Greater Mekong Subregion Flood and Drought Risk Management and Mitigation Project

SUPPORT TO THE NATIONAL FLOOD FORECASTING CENTRE (NFFC)

Ministry of Water Resources and Meteorology, Cambodia

Institutional Report

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Prepared by: Paul Taylor, International Institutional Specialist and
Komar Khoun, National Institutional Specialist

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Abbreviations

3S	Sekong, Sesan and Srepok rivers/basins
4P	Prek rivers/basins
ADCP	Acoustic Doppler current profiler
ADGTS	Assistant Director-General Technical Services (MOWRAM)
ADB	Asian Development Bank
ARG	Automatic rain gauge
AWL	Automatic water level
AWS	Automatic weather station
CDTA	Capacity development technical assistance
DHRW	Department of Hydrology and River Works
DEM	Digital Elevation Model
DOM	Department of Meteorology
EU	European Union
FFGS	Flash Flood Guidance System
GIS	Geographical Information System
HR	Human resources
JICA	Japan International Cooperation Agency
MOWRAM	Ministry of Water Resources and Meteorology
MRC	Mekong River Commission
NCDM	National Committee for Disaster Management
NGO	Non-government Organisation
NOAA	National Oceanic and Atmospheric Administration (US Government)
NWP	Numerical weather prediction
NWSP	National water sector profile for Cambodia, 2001
PCDM	Provincial Committee for Disaster Management
PDWRAM	Provincial Department of Water Resources and Meteorology
PIN	People in Need
RFMMC	Regional Flood Management and Mitigation Centre
SOP	Standard Operating Procedure
UNDP	United Nations Development Programme
WB	World Bank

Executive Summary

Flood forecasting and drought prediction need to be performed more effectively in Cambodia. This institutional study concludes that, although there is great scope for improving facilities and technology, the critical barrier to improvement is the capacity and application of professional staff. The Government of Cambodia is faced with a generational problem in technical areas. Very strong measures will be required to overcome the human resources challenge in the short term.

The Asian Development Bank agreed with the Government of Cambodia to strengthen the flood forecasting and drought prediction capacity of the Ministry of Water Resources and Meteorology (MOWRAM). The project, **Support to National Flood Forecasting Centre** (NFFC), has been designed to achieve the necessary improvements.

The concept of an NFFC was put forward as a way to support the use of more advanced information and analytical technology along with on-the-ground data collection, and to improve the ability of MOWRAM to forecast flood events at more local scales and to improve drought prediction. The nature of such a 'Centre' was left open in the project's Terms of Reference (TOR), except that it was to be associated with the Department of Hydrology and River Works (DHRW) within MOWRAM. The Department of Meteorology (DOM) also has a significant role to play with respect to flood forecasting and drought prediction functions.

One of the project's challenges was how to help the Ministry develop an organisational structure that will support the required improvements in flood forecasting and drought prediction. Institutional specialists were engaged to undertake a review of existing arrangements and to identify the organisational and capacity requirements for the NFFC, however NFFC may be structured.

This report discusses the institutional and capacity building requirements for an effective flood forecasting centre for Cambodia.

MOWRAM is responsible for flood forecasting, which is performed by the Department of Hydrology and River Works (DHRW) and the Department of Meteorology (DOM). MOWRAM is also expect to perform a drought prediction function.

At the time of conducting this study, MOWRAM did not have a flood forecasting centre as such. The Office of Research and Flood Forecasting in DHRW was identified by MOWRAM as the location for the NFFC, however DHRW had not been officially designated as the flood forecasting centre.

Comprehensive flood forecasting involves both hydrology and meteorology. The determination of information and data on river and stream levels and discharges is a hydrologic function. Weather observation data are required to identify the likely flood impacts of precipitation, humidity, evaporation and the like. In the current organisational setup, some flood forecasting functions should be undertaken by DOM, while others are better located within DHRW. A finding of the study, and the project as a whole, is that there needs to be an exchange of data and information between DOM and DHRW, in order to improve the flood forecasting and drought prediction functions.

A second conclusion is that the technical and professional capacity of MOWRAM is low in both hydrology and meteorology. The chief reason is that the Ministry lacks the required number of qualified and experienced meteorologists and hydrologists who are capable of performing forecasting and related functions. Though staff competencies could not be appraised individually, it appeared evident that many positions, which require hydrology and meteorology skills, are filled by staff without either relevant professional qualifications or experience and skill to perform more than manual or basic tasks, as distinct from exercising professional ability and judgement.

As for the meteorological observation and hydrological measurement network, provincial offices are responsible for field tasks. Two features of the administrative setup are important.

Firstly, provincial offices follow the departmental structure of head office, but they are not under the direct control of the head office departments. Thus, observation staff for weather stations, for example, perform their duties according to technical guidelines laid down by DOM and report information to DOM, but are not part of DOM itself. The same applies to hydrological staff at the provincial level. This means that the head office departments do not have full control over field operations and rely on provincial offices to provide staff for these functions.

Secondly, the total number of field and observation staff are quite inadequate. Most provinces have one or two staff covering both meteorology and hydrology amongst other assigned duties and responsibilities. Hydrology staff are engaged in non-flood and non-weather hydrological studies with respect to irrigation and other water projects.

Thirdly, the technical capacity of provincial staff is reportedly very uneven. It is apparently not possible to recruit engineers and professional meteorologists to provincial positions at this time. Some provinces may only have technicians and those staff may not have a high degree of technical knowledge or skill.

Meanwhile, both the observation network of automatic weather stations and automatic water level recorders are being installed in significant numbers with support by several donors. Apart from the problem of differences in the technical specification for equipment provided by different donors, the expansion of the networks imposes a greater burden in data collection, data transmission, operation and maintenance, and eventually repair and replacement of equipment. It is most likely that equipment will be abandoned as it fails, as has already occurred in the past.

It should be said that automation does not mean an absolute reduction of staffing demand. Automated equipment must be calibrated and serviced at reasonable intervals in order to perform

and provide reliable and creditable within data. Therefore, the expansion of the observational networks may impose a greater cost burden on the Ministry.

The NFFC Project is upgrading flood modelling tools, simulation model and flood mapping technology. This upgrade is intended to enable the Ministry to improve its forecasting capability beyond reliance on the Mekong River Commission. The improvement will involve upgrading of professional staff in Phnom Penh. It is desirable also that provincial capacity be improved, not in forecasting as such but in the areas of equipment maintenance, data quality review, and for on-ground flood event tracking and monitoring. The provincial level also plays an important role in community education and communicating information.

This report sets out a vision for the NFFC, its functions and services. However, this vision cannot be achieved at this time due to institutional and human resource constraints.

After discussing the organisational options with the Ministry, it is recommended that a Flood Forecasting Centre (FFC) be created officially within DHRW. The Office of Research and Flood Forecasting (ORFF) could be redesigned to support the functions of a flood forecasting centre, which covers hydrological information analysis and forecast generation. Meanwhile, it is very important that the weather forecasting functions of DOM and the hydrologic data from DHRW be linked in order that comprehensive information, as far as possible in real time, is used. This requires active linking of the real-time data and forecasts systems of DHRW and DOM.

The establishment of the Flood Forecasting Centre (FFC) within DHRW is the minimal option, and through consultation it was determined that the Ministry is not prepared to go further at this time. Even if the Office of Research and Flood Forecasting in question is reconfigured to become a flood forecasting centre, its success will not only depend on its institutional structure. The structure is only a tool to create the forecasting expertise required.

The Ministry asked that the term ‘national’ be dropped from the proposed unit as it has large organizational and institutional connotations within the nomenclature used by the Royal Government of Cambodia.

The Institutional specialists identified functions that could be developed under the umbrella of flood forecasting and drought prediction service. These include short-to-medium term programs, such as flood risk mapping and mapping of drought hazard, as well as continuing activities that need to be enhanced or introduced. Agreeing to these program areas will focus effort on the nature of the NFFC and identify the focus for capacity building.

