for the steady flow component were incorporated into the unsteady flow module.



278. Special features of the unsteady flow component include: extensive hydraulic structure capabilities; dam break analysis; levee breaching and overtopping; Pumping stations; navigation dam operations; pressurized pipe systems; automated calibration features; User defined rules; and combined one and two-dimensional unsteady flow modelling.

Steady Transport/Movable Boundary Computations

279. This component of the modelling system is intended for the simulation of one-dimensional sediment transport/movable boundary calculations resulting from scour and deposition over moderate time periods (typically years, although applications to single flood events are possible).

280. The sediment transport potential is computed by grain size fraction, thereby allowing the simulation of hydraulic sorting and armouring. Major features include the ability to model a full network of streams, channel dredging, various levee and encroachment alternatives, and the use of several different equations for the computation of sediment transport.

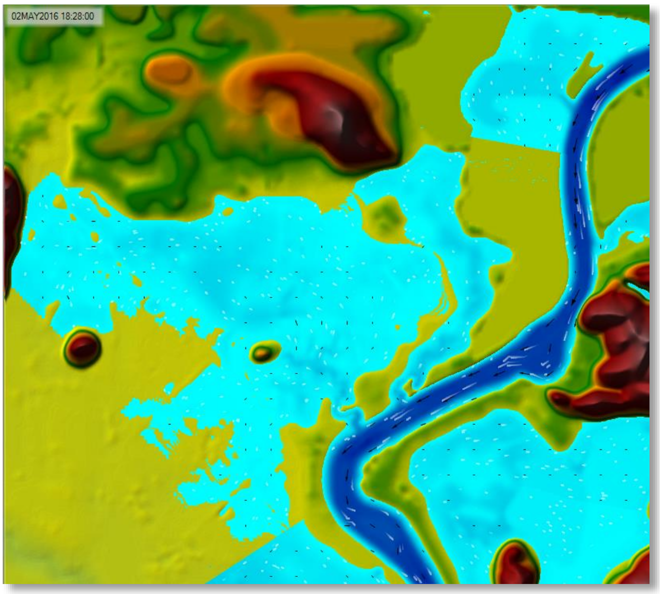
281. The model is designed to simulate long-term trends of scour and deposition in a stream channel that might result from modifying the frequency and duration of the water discharge and stage, or modifying the channel geometry. This system can be used to evaluate deposition in reservoirs, design channel contractions required to maintain navigation depths, predict the influence of dredging on the rate of deposition, estimate maximum possible scour during large flood events, and evaluate sedimentation in fixed channels.

Water Quality Analysis

282. This component of the modelling system is intended to allow the user to perform riverine water quality analyses. An advection-dispersion module is included with this version of HEC–RAS, adding the capability to model water temperature. This new module uses the QUICKEST-ULTIMATE explicit numerical scheme to solve the one-dimensional advection-dispersion equation using a control volume approach with a fully implemented heat energy budget. Transport and Fate of a limited set of water quality constituents is now also available in HEC-RAS. The currently available water quality constituents are: Dissolved Nitrogen (NO3-N, NO2-N, NH4-N, and Org-N); Dissolved Phosphorus (PO4-P and Org-P); Algae; Dissolved Oxygen (DO); and Carbonaceous Biological Oxygen Demand (CBOD).

Graphics and Reporting

283. Graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and inundation mapping. A three-dimensional plot of multiple cross-sections is also provided. Inundation mapping is accomplished in the HEC-RAS Mapper portion of the software. Inundation maps can also be animated, and contain multiple background layers (terrain, aerial photography, etc…). Tabular output is available. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer (or plotter), or passed through the Windows Clipboard to other software, such as a word-processor or spreadsheet.



RAS Mapper

284. HEC-RAS has the capability to perform inundation mapping of water surface profile results directly from HEC-RAS. Using the HEC-RAS geometry and computed water surface profiles, inundation depth and floodplain boundary datasets are created through the RAS Mapper. Additional geospatial data can be generated for analysis of velocity, shear stress, stream power, ice thickness, and floodway encroachment data. In order to use the RAS Mapper for analysis, you must have a terrain model in the binary raster floating-point format (.flt).resultant depth grid is stored in the .flt format while the boundary dataset is store in ESRI's Shapefile format for use with geospatial software.