The study identified the following functions that should be performed for flood forecasting:

1. Providing advice on flood policy and strategy (senior official)
2. Food forecasting and drought prediction (DHRW/DOM)
3. Flood hazard mapping and modelling (DHRW)
4. Flood risk assessment (DHRW)
5. Flash flood risk identification and warning (DOM)
6. Community education and awareness, standard operating procedures (SOP), and information dissemination (DHRW/DOM and provincial)

The project put forward the following programs for the NFFC, which were broadly accepted at a February 2017 meeting:

Table 1: NFFC Programs and Functions

NFFC Program		Description	Location
1	Flood/drought policy	New, ongoing	Senior level
2	Flood forecasting	Existing, to be improved through advanced modelling	FFC (DHRW) based on input from provincial offices, DOM and MRC
3	Flash flood warning	New, use of new technology to identify locality and characteristics of flash floods	DOM with added information from FFC (DHRW) flood models when operational
4	Flood/drought mapping	New and short/medium term activity	FFC (DHRW)
5	Drought hazard risk assessment	New and initially short/medium term also ongoing	FFC (DHRW) based on mapping, with added development and meteorology data
6	Community education and awareness	Existing, to be enhanced	FFC (DHRW) and provincial officers
	Administration	Ongoing requirement (existing or expanded)	DHRW

These programs or functions belong to a head office-based NFFC and which must be supported by provincial activities that involve data collection and the need to install, operate, maintain and replace/upgrade equipment and communication systems. These required provincial activities are shown in Table 2.

Table 2: Provincial Functions - now and future

Provincial Program/activity	Description
Data collection and transmission: hydrology and meteorology	**Existing** but needs to be expanded with expanding numbers of AWLs and AWSs
Equipment management: water level recording and weather observations	**Existing,** but needs improvement in protection, operation, technical capacity for maintenance, repair and replacement
Flood event monitoring, tracking, and recording	**New**, proposed through assessment of local data, which could include local warnings
Weather data assessment	**Existing/New** Local checking, verification of weather station data Analysis of some meteorological data in province?
Community awareness and communication	**Existing**, to be enhanced

After discussion with officials of MOWRAM at two working meetings, the consultants concluded that an NFFC cannot be established as an independent unit. Firstly, Ministry officials did not prefer this option. Secondly, the limited technical capacity within the two departments prevents it. The project recommends that MOWRAM consider developing a strategy to establish a fully functional NFFC with the responsibilities noted in Tables 1 and 2.

In the meantime, MOWRAM is advised to focus on matters that involve DHRW and DOM such as:

- Redesign positions and responsibilities within existing departments to reflect the NFFC's programs and activities
- Upgrade capacity of existing staff
- Seek approval for the recruitment of suitable staff
- Create formal data access and sharing arrangements between DHRW and DOM
- Develop common modelling programs that involve DHRW and DOM inputs and outputs
- Increase provincial responsibilities and staffing capacity in line with the decentralisation policy
- Develop a longer-term strategy for creating the NFFC

As the result of this study, the project recommends that the Office of Research and Flood Forecasting in DHRW be modified to create the NFFC in an initial form and that it be developed over time to become a more active Centre. The study also recommends, for short-term action, that:

- The proposed structure for the FFC be used as a guide to develop programs and establish staff positions for the FFC
- MOWRAM institute a data exchange protocol between DHRW and DOM to enable real-time data and forecasts/model outputs to be available and easily shared
- Regular briefings be held during flood season and flood events between DHRW and DOM to exchange information on the current and forecast situation
- MOWRAM ensure that real-time from all hydrologic and meteorologic sources is immediately available to DOM and DHRW-FFC
- MOWRAM establish minimum professional qualifications required for recruiting hydrologist and meteorologist
- MOWRAM ensure that a technically qualified member of DOM and DHRW is involved in the selection and recruit process to staff positions requiring tertiary technical qualifications
- MOWRAM develop a long-term capacity building plan to upgrade the skills of provincial staff(i) in maintaining and operating water level recorders and weather stations, (ii) in recording, storing and reviewing the quality of flood-related data, and (iii) in tracking and monitoring flood events
- MOWRAM plan for an increase in provincial staff to cover the expanding hydrologic and meteorological networks in Cambodia

For the longer term, the study recommends that:

- NFFC functions carried out by DHRW and DOM be developed to use advanced models and mapping technology
- Satellite data be combined with on-the-ground information to provide flood risk assessments
- Capacity for short-term forecasting in DOM be strengthened based on NOAA satellite data
- The FFC be established as a fully-functioning flood forecasting and drought prediction unit

- A long-term funding program be established for DOM, DHRW and the NFFC

The Institutional specialists have also provided an outline that may aid MOWRAM develop a long-term plan to establish the NFFC as a hydrometeorological unit or agency, similar to those of other countries, where hydrology and meteorology are being performed with greater institutional integration. A 'fully-fledged' NFFC, would differ from the proposed FFC in the following respects:

- It would be managed, communicate, and issue flood warnings independently of either of the existing departments
- It would possess expertise in meteorology, climatology, and hydrology and would use and develop flood simulation models, flood hazard mapping, and related tools
- It would be supported by accurate, continuous real-time data with staff in provincial locations
- It would have direct access to high levels in the Government and have direct communication with the National Disaster Management Committee (NDMC)

The study considered potential barriers to achieving effective flood forecasting, wherever that function is located. It concluded that the key barriers are related to the difficulty in obtaining and retaining staff (i) with appropriate tertiary qualifications, (ii) with the ability to make effective use of simulation models and to analyse data, (iii) with willingness to perform important tasks consistently, and (iv) who are likely to stay with the Ministry given the current working conditions.

1 Introduction

This report investigates the current institutional arrangements and capacity of MOWRAM to host a proposed national flood forecasting centre (NFFC). The report proposes a structure and staffing for a flood forecasting centre located within the DHRW of the MOWRAM but closely connected to the Department of Meteorology. The report attempts to identify and analyse potential institutional difficulties in operationalising an effective flood forecasting centre, and the challenges facing the Royal Government of Cambodia in this respect.

1.1 Subject of the Report

This report presents with the institutional and capacity requirements to create an effective and responsive flood forecasting and drought organisation for the Royal Government of Cambodia.

The proposed organisation is a National Flood Forecasting Centre (NFFC), which is being supported by the Asian Development Bank (ADB). The Ministry of Water Resources and Meteorology (MOWRAM) is the responsible ministry.

The report covers the following:

- The present capacity of MOWRAM in hydrology and meteorology
- The capacity requirements to perform advanced hydrological analysis and forecasting consistent with the technology being developed by the project
- The institutional options for a flood forecasting centre in MOWRAM and external to the MOWRAM
- The requirements for strengthening technical staff capacity and management in the MOWRAM
- Institutional and capacity development steps to be taken in the short to long term

- The structure of a future flood forecasting centre and steps that should be taken towards this goal
- Support required in the immediate term to implement and sustain a flood forecasting and drought prediction service

1.2 Impetus for a Flood Forecasting Centre

Cambodia, along with Lao PDR, Thailand, and Vietnam, forms the territory of the Lower Mekong River basin and shares with its neighbouring countries the annual cycle of Mekong-based flooding. The Mekong River Commission (MRC) in which Cambodia and its neighbours participate, has a hydrologic program for detecting and warning the Lower Mekong countries about water levels in the Lower Mekong River and the Tonle Sap area. Flood forecasting is one of MRC chief aims, along with hydrology studies to identify the water resource development opportunities.

The MRC has a Regional Flood Forecasting and Management Centre (RFFMC), located in Phnom Penh, oversees the operation of the MRC designated water level observing stations and generates flood forecasts. However, the MRC wishes to see the establishment of flood forecasting expertise its member countries and has been supporting the idea of a dedicated centre for flood forecasting in Cambodia.

Similarly, donors who have been supporting water resources projects in Cambodia and MRC programs, in particular the Asian Development Bank and World Bank, have been encouraging the Royal Government of Cambodia to improve its food forecasting capability and have promoted the need for a National Flood Forecasting Centre (NFFC).

MOWRAM has consider establishing the NFFC, however at the time of preparing this report a NFFC does not exist.

The Terms of Reference (TOR) for the Project - Support to the National Flood Forecasting Centre, included the need for an institutional review to provide advice on the organisation and staffing of the NFFC. Given that the project is developing flood forecasting tools in the form of more advanced hydrological models, which consider digital elevation models and GIS-based mapping, it is important to consider the institutional implications with respect to the effectiveness and sustainability of the technology being developed.

1.3 Terms of Reference

ADB provided Terms of Reference (TOR) for consultants to investigate the current capacity within government in Cambodia for a flood forecasting and warning services, along with drought prediction, and to make recommendations on creating a National Flood Forecasting Centre, which was not formally established at the time of preparing this report.

The TOR were:

i. Review project design and progress reports to obtain a clear understanding of the project, progress to date, and the institutional context for the project
ii. Conduct a detailed institutional assessment of the functions and capacity of the Department of Hydrology and River Works (DHRW), the Department of Meteorology (DOM) and the National Flood Forecasting Centre (NFFC) including constraints that may affect a collaborative and coordinate approach to the generation and dissemination of flood and drought forecasts
iii. Develop recommendations that would address any coordination and collaboration challenges including organizational changes and staff complements and skills

iv. Prepare an outline of the required institutional and capacity building plan to fully operationalize NFFC for the short-term given the existing environment as well as for the long-term to ensure sustainability

In addition, the consultants were asked for a scan of donor projects that include the installation of hydrological or meteorological recording stations which overlap with or complement the Project.

1.4 Scope of the Report

This report attempts to provide support to MOWRAM for the establishment of an effective NFFC and to enhance MOWRAM capacity in flood forecasting. The report includes:

- An institutional assessment of the departments of MOWRAM who are responsible for hydrology and meteorology, which are the Department of Hydrology and River Works (DHRW) and the Department of Meteorology (DOM)
- An overview of provincial activities of MOWRAM related to hydrological and meteorological data and flood forecasting
- A discussion of organisation design, options, and opportunities, in consultation with the MOWRAM
- The identification of challenges in staff capacity, including recruitment, education, and training in professional fields related to early warning and flood forecasting
- The identification of requirements to improve and sustain provincial and head office technical and professional capacity

2 Flood-Related Functions

The central flood forecasting functions of MOWRAM are located in two departments, the Department of Hydrology and River Works (DHRW) and the Department of Meteorology (DOM). The Mekong River Commission provides the basic data and analysis related to the Mekong River.

2.1 Organisational Roles in Flood Forecasting and Warning

Cambodia participates, with three other Lower Mekong countries, Thailand, Vietnam and Laos, in the coordinated management of the Lower Mekong River and its tributaries. The Mekong River Commission (MRC) was established to foster cooperation on the management and development of the waters of the Mekong River. The MRC has provided a central point among the member countries for technical studies and real-time monitoring with one of its objectives being to minimise the impact of flooding.

In April 2008, the MRC established a Regional Flood Management and Mitigation Centre (RFMMC), located in Phnom Penh, to serve the requirements of the four Lower Mekong countries. The RFMMC monitors the flow in the Mekong River from the upstream countries through Cambodia and into the Vietnamese delta. The RFMMC issues daily flood forecasts and warnings based on water level recording stations on the Mekong river, on the Bassac river downstream of Phnom Penh, and a station on the Tone Sap river to monitor inflow and outflow from the Mekong.

The RFMMC coordinates with MOWRAM the daily issuing of flood warnings.

During the war in the 1970s, flood forecasting in Cambodia was severely weakened and much of the human capital was lost. Cambodia has struggled to recover from the loss of professional people since that time.

Flooding in Cambodia results from high water level in the Mekong River, which feeds the Tonle Sap Lake, from the flow in major tributaries to the Mekong River in Cambodia, which flow from north to

south and east to west from Laos and Vietnam, and from upland tributaries that flow directly to the floodplain of the Tonle Sap basin. Furthermore, there are coastal river basins, which can be affected by ocean surges and storms.

The MRC monitors the Mekong River, but other parts of Cambodia, despite being part of the Mekong River basin, are the responsibility of Cambodia alone.

2.2 Institutional Assessment

Institutional capacity in MOWRAM has been the subject of a number of studies. Most recently the *Report on Institutional Arrangements for the Management of Water Resources in Cambodia*, funded by ADBTA 7610-CAM was completed in January 2015. It draws heavily on the National Water Sector Profile (NWSP) of 2001, completed by MOWRAM with ADB assistance.

The 2015 report provides an analysis of DHRW and DOM. The situation in the two years since 2015 is not believed to have changed significantly, except that, reportedly, more funds have been made available to DOM, due to greater emphasis by the Minister on weather forecasting in general. Apart from this aspect, conclusions in that report are believed to be reasonably accurate today.

The information presented in this section of the report was derived in part from the 2015 ADB report, and updated based on more recent commentary, information gathered at meetings, and data provided by the Departments. There remain ambiguities about such questions as the total numbers of staff in the departments, but the general outlines are not in question.

The two departments with functions and technology relevant to flood forecasting, early warning, and drought prediction are DHRW and DOM.

MOWRAM has a provincial and district structure with Provincial Department of Water Resources and Meteorology (PDWRAM) offices in each province. Within each PDWRAM is normally one staff member assigned to DHRW and DOM related responsibilities. A few of the larger provinces have more than one staff member assigned. However, the majority of the Provincial Departments reportedly have only a single staff member who may have other technical responsibilities in addition to hydrology and meteorology.

2.3 Ministry Responsibilities

Flood forecasting in Cambodia is the responsibility of the Department of Hydrology and River Works (DHRW) within MOWRAM. The Department of Meteorology (DOM) has related forecasting responsibilities, which includes early warning, based on weather station observations, incoming data from satellite and radar. It issues weather forecasts, which have a bearing on flood conditions, while DHRW issues forecasts of river levels for the Mekong River and the Tonle Sap lake system. The two departments operate separately.

This report makes an institutional assessment of the Department of Hydrology and River Works and the Department of Meteorology in respect to flood forecasting. There is also comment on the National Committee for Disaster Management (NCDM)

2.4 Related Agencies

MOWRAM shares flood-related responsibilities with related agencies. The Department of Hydrology and River Works (DHRW) is the professional hydrological centre in MOWRAM. Two of the functions under DHRW, river works and water quality monitoring, are reflected in its structure but are not very active.

2.4.1 National Committee for Disaster Management

The Government of Cambodia has set up a National Committee for Disaster Management (NCDM). Cambodia has followed the practice of most regional countries (Thailand, Laos, Vietnam, Myanmar, for example). As a result, the role and functions of the NCDM are similar to the function of disaster management committees in these neighbouring countries.

Its responsibilities in respect to flooding and drought are governed by the Law on Disaster Management (2015) [*NS/RKM/0715/007*]. Article 15 of the Law states:

> *"NCDM shall coordinate all disaster management activities together with ministries, institutions, armed forces, the public sector, private sector and civil society in promoting safety and resilience to disasters"*

These powers have implications for MOWRAM, which is the Ministry with the forecasting and warning responsibilities.

The provincial governor presides over the PCDM and district and commune-level authorities preside over the lower level committees. MOWRAM branches participate in the national, provincial, and district levels through their provincial director and district office head.