Appendix 3: Project Team

PROJECT TEAM

Team Organization:

International Team:

TEAM LEADER HYDRO-METEOROLOGICAL ADVISOR Russell BOALS 	Mr. Boals holds a B.Sc. in Water Resources Engineering and two Masters in Water Resource Engineering. He has over 35 years of projects and programs management experience with governmental and non-governmental organizations, as well as with the private sector. He has lead teams in the evaluation, design, and implementation of hydrometeorological monitoring and water sector programs in Lao PDR, Vietnam, Afghanistan, Central Asia, Egypt, Ghana, Kenya, Mexico, Nile basin, Poland, Russia, Sri Lanka, as well as a number of countries in the Middle East and the SADC region of Africa. The majority of these were water resources management and hydrometeorological related projects involving the assessment, planning, design, and implementation of national and regional water monitoring and management programs. His international experience covers hydrometeorological network development, water resources management and institutional strengthening projects in support of IWRM and flood and drought management for a number of major river basins including the Mekong river basins, in which he has been Team Leader of a WB funded project in Lao PDR for the last 5 years. Mr. Boals is a registered member of the Association of Professional

	Engineers of Saskatchewan. He was the National President of Canadian Water Resources Association and continues to be a member of the National Board of Directors. He is member of the Canadian Society for Hydrological Sciences, North American Stream Hydrographers Association, and the Canadian Geophysical Union. Mr. Boals has been involved in various projects financed by IFIs, such as the Asian Development Bank and the World bank in the Region of South East Asia.
METEOROLOGIST 1 (METEOROLOGICAL NETWORK IMPROVEMENT) Eric TILMAN 	Our proposed Meteorologist 1, Mr. Tilman, holds a M. Sc in Civil Engineer and postgraduate diplomas in Water Resources Management and Geographical Information Systems. He has more than 30 years of overall experience. He is a specialist in the development of HydroMeteorological Networks and he has worked steadily in the Mekong Region for the last 10 years, specifically in Cambodia, Lao PDR, and Vietnam; this confers him an in-depth knowledge of the Mekong River and its tributaries. He is currently involved with EPTISA as Team Leader for the ADB funded project: Capacity Building of National Early Warning Center under the GMS Flood and Drought Risk Management and Mitigation Project in Lao PDR. Mr. Tilman accounts for a vast experience in water risk management and mitigation projects, providing tailor made training and capacity building activities to hydrometeorological organizations on data collection and management; on flood forecasting and on strategies for risk mitigation. He has a perfect command of GIS systems, such as ESRI, Map Window of Web Mapping. Along his career, he has advised to several national and regional organizations on the equipment and tools to be installed to perform the most suitable predictions for early warning. He has worked on projects for different international organizations such as ADB and bilateral aid (KfW, JICA, Belgian Bilateral Aid).
METEOROLOGIST 2 (WEATHER FORECAST) Jayaraman POTTY 	Dr. Potty holds a M.Sc. on Meteorology and a Ph. D. in Numerical Weather prediction. He has more than 15 years of experience in simulation of atmospheric severe phenomena such as tropical cyclones, monsoon depressions, and over 10 years of experience in projects related with drought and flood management. Currently he is working in Lao PDR as Meteorologist for EPTISA in the ADB funded project Capacity Building of National Early Warning Center (NEWC) under the GMS Flood and Drought Risk Management and Mitigation Project. For 3 years he worked as Climatologist for the Asian Disaster Preparedness Center providing technical hydro-meteorological expertise in establishing the Regional Center for Multi-Hazard Early Warning. In addition, since 2010 he has worked for the Regional Integrated Multi-Hazard Early Warning Systems, for which he developed and implemented Hydro-Meteorological Early Warning System Projects in the Asian Pacific Region. As well, he has participated in several projects funded by international organizations such as DANIDA or UNDP, developing out to date technologies on weather data management, and implanting capacity building activities to relevant authorities.