Technical staff of MOWRAM are located in head office departments and PDWRAMs. District offices have limited function. Therefore, the participation of MOWRAM at national and provincial levels is most relevant to flood forecasting.,

The powers under the Law of Disaster Management have implications for MOWRAM. The first is that MOWRAM and NCDM must cooperate with respect to serious emergencies, namely flood events, and that NCDM has timely information to pass to its provincial, district, commune and village branches. The second is that early warning is a function of both MOWRAM and NCDM, and that issuing warnings is to some extent a responsibility of both agencies. The third is that MOWRAM participates in the NCDM and its lower level committees through provincial and district offices. The fourth is that MOWRAM undertakes duties as directed by the NCDM during emergencies.

The National Committee for Disaster Management (NCDM) is responsible for issuing the severe flood warnings, which it receives from MOWRAM, as well as organising flood response. Flood preparation is also the responsibility of the NCDM, which has Provincial Committees for Disaster Management (PCDM) and also has district level (DCDM) and village disaster management teams (VDMT).

MOWRAM provides flood information to the NCDM when the flood situation is considered serious. The Minister of MOWRAM is provided personally with flood information, except for routine flood bulletins, which are issued by DHRW in the form of a letter or on its website.

The role of DHRW and NCDM are that of information provider and information publisher respectively for major flood events. Flood information may also be provided by Provincial Departments of Water Resources and Meteorology (PDWRAMs) as well as PCDMs. But the number of PDWRAM staff responsible for hydrology and meteorology are limited, are often without training, and also have other responsibilities and duties.

In summary the overall context for flood forecasting in Cambodia is that MOWRAM generates all forecasts and warnings, via DOM and/or DHRW. The NCDM relies on MOWRAM for all technical assessments of predicted rainfall, river levels, and flood events.

2.4.2 Regional Flood Management and Mitigation Centre (MRC)

The MRC currently operates a network of AWLs in the Lower Mekong River basin, and along the Mekong River mainstream in Thailand, Laos, and Vietnam. The river level data from upstream, Laos in

particular, is important for Cambodia, as it is used to predict the flow in Cambodia. However, the mainstream Mekong system is not the only area in Cambodia subject to flood threat, but it is the most important one along with the Tonle Sap system

2.4.3 Province and Local Authorities

Every province has a disaster management committee chaired by the Secretary to the Provincial Governor. DHRW and DOM communicate directly with MOWRAM's provincial offices. Provincial Directors then communicate with the provincial Secretary. Information flows directly to the provincial authority, which informs the community of flood threat and floods occurring.

Some provincial offices of MOWRAM record flood events photographically and using GPS to identify the extent of the floodwaters. This information can be used to compile a local archive of flood data that can be associated with AWL data.

3 Department of Hydrology and River Works (DHRW)

The Department of Hydrology and River Works is the professional hydrological centre for MOWRAM. Two of the functions in its mandate, river works and water quality monitoring, are reflected in its structure but are not very active. The structure and functions of the department are set out, including those of the office most relevant to flood forecasting and warning, the Office of Research and Flood Forecasting.

3.1 Scope of the Department

The Department has three major functions, (i) hydrologic networks and flood forecasting along with drought prediction, (ii) river works, and (iii) water quality monitoring. The analysis conducted in this report deals with hydrology related to flood forecasting and drought prediction, which involves the river and stream flow gauging network as well as hydrologic mapping and analysis based on data obtained from the monitoring network.

River works and water quality are not of interest to this analysis, so their offices are not described.

3.2 Objectives and Responsibilities

The official document governing DHRW is *Prakas* 229 BK/ dated 30 December 2010. It sets out the duties and responsibilities of the Department.[1] These are:

- To prepare plans for the installation of hydrological stations on the main water sources to serve water resources development
- *[To prepare short, medium and long-term strategic plans on protection of erosion, sedimentation, and river banks]*

[1] Responsibilities not related for flood and flood forecasting are in italics and brackets

- To research and monitor surface water and groundwater regimes by managing and installing hydrological stations, as well as collecting and analysing data to serve various water related sectors
- To implement and monitor water levels, water discharges, and sediment in river basin systems
- {*To monitor water quality at the main hydrological stations]*
- To study and research hydrological phenomena, models, computations, surface water and groundwater potential
- To manage and exchange hydrological information
- To issue forecasts and early warnings of possible floods and droughts to allow timely and appropriate mitigation measures to be taken
- To establish geographical information systems (GIS) related to water resources development

In summary, DHRW is responsible for collecting, analysing, and disseminating surface water information and data, and making projections and forecasts that the data allow. Desirable aims of DHRW, in respect to hydrology and flood/drought forecasting, might be expressed as:

- Maintain and develop an effective surface water monitoring system capable of producing accurate and timely information on water levels and river flow throughout Cambodia
- Develop accurate and timely flood and drought forecasting and warning systems, based on reliable and comprehensive climate and hydrologic data
- Disseminate accurate and timely warnings to communities to prevent or minimise the impacts of flooding on human life and property
- Develop and communicate flood information to communities that are at risk of flooding

Some performance indicators might be, in respect to the flood and drought information activities of DHRW are:

- Comprehensive, reliable and timely surface water data is collected and securely archived
- Useful and detailed analyses of surface water and climate data are conducted in the form of flood and drought projections and warnings
- Reliable and timely warnings and forecasts are transmitted to communities, enabling them to take measures to minimise the adverse impacts of floods and droughts

It is desirable that DHRW, with input from DOM, develop indicators along these lines for its own monitoring and performance purposes and to report on its effectiveness externally. Of course, DHRW should provide information about water availability as well as flood-related information.

3.3 Department Structure and Offices

DHRW is headed by a Director, who reports to a Deputy Director-General Technical Services. The Department has three deputy (or vice) directors and five offices, namely:

1. Administration
2. Hydrological Works
3. Research and Flood Forecasting
4. Water Quality Analysis
5. River Bank Management

Of these, the **Hydrological Works Office** and the **Research and Flood Forecasting Office** are the offices relevant to the NFFC strengthening project. The structure of the Department is shown in Figure 1.

Table 3 presents DHRW's responsibilities and the activities of the offices.

Table 3: Formal Responsibilities of DHRW

Responsibility		Office
1	To prepare plans for the installation of hydrological stations on the main water sources to serve water resources development	Office of Hydrologic Works
2	To prepare short, medium and long-term strategic plans for the protection of erosion, sedimentation and river banks	Office of River Works
3	To research and monitor surface and ground water regimes by managing and installing hydrological stations, collecting and analysing data to serve various water related sectors	Office of Hydrological Works for surface water: groundwater monitoring not undertaken
4	To implement and monitor water level, water discharge and sediment in the river basins system	Office of Hydrologic Works
5	To implement water quality monitoring at the main hydrological stations	Office of Water Quality Analysis
6	To study and research hydrological phenomena, models, computations, surface and ground water potential	Office of Research and Flood Forecasting (which is the only office with modelling activity)
7	To manage and exchange the hydrological information; to issue forecasts and early warnings of possible flood and drought for appropriate measures of mitigation in time	Office of Research and Flood Forecasting
8	To establish geographical information systems (GIS) relevant to water resources development	Office of Research and Flood Forecasting (although not undertaken at present)

The Department reportedly has a total 62 staff. Of these, ten are located in the Hydrological Works Office and eighteen are located in the Research and Flood Forecasting Office. These are not large numbers of staff for a national agency with responsibility for surface water data collection, analysis, use, and dissemination.

An outline of the qualifications of DHRW staff is shown in Table 4.

Table 4 Qualifications of DHRW Staff

Educational level	Where obtained	No. Staff
Master of Science (MSc)	Belgium, AIT (Thailand)	7
Master Engineering (MEng)	Russia, Netherlands, ITC (Cambodia)	22
Technical certificate (hydrology)	Vietnam	15
Technical certificate (hydrology)	Prek Learp Hydrological College (Cambodia)	5
High School	Cambodia	6
Boating certificate	Cambodia	1

Some PDWRAM staff are assigned to hydrology. However, a single member of staff in each district is normally responsible for all hydrologic work and most of these staff are not trained or qualified beyond a high-school level with perhaps some technical instruction related to river level and weather observation equipment. Those who have qualifications in hydrology are working on irrigation and other development projects.

DHRW does not presently have the technical capability to forecast flooding in important sub-catchments. DHRW only provides three-day forecasts based on water levels recorded by the seven stations along the Mekong-Tonle Sap-Bassac River system, using a simple regression models.

As well, the NWSP report made a particular point about strengthening of laboratories, to ensure that DHRW is correctly equipped, in personnel and instruments, for water quality analysis including sediment transport at river gauging stations. Specific training will be required for this.

3.4 Office of Hydrological Works

The purpose of the Hydrological Works Office is to collect surface water information (flow, water levels, discharges and rapidity), to store these data, and make these data available for water management purposes. Its primary area of activity is to install, operate and maintain the national network of water level monitoring stations and other water level measurement devices (staff gauges for instance), to produce reliable data, and to collect and store these data.

The official responsibilities of the Office are:

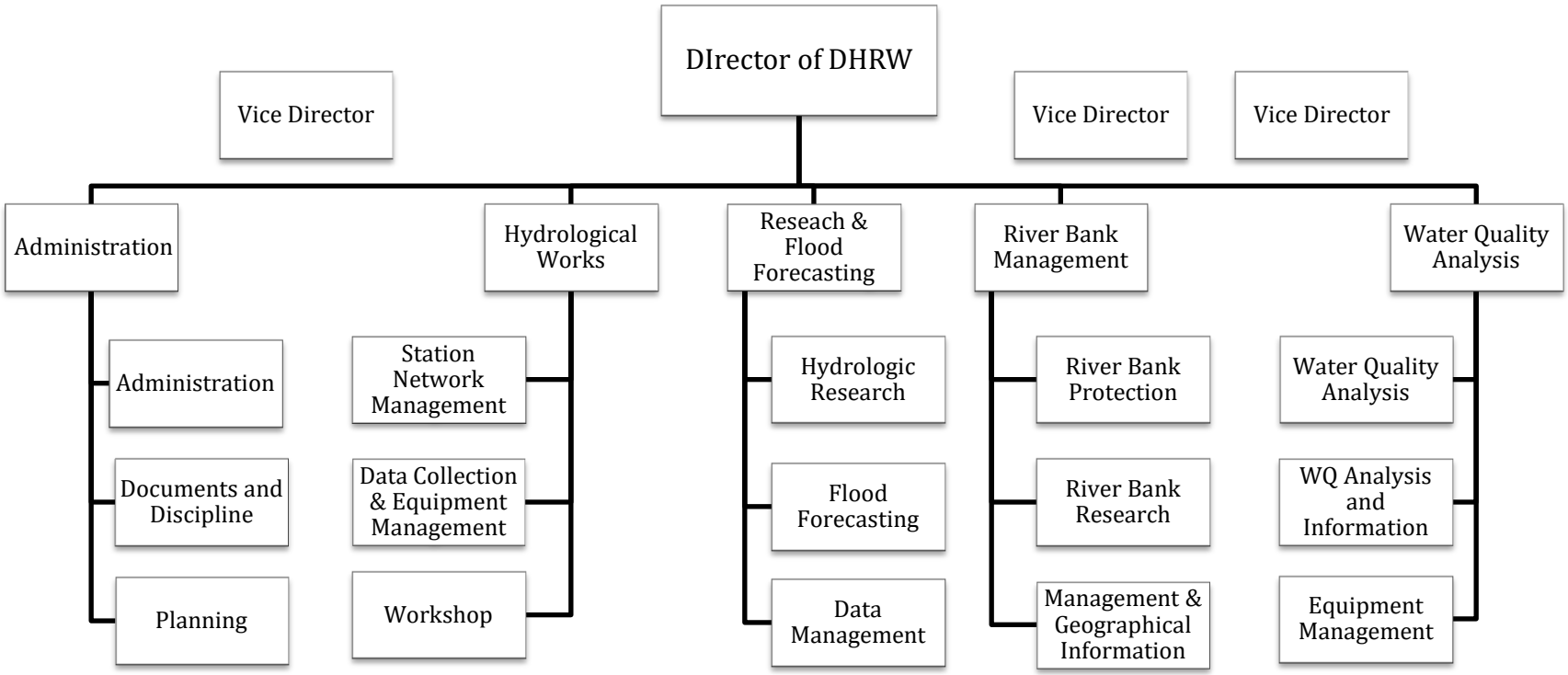
- Prepare work plans for the management and expansion of hydrological stations along rivers, streams, preks, lakes and other major water sources in order to serve water sector development
- Continue to improve, use and maintain all existing hydrological network stations and newly established stations ensuring their effectiveness and sustainability
- Regularly measure water levels, rainfall, discharge, sedimentation at the stations along rivers, streams and preks, lakes and at hydrological stations throughout the country
- Collect hydrological data, including water levels, rainfall, discharge and sedimentation from the hydrological stations throughout the country and send these data to the hydrological document custodian
- Manage and maintain hydrological equipment
- Repair, maintain and produce hydrological equipment

- Strengthen technical knowledge and skills of staff and improve modern technology in the field of operation and management of the hydrological stations network throughout the country

Presently there are 12 Mekong River Commission automatic water level (AWL) monitoring stations in operation, most of which have automatic rain gauges. These rain gauges are operated by DHRW, while the rest of the climate network is operated by DOM. In addition, there are 30 AWL stations installed under Asian Development Bank's Upland project and JICA has support the installation of 12 AWL and 9 automatic rain gauges.

The rainfall data from Mekong AWL stations is transmitted to DOM for weather forecasting.

Figure 1: Structure of Department of Hydrology and River Works



The Office of Hydrologic Works has ten staff, eight of whom are competent in the maintenance of automatic water level stations and in the conduct of discharge measurements required to calibrate the stations for the generation of discharge information. Teams of four conduct the measurement program, with support from PDWRAM staff. While the Department estimated that about ten measurements campaigns maybe conducted annually (roughly once a month in the dry season and three or four in the wet season) the work in this area is very much project-based. As a result, stations no longer covered by a project may not be calibrated for a very long time.

The Department has its own boats. The equipment for station calibration (depth sounders, flow meters and the like) is 'about ten years old' according to the Director.

MRC funding support is being withdrawn. At the same time, the number of water level stations is being increased and will increase further with the installation of new stations under the NFFC, JICA, and World Bank projects. In addition, special investigations for project design, involving temporary water level stations or staff gauges divert DHRW staff, causing routine work to be delayed.

Staff of the Office are reportedly competent in the maintenance and repair of the existing stations. However, with the addition of new stations, there will be greater demand of staff and given the limited funds, the condition of the network may deteriorate and the calibration of the stations become less reliable, which is the major concern for the accuracy of discharge computations.

An issue raised with the consultants by the DHRW Director was the lack of funding to operate and maintain the network. Operation and maintenance involves the following activities:

- calibrating and recalibrating discharge calculations for AWL stations by transecting rivers from time to time
- fixing breakdowns, which can only be remedied by a few staff in head office, as provincial staff do not have more than basic knowledge of the technology
- periodically maintaining the equipment and checking its accuracy

There are also staff gauges to be maintained from which water level data is collected by volunteers who are paid a small amount for their activity.