HYDROLOGICAL MODELLING EXPERT Miguel BONED 	Mr. Boned is an Engineer with more than 30 years of general experience, specialized in hydrological modelling and flood studies. He works for EPTISA as a Project Manager for Hydrologic Engineering Projects. Mr. Boned accounts for a wide experience in the fields of development of hydrological models, including forecast systems; development of flood mapping, hazards, and flood risk monitoring; early warning systems and design and implementation of training activities. Apart from his broad technical expertise, he is currently involved as Hydrological Modelling, Forecasting and Warning Expert in the ADB funded project in Lao PDR: *Capacity Building of National Early Warning Center under the GMS flood and drought risk management and mitigation project.* He also accounts for a wide international experience in Georgia, Serbia, Bosnia and Herzegovina, Bolivia, and Brazil among others.
HYDRAULIC MODELLING EXPERT Fernando MENDIZABAL 	Mr. Mendizábal holds a Postgraduate Degree in River morph-dynamic mapping of flooded areas. He has over 24 years of experience providing technical assistance in more than 50 projects. He has been part of EPTISA for the past 20 years, where he has participated in the projects related with flood management in Spain as well as internationally. He is currently involved as Hydraulic Modelling Expert in the ADB funded project in Lao PDR: *Capacity Building of National Early Warning Center under the GMS Flood and Drought Risk Management and Mitigation Project.* He has broad experience in selecting and developing appropriate hydraulic models to forecast operations, preparing flood risk mapping and monitoring, as well as developing tailor made capacity building activities such as trainings or study tours for international agencies. He has also participated in other related projects developed in Brazil, Albania, Croatia, Turkey, Vietnam and Bosnia & Herzegovina. He accounts for an outstanding command of HEC-HMS, HEC-RAS, Infoworks, and ICM tools.
FORECAST AND WARNING DISSEMINATION EXPERT Rutger-Jan SCHOEN 	Rutger-Jan Schoen has a M.A. in Communication science and a B.A. in Social Anthropology. He has more than 25 years of practical experience in communication strategy development in governmental and non-governmental organizations and projects. He has worked on 100 assignments in 40 different countries, including Lao PDR, Vietnam, the Philippines, and Indonesia. His specific experience lies on stakeholder communication and engagement in large-scale projects. He has worked as senior advisor on large water resources and environment programs reaching hundreds of thousand beneficiaries. Mr. Schoen has been involved in several large projects in Asia for the WB and the ADB.

INSTITUTIONAL SPECIALIST
Paul TAYLOR

Mr. Taylor, Bachelor of Arts with Honours at London University, accounts for wide experience in the field of water resources management, since 1986 in the New South Wales Government, with earlier background in the rural water sector. Since 1992, his experience in water management outside Australia was developed in Asian countries including Cambodia, Lao PDR, and Vietnam. The Philippines, Indonesia, and Thailand. Since 2001, he has been an independent consultant.

He has specific experience related with the public sector in: national and sub-national water sector institutional analysis and development, including river basin organization; water resources planning; water sector service regulation and water access; privatization of rural water services; water sector consultation and negotiation; coordination structures in the water sector; development and drafting of water resources legislation; human resources strategies; policy development; and water resources management capacity building and training.

He has been involved as Institutional Specialist for multiple water resources related projects in the Mekong Basin, several of them funded by ADB.

National Team:

DEPUTY TEAM LEADER
HYDRO-METEOROLOGICAL ADVISOR
Sopharith TES

Mr. TES has two M.Sc. in Hydrology Engineering and in Water Resources Engineering. He has over 23 years of professional experience, and he has occupied various positions, such us: hydro-meteorologist, early warning and disaster management information system specialist, flood forecasting modeller, water resources specialist, hydrological and hydraulic modeller and basin planner.