3.5 Structure

The Office has three units:

1. Hydrological unit
2. Workshop unit
3. Equipment unit

The Hydrological unit has the experienced and qualified staff responsible for maintaining the network and its equipment. The Hydrological unit is responsible for the operation and maintenance of the automatic water level network and receiving the transmitted data. Activities include:

- operation and maintenance of the existing network, with limited assistance from PDWRAMs
- calibration and re-calibration of recording stations by creating riverbed cross-sections and conducting discharge measurements
- reviewing the adequacy of the network and identifying locations for new stations
- maintaining the data communications links between the stations and data reception computer
- transmitting daily water level data to MRC

Five of the Unit's staff have a background in hydrology.

The Workshop unit is located at the MOWRAM compound on Preah Monivong Boulevard. it is attended by one member of staff. There is no permanent work at the workshop. When work arrives, temporary workers are recruited from outside the Ministry.

Activities include:

- Fabricate structures for installing and housing water level recorders
- Repairs to water level recording equipment, boats, and traverse equipment including flow meters

The Equipment unit manages and inventories all hydrologic equipment.

3.6 Hydrologic Data Transmission and Network

Daily water level records are generated at 7.00am and transmitted from the network to the Office of Hydrology and the MRC Regional Flood Management and Mitigation Centre (RFMMC), where they are entered into the HYCOS flood model. The MRC publishes its data at 11.00am, which includes upstream information. Water/flood levels.

The number of automatic water level recorders is being significantly increased. Some 27 automatic water level recorders have been installed by JICA in the Tonle Sap basin and a further six are planned for installation in 2017. In addition, up to 25 more AWLs are proposed by existing and planned projects. The details of these networks are shown in Annex 2. It is important to noted that some provincial directors put little faith in the results received from AWLs, and prefer manual observations of water levels.

This influx of new automated equipment poses a challenge for the Department, both at head office and at provincial levels. Provincial limitations are:

- Numbers of responsible staff – one staff member in most provinces
- Funds for travel to field sites for maintenance are limited and in some provinces not available
- Payments to local volunteers to collect staff gauge information are being phased out, with so far unforeseen consequences2

In general, provincial support is very limited to ensure the sustainability of the planned stations and to ensure that the network provides the required data.

3.7 Summary

The capacity of the Office of Hydrology is quite low. Of the ten staff, eight are involved in duties related to the operation and maintenance of automatic water level recorders. However, staff have no post-secondary qualification related to hydrology. Some staff have received minimal short-course exposure (measured in days or at most a few weeks) and have learned everything else on the job.

The capacity of the Office to take on additional work is limited. As well, several other factors are challenging the ability of the Office to manage the surface water network:

- withdrawal/reduction of MRC funds for network maintenance
- expansion of the network and planned further expansion

[2] As reported by the Director DHRW

- staff are spread too thinly

The lack of hydrologic training has implications for the ability of the Office to effectively review the Cambodia-wide network. While the Office is capable of managing some of the routine operation/maintenance of the network as it currently stands, the quality of the network will deteriorate in the future for the reasons given above. This will have significant implications on data quality.

3.8 Implications for the NFFC

The responsibilities of the Office of Hydrology should not be part of an NFFC, but the data collected by the Office of Hydrology must feed into the NFFC. Accordingly, the responsibility for the hydrological network should remain with the Office of Hydrology but be closely linked to the NFFC. This is discussed further in this report under Section 12 Data Questions.

Will data quality be maintained with the expansion of the network? Data quality refers to the reliability of water level data. Data quality can be affected by a number of factors:

- Imperfect calibration of automatic equipment
- Infrequent discharge measurements, which affects the accuracy of discharge calculations because of river bed profile changes (in some cases there may be rapid profile change due to the flood events
- Periods of non-collection of water level data due to equipment failure
- Periods of non-collection due to absence of the volunteer data collector

It is suggested that a plan to maintain and improve data quality is needed for the Office of Hydrology.

4 Office of Research and Flood Forecasting

The Office of Research and Flood Forecasting contains the hydrology, flood warning and assessment function of the Ministry. It receives data from MRC and other hydrological sites, but the reliability of these data is in question given the lack of calibration and site maintenance that has occurred over time. Current staff with the ability to use hydrological models effectively seems very limited and most tasks conducted are of a relatively basic nature.

4.1 Responsibilities of the Office

This Office is the key office for flood data analysis and modelling and the generation of flood-based warnings and drought predictions. Some of the data required by the Office is generated by DOM, namely weather (precipitation, saturation) and long-term climate analyses.

Official responsibilities of ORFF according to the *prakas* are:

- Manage and exchange hydrological information, as well as forecasting and early warning on flood and water scarcity in order that appropriate measures can be taken
- Collect and analyse hydrological data, to serve water sector development and water related sectors
- Study and research hydrological events, hydrological tools, and water potentials in the country
- Prepare and manage a hydrological data system;
- Compile and prepare the annual hydrological yearbook

The ORFF should compile and keep the hydrologic data archive, rather than the Office of Hydrology as ORFF has a data management unit for this purpose. The purpose of the ORFF can be expressed as:

- to develop timely and accurate information about existing surface water levels, extent, direction and movement and forecasts for the height/level, extent, duration, direction and movement of flood waters
- to develop long-term forecasts of drought and flood conditions in Cambodia
- to publish, communicate and disseminate information on flood and drought in an understandable form to affected localities and communities, including flood warnings
- to communicate with the government and NCDM on flood situations, providing timely and reliable information and predictions.

The Office performs its functions by receiving surface water level data and analysing it to produce flood predictions. In this, it relies heavily on the HYMET system operated by MRC, which incorporates precipitation and weather forecast information.

4.2 Structure of the Office

The Office has three units:

1. Forecasting unit
2. Database management system unit
3. Hydrology Research study unit

4.2.1 Forecasting Unit

The Forecasting unit is the key unit of the ORFF. This unit receives the daily water level data from the Mekong AWL station and operates the flow and water level models. The water level data is entered in to HYMET and plotted, and a regression model is used to forecast water levels at key forecast points. Recent improvements in modelling capacity by the MRC regional flood management and mitigation centre are not reflected in the activities of the forecasting unit.

A difficulty is that some of the staff of the unit, who are in technical positions, do not have training nor a mathematical basis sufficient to enable them to use hydrologic models beyond basic functions. This means they cannot perform more advanced modelling functions, which will be required with the upgrading of technical tools for flood warning and forecasting.

4.2.2 Database Management Systems Unit

The unit maintains a database of water level information. Historical data were lost in the 1970s due to civil strife in Cambodia. Apart from the missing time series, the electronic archive requires upgrading

4.2.3 Hydrology Research Study Unit

The consultants were informed that the Office does not carry out research as such. This unit, which has 'only a few' staff, coordinates with international donors, educational institutions, and relevant forums.

4.3 Staff – Weakness in Hydrology

The ORFF has 17 staff. Only three have tertiary qualifications related to hydrology. The other staff have backgrounds in law, accounting, management, English and information technology. These numbers indicate the technical weakness of the Department in flood forecasting.

This Office suffers from the same difficulties as the Office of Hydrology – in being unable to recruit new staff with any hydrologic, water resources or even engineering background.

It is possible to recruit staff with knowledge of information and communication technology (ICT), but they come into the Department without an understanding of water and hydrology. Some of these staff have been given short training courses. Some have been sponsored by JICA to attend courses in hydrology in Japan, but the courses have been only at a basic level.

The development and use of computer simulation models to identify flood duration and extent, and forecast flood movement and the like, is both an advanced technical task and ideally an art (meaning that the experienced modeller becomes so familiar with the modelled terrain, stream, river basin that he or she gains an immediate instinct for the accuracy and reliability of the performance of the model and the reliability of its outputs, even without immediate verification through information from the field).

The last hydrologic studies sponsored by Russia ended in 1996, some twenty years ago. Since then, there have been no fully trained hydrologists in Cambodia. The experienced and qualified hydrologists who remain with the Department are now approaching retirement. As already noted, newer staff do not have tertiary qualifications hydrology or related fields (even engineering).