Mr. TES has also worked for projects in Cambodia financed by International Financial Institutions, such as the ADB (Supporting Policy and Institutional Reforms and Capacity Development in Water Sectors) and the WB (Strengthening the Disaster Management System in Cambodia through Risk Assessment, Early Warning System and Developing Building Codes; Mekong Integrated Water Resources Management Project APL 2).

EXPERT	POSITION	YEARS OF EXPERIENCE
ChannMony BIN	METEOROLOGIST	23
Dr. Katry PHUNG	HYDROLOGICAL MODELLING SPECIALIST	19
Dr. Sothea KHEM	HYDRAULIC MODELLING SPECIALIST	22
Vuthy CHUM	FORECAST AND WARNING DISSEMINATION SPECIALIST	12
Komar KHUON	INSTITUTIONAL SPECIALIST	42

Appendix 4: Terms of Reference

Terms of Reference

Support for Strengthening the National Flood Forecasting Center (NFFC)under the GMS Flood and Drought Risk Management and Mitigation Project

Project Result

The Project will support the Government to undertake structural and non-structural measures to prepare for and mange disaster risks linked to floods and droughts.

The goal is to strengthen the National Flood Forecasting Centre (NFFC) and by doing so will enhance the regional data, information, and knowledge base for the managing floods and droughts.

Outputs

The expected outputs of the NFFC outputs are:

i. Assess the hydro-meteorological network and data acquisition system required for flood forecasting and early warning in the major tributaries and to implement priority network and data acquisition improvement activities;
ii. Assess the current forecasting capacity and propose necessary flood and drought forecasting tools (hydrological and hydraulic models, rainfall forecasting including regional storm tracking and satellite based rainfall estimates);
iii. Assist in the preparation of specification for procurement of equipment, instruments and tools for the NFFC;
iv. Develop and pilot an operational strategy for disseminating nationwide flood forecasting and early warning at the community level;
v. Provide necessary trainings and capacity development for sustainable operation of the NFFC including recommendations of the institutional setup of the NFFC and within the Department of Hydrology and River Works (DHRW);
vi. Provide guidance to improve coordination to provide national forecast data for regional forecasting and vice-versa;
vii. Risk assessment of impact of floods and droughts with different probabilities;
viii. Evaluation of residual risk under varying degrees of protection;
ix. Comparison of flood and drought hazards with the standards currently applied;
x. Estimates of the cost of infrastructures related to flood and drought proofing for floods and droughts of different frequencies;
xi. Development of design criteria for structural flood and drought control in the Mekong area (and elsewhere) in Cambodia; and
xii. Provision of guidelines for climate resilient design of structures in the Mekong area (and elsewhere) of Cambodia.

Consultancy services are required for a 24 month period with input of 28 person-months of International expert and 68 person-months of National Experts.

Summary of Experts	No	Input (Months)
International:		
International Hydro-Meteorological Advisor/Team Leader	1	12
Meteorologist 1 (Meteorological Network Improvement)	1	2
Meteorologist 2 (Weather Forecast)	1	4
Hydrological Modelling Expert	1	3
Hydraulic Modelling Expert	1	3
Forecast and Warning Dissemination Expert	1	2
Institutional Specialist	1	2
	Sub-total	**28**
National:		
Hydro-Meteorological Advisor/Deputy Team Leader	1	24
Meteorologist	1	12
Hydrological Modelling Specialist	1	12
Hydraulic Modelling Specialist	1	12
Forecast and Warning Dissemination Specialist	1	4
Institutional Specialist	1	4
	Sub-total	**68**
	Grand Total	**96**

International Hydro-Meteorological Advisor/Team Leader

The International Hydro-Meteorological Advisor will be a qualified hydrologist with approximately 20 years practical experience in data collection, processing and management; capacity building for hydro-meteorological organizations preferably in developing countries; and hydrological and hydraulic modelling applications.