An indication of the level of capacity is shown by the fact that when MRC offered training in the FEWS model, the training was not successful because it was too advanced for the departmental staff who attended. Therefore, the Department has not made use the FEWS model.

Without a change in the recruitment of technical staff for the Department, the capacity to undertake flood and drought forecasting in Cambodia will further reduce as experienced staff retire. This is a matter of serious concern to the managers.

It is difficult to say how many of the modelling staff are more than data inputters. When modellers approach the task from an IT and data manipulation perspective only, they develop a limited ability to judge whether the model is reflecting the external reality of the hydrologic system and water movement and behaviour.

4.4 Funding Hydrologic Data Collection

The funding of data collection is an issue for MOWRAM.

> *The national budget allocated to hydrological data collection is insufficient for operating and maintaining the established stations after the completion of the project has let to neglect and deterioration of station infrastructures and loss of field personnel such as observers especially funds for regular discharge measurement*.
>
> Quoted from **Proposals for Hydrological and Meteorological Network Improvement August 2011**, **MOWRAM**.

DOM reports that since 2011 there has been improvement in data collection, with an increase in government funding for this responsibility. Meteorology is reportedly a priority for the Minister.

Although some increase in funding has been allocated from central sources to the Ministry, the consultants were informed that no actual increase to DHRW has occurred.

Budgets for travel (staff and vehicles) have not increased significantly at the departmental level. In 2011 budget levels were considered inadequate. The demand for travel is increasing with additional stations being installed. It is expected that the network will be less well maintained on a yearly basis.

4.5 Summary

The Office of Research and Flood Forecasting is a hydrologic modelling unit which links with and relies heavily on the activities of the MRC-RFMMC. The Office is struggling to maintain expertise in hydrologic modelling that it requires to fulfil its responsibilities and its level of competence is likely to reduce when experienced and qualified staff retire. The Office has not been capable of keeping current with recent MRC models, such as FEWS, because staff are not able to follow the training. This shows that the Office faces severe challenges.

The introduction of new technology in the form of two and three-dimensional models may be beyond the capacity of the Office to use effectively, even with the normal level of training that accompanies such software.

Therefore, there is a serious question as to how the Office of Research and Flood Forecasting can become the core for an NFFC at this time without long-term hand-holding by external professionals. And if new functionality, such as locality-specific flash flood risk assessment based on FFGS, is introduced, it may be that the Office will not be able, at this time, to use the models effectively, or only with limited usefulness.

This question is taken up further in Section 11 Barriers and Challenges.

5 Department of Meteorology

The Department of Meteorology has been given priority by the Ministry in recent years and its funding and facilities have improved. The Department's structure and functions are described. The capacity of current staff remains limited, however, and its staff numbers a very low for a national meteorological agency. The Department is centrally-located. Observational data are collected by provincial staff who are not considered part of the Department's staff compliment.

5.1 Official Responsibilities

The Department of Meteorology of MOWRAM, along with provincial branch staff, is responsible for weather observation, weather forecasting and long-term climate analysis and research. DOM is not working in climate change, which is under the Ministry of Environment. Apart from short-term weather forecasting, DOM should be contributing to long-term forecasts and supporting the analysis and modelling of flood impacts of precipitation events. To date, that is not undertaken by the Department.

The official responsibilities of the Department of Meteorology are set out in Prakas #194 of 2010 on the organisation and functioning of DOM.

Administration, Office of Research and Weather Forecasting, Office of Equipment and Material Management, Office of Climatology, and Office of Weather Observation are under the supervision of the DOM. The roles and responsibilities of each office are presented in the following sub-sections.

5.1.1 Office of Administration

The responsibilities of the Office of Administration are typical for such offices in MOWRAM:

- Manage and circulate all departmental documents, manage documents, files and legal instruments

- Coordinate the inter-department activities of all the offices of the department, the Ministry, and provincial departments
- Summarize and make reports on activities and work carried out by the department
- Prepare guidelines on administrative procedures
- Compile and prepare short, medium, and long-term work plans for the department
- Manage accounts and create inventories in the department
- Disseminate circulars, sub-decrees, instructions, decisions, and so on, within the department
- Be responsible for security, order, and discipline within the department

The Office of Administration has three units, Staff and Training, Planning and Documents, and Discipline.

5.1.2 Research and Climate Forecasting Office

The Research and Weather Forecasting Office is responsible for:

- Preparing and circulating weather-related forecasting documents
- Analysing and disseminating real time weather-related information to citizens, enterprises, businesses, and concerned institutions through mass media, such as newspapers, TV, radios, bulletins, magazines and others
- Providing training and conducting research on climate forecasting;

This Office is the critical area for receiving weather and climate data, including precipitation information. The Director indicated that the Office does not undertake research as such. The Climate Office attempts to keep up with contemporary developments in climatology, but for the most part undertakes its normal duties.

This Office has three units: Analysis and Climate Research (see note above), Climate Forecasting and Observation, and Climate Information.

The Analysis and Climate Research unit is responsible for the following:

- Training in climatology observation, analysis and real-time announcement of forecasts to the public and through media
- Collecting relevant data from various stations throughout the country, managing and verifying data and sharing data and information within the cooperation framework at national and international levels

The Weather Forecasting and Observation Unit has the weather forecasting responsibility, receives satellite data and issues climate and weather forecasts for Cambodia. This unit receives observation data which is further analysed. However, the analytical capacity of staff is believed to be limited. There are seven staff in this unit.

5.1.3 Equipment and Material Management Office

This Office is responsible for the meteorological network of rainfall and climate stations. The bulk of the stations have automatic rainfall gauges (ARG) with one or two other measurements such as temperature and humidity being conducted. Data on wind speed and direction are not comprehensively collected through Cambodia – only at selected stations. The key skills required in this Office are instrumentation and technical.

- Prepare and circulate relevant documents on meteorological equipment
- Train staff on how to use meteorological equipment

- Prepare work plans for the operation and maintenance of meteorological equipment in accordance with the norms of the WMO at stations located in the city and provinces
- Monitor, manage, and evaluate the quality and quantity of meteorological equipment
- Cooperate and jointly work with donors, both national and international

There are three units under this Office: Meteorological Equipment Control, Installation and Repair of Meteorological Equipment, and Meteorological Equipment Management.

5.1.4 Climatology Office

The responsibilities of the Climatology Office are:

- Prepare related documents and circulate documents concerning meteorological data
- Collect meteorological data from all rainfall stations in the city and provinces
- Manage and rectify meteorological data in accordance with database
- Research and analyse long-term data
- Disseminate and communicate the data within the context of national and international cooperation partners

There are three units under the Office, Meteorological Data Collection, Meteorological Data Management, and Meteorological Data Adjustment.

5.1.5 Weather Observation Office

The official duties of the Weather Observation Office are:

- Prepare related documents and circulate documents concerning weather observation
- Manage the quality of equipment/materials for weather observation
- Make report on any change of climate through the system of weather observation equipment
- Rectify and compare the data received from observation and those are from rainfall stations
- Make test on agro-meteorology

There are three units under this Office: Weather Observation, Agricultural-Meteorology, and Adjustment and Data Transfer.

The structure of DOM is shown in Figure 2.

5.2 Human Resources

In 2017 the Department has 44 staff. There are five managerial level staff (Director, three Deputy-Directors, and one Cabinet Official) The number of staff are shown in Table 5.

Table 5: Profession of Staff of DOM

Staff category	Number
Managerial	**5**
Administration	**9**
Weather	**6**
Weather forecaster	**6**
Weather observer	**9**
Equipment/materials	**7**

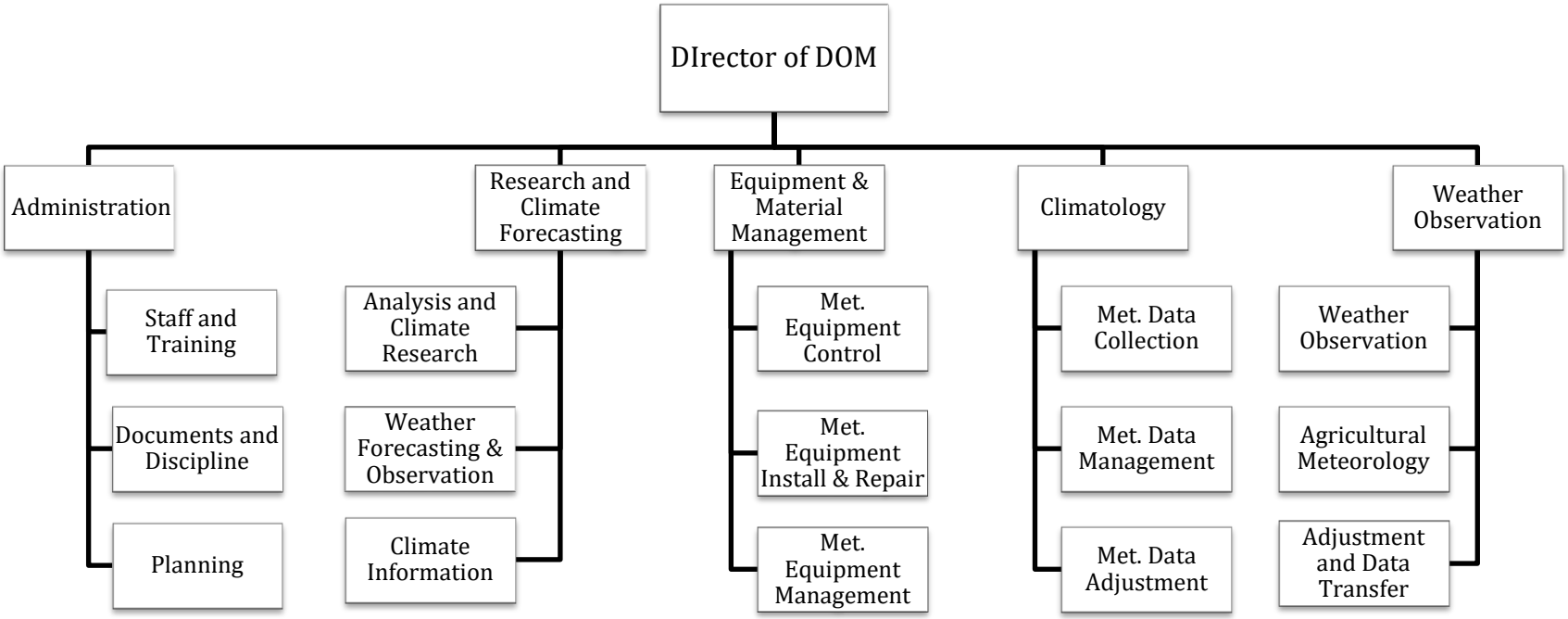
Staff category	Number
IT	**2**
Total	**44**

The qualification of staff in DOM include five with master degrees, ten with bachelor degrees and sixteen who have completed high school. The others have lesser education.

In 2015, DOM had 47 listed staff, 13 of which participated in a TNA. These staff had a median age of 39, of which eight were in the 30-39-year age group and five were in the 40 to 49-year age group. Three of the participants had an engineering degree and two a Masters. Two were female, one of which had engineering qualifications and the other was a technician.

DOM staff included five with a bachelor or masters in meteorology, 22 meteorologist technicians CL3, and 11 meteorologist technicians CL4. Other staff are from the fields of construction, archaeology, commerce, management and non-qualified staff. Graduates were trained in Russia and Viet Nam during the early 1990s, and since then there have been no more staff trained in this specialist field.

Figure 2: Structure of Department of Meteorology



Other newly recruited staff are IT staff to support the operation of the Doppler radar. Similar to DHRW, DOM suffers from staff shortage and generation gaps of qualified professional staff. Despite the fact that five IT, meteorologist personnel, and forecasters have been recruited and trained in France, and with better pay than professional meteorologists, the radar has not been fully implemented to support short term rainfall and wind forecasting.

Reportedly, there is no technical capacity at DOM in the field of Numerical Weather Prediction (NWP).

Provincial offices have no skilled staff and those that have the necessary skills retired and have not been replaced. There are some 40 technician meteorologists at DOM in Phnom Penh.

The Department of Meteorology has five offices. Each office has three units. There are three Assistant Directors (not shown in Figure 2). Three of the offices have a Head, (Administration, Climate Observation and Equipment Management). Each office has one, two, or three Deputy Heads. The staffing profile is shown in Table 6.

Table 6: Offices and Staff of DOM

Office	Head	Deputy	No. Staff	Total
Director and Assistant directors	4 + 1			**5**
Administration	1	1	8	**10**
Research and Weather Forecasting	0	3	3	**6**
Equipment and Materials Management	1	3	3	**7**
Climatology	0	2	4	**6**
Weather Observation	1	2	6	**9**
Totals	**3**	**11**	**24**	**43**

The total staff, excluding managers and administrative officers, but including deputy heads of offices is twenty-six.

5.3 Staffing Profile

The distribution of staff in DOM is as shown in

Table 7.

Table 7: Distribution of Staff Within DOM

Task		Subtasks
Managerial	5	Director, 3 deputy directors and deputy cabinet
Administration	9	General office staff
Climate	6	Meteorologists
Weather forecasting	6	Meteorologists
Weather observation	9	Instrumentation and weather observation
Equipment/material	7	Instrumentation/technician
ICT	2	Computer/IT
Total staff	**39**	**Men 29, Women 10**

The qualifications of staff in DOM are shown in Table 8..

Table 8: Staff of DOM by Qualification

Education level	Number of Staff	Related
Master degree	5	Other
Bachelor degree	10	Other
High school	16	n/a
Elementary school	8	n/a
'Ordinary' staff	5	n/a

Table 8 shows that a total of 15 out of 44 staff have a tertiary qualification. Some recent recruits may have tertiary study in fields unrelated to meteorology. The 'related' column indicates whether the qualifications are related to meteorology or are in other fields. 'Ordinary' staff are those who carry out basic and unskilled tasks for the Department.

5.4 Equipment

The NWP reported that, to a large extent, DOM data collection relies on simple, robust equipment that has survived time with limited maintenance. Continue use of the equipment will depend on a reasonable capacity for maintenance and repair, or replacement of out-dated materials.

The choice of new sophisticated devices or more simpler ones must be made taking into account the capability of field observers to undertake effective work after reasonable training, as well as the numbers of staff available in provincial offices.

The major asset of DOM is the Doppler Radar. However, the NWP reported that the decision to opt for such high level technical investment seems not to have been well prepared, with little involvement from technical staff.

DOM may still be facing difficulty in putting the Doppler Radar into full operation, due to lack of expertise and field experience in the field. As of 2015 DOM could not provide rainfall intensity mapping in near real-time for flood forecasting nor to provide early warning to the most vulnerable people in critical sub-basins.

The Director of DOM indicated that the radar was subject to interference from tall buildings in the vicinity. He also mentioned that on-ground calibration and verification had not been undertaken. The impression was given that there are problems with obtaining useful information from the radar and that it is not being used according to its intended purpose at present.

With the relocation of the Office from Pochentong Airport to the new location in the MOWRAM compound, DOM has more office space, including the space allocated to the Doppler Radar building. Yet, similar to DHRW, it does not have storage room, or space for equipment calibration or maintenance. Furthermore, for new installations, DOM will need more space, as well as practical training for staff and observers located in the provinces.

The management level could also do more to be more visible to potential data users and the public, especially integration