Specifically the specialist will:

i. Prepare a plan with specifications for upgrading the hydro-meteorology field network (rehabilitation, additional stations, data transmission system, staff training) for the two priority basins;
ii. Prepare a plan with specifications for improved data acquisition, processing and management;
iii. Develop a training plan for the field and data management functions;
iv. Prepare a plan for improvements to forecast operations including the selection of appropriate hydrological and hydraulic models;
v. Prepare a training plan for hydrological forecasting and calibration of models;
vi. Prepare specifications for procurement of instrumentation and equipment for upgrading and expansion of the early warning field network;

vii. Complete field installation and upgrades and begin preliminary operations with the early warning system to debug the field, data processing, and forecasting systems and to assess the integration of the early warning system;

viii. Prepare draft awareness plan for flood prone areas;

ix. Conduct mock drill of the early warning system to assess interconnections with the local and national disaster emergency organizations;

x. Update and refine the early warning system and implement improvements based on lessons learned from preliminary operations; and

xi. Implement awareness plan and develop communications strategy.

Meteorologist 1 (Meteorological Network Improvement)

The International Meteorologist (Meteorological Network Improvement) will be a qualified meteorologist with 15 years practical experience in meteorological network improvement; data acquisition, transmission, receiving and processing system; and developing field data management plan.

Specifically the specialist will:

i. Prepare a plan with specifications for upgrading the hydro-meteorology field network (rehabilitation, additional stations, data transmission system, staff training) for the two priority basins;

ii. Prepare a plan with specifications for improved data acquisition, processing and management; and

iii. Develop a training plan for the field and data management functions.

Meteorologist 2 (Weather Forecast)

The Specialist will be a qualified meteorologist with 15 years practical experience in: improvement of weather forecast system and operations; data processing and weather forecast model development; and preparation of training plan for weather forecast operations.

Specifically the specialist will:

i. Prepare a plan for improvements to weather forecast operations including the selection of appropriate weather forecast models; and

ii. Develop training plan for the weather forecast operations and models.

Hydrological Modelling Expert

The International Hydrological Modelling will be a qualified hydrologist with approximately 15 years practical experience in: hydrological modelling; data processing and hydrological models development; and developing training plans for capacity building for hydrological modelling.

Specifically the specialist will:

i. Prepare a plan for improvements to forecast operations including the selection of appropriate hydrological models;

ii. Develop hydrological models;

iii. Develop training plan for the hydrological model operations; and

iv. Prepare flood risk mapping and flood monitoring and evaluation by using satellite.

Hydraulic Modelling Expert

The International Hydraulic Modelling Expert will be a qualified hydraulic engineer with 15 years practical experience in: hydraulic modelling; data processing and hydraulic model development; and developing training plans for capacity build up on hydraulic modelling.

Specifically the specialist will:

i. Prepare a plan for improvements to forecast operations including the selection of appropriate hydraulic models;
ii. Develop hydraulic models;
iii. Develop training plan for the hydraulic model operations; and
iv. Flood risk mapping, Flood Monitoring and Evaluation by using satellite.

Forecast and Warning Dissemination Expert

The International Forecast and Warning Dissemination Expert will have a post-graduate degree in a relevant discipline and will have 15 years of practical experience in: forecast and warning dissemination systems; developing communication strategy for forecast and warning dissemination; and developing plan for awareness progress in pilot sub-basins.

Specifically the specialist will:

i. Prepare a plan for improvements to weather forecast and warning dissemination operations including the selection of appropriate communication system; and
ii. Develop and implement plan for public awareness program on forecasting and warning system.

Institutional Specialist

The International Institutional Specialist will have a tertiary degree in a relevant discipline and will have approximately 10 years of practical experience in: institutional strengthening of similar organizations; and preparing the plan for institutional strengthening for achieving effective forecast and warning dissemination.

Specifically the specialist will:

i. Assess the situation of human resources and organizational set up of DHRW and NFFC; and
ii. Prepare a plan for institutional strengthening to achieve an effective forecast and warning system and dissemination of forecast and warnings to target groups.

Hydro-Meteorological Advisor (National)

The National Hydro-Meteorological Advisor will be a qualified hydro-meteorologist with 15 years of practical experience in: data collection, processing and management; capacity building for hydro-meteorological organizations; and meteorological forecasting and awareness communications.

Specifically the specialist will:

i. Prepare a plan with specifications for upgrading the hydro-meteorology field network (rehabilitation, additional stations, data transmission system, staff training);
ii. Prepare a plan with specifications for improved data acquisition, processing and management;
iii. Develop training plan for the field and data management functions;
iv. Prepare a plan for improvements to forecast operations including the selection of appropriate hydrological and hydraulic models;
v. Prepare training plan for hydrological forecasting and calibration of models.
vi. Prepare specifications for procurement of instrumentation and equipment for upgrading and

expansion of the early warning;

vii. Complete field installation and upgrading and beginning preliminary operations with the early warning system to debug the field, data processing, and forecasting systems and to assess the integration of the early warning system;

viii. Prepare draft awareness plan for flood prone areas;

ix. Conduct mock drill of the early warning system to assess interconnections with the local and national disaster management organizations;

x. Update and refining the early warning system and implement improvements based on lessons learned from preliminary operations; and

xi. Implement awareness plan and develop communications strategy.

Meteorologist (National)

The National Meteorologist will be a qualified meteorologist with 15 years practical experience in: meteorological network improvement; data acquisition, transmission, receiving and processing system; developing field data management plan; and weather forecast models operations.

Specifically the specialist will:

i. Prepare a plan with specifications for upgrading the hydro-meteorology field network (rehabilitation, additional stations, data transmission system, staff training);

ii. Prepare a plan with specifications for improved data acquisition, processing and management;

iii. Prepare a plan for improvements in weather forecast operations including the selection of appropriate weather forecast models; and

iv. Develop training plan for weather forecasting operations and models.

Hydrological Modelling Specialist (National)

The National Hydrological Modelling Specialist will be a qualified hydrologist with 10 years practical experience in: hydrological modelling; data processing and hydrological models development; developing training plans for capacity build up on hydrological modelling.

Specifically the specialist will:

i. Prepare a plan for improvements to forecast operations including the selection of appropriate hydrological models;

ii. Develop hydrological models for pilot sub-basins;

iii. Develop training plan for the hydrological model operations; and

iv. Prepare flood risk mapping and flood monitoring and evaluation by using satellite.

Hydraulic Modelling Specialist (National)

The National Hydraulic Modelling Specialist will be a qualified hydraulic engineer with 10 years practical experience in: hydraulic modelling; data processing and hydraulic models development; and developing training plans for capacity build up on hydraulic modelling.

Specifically the specialist will:

i. Prepare a plan for improvements to forecast operations including the selection of appropriate hydraulic models;

ii. Develop hydraulic models; and

iii. Develop training plan for the hydraulic model operations.

Forecast and Warning Dissemination Specialist (National)

The National Forecast and Warning Dissemination Specialist will have a tertiary degree in a relevant discipline with approximately 10 years of practical experience in: forecast and warning dissemination system; developing communication strategy for forecast and warning dissemination; and developing plan for awareness progress in pilot sub-basins.

Specifically the specialist will:

i. Prepare a plan for improvements in weather forecast and warning dissemination operations including the selection of appropriate communication system; and
ii. Develop and Implement plan for public awareness on forecast and warning system.

Institutional Specialist (National)

The National Institutional Specialist will have a tertiary degree in a relevant discipline with 10 years of practical experience in: institutional strengthening of similar organizations; preparation of plans for institutional strengthening for achieving effective forecast and warning dissemination.

Specifically the specialist will:

i. Assess the situation of human resources and organizational set up of the DHRW and the NFFC; and
ii. Prepare a plan for institutional strengthening to achieve an effective forecast and warning system and dissemination of forecast and warnings to target groups.

5. DELIVERABLES (Reports)

i. Inception report, at end of month 3;
ii. Inception Workshop to disseminate Inception Report;
iii. Quarterly and Annual Progress Reports;
iv. Mid Term Report, at end of month 12;
v. Mid Term Workshop for disseminating Mid Term Report;
vi. Draft Final Report, at end of month 22;
vii. Workshop for disseminating Draft Final Report; and
viii. Final Report, at end of month 24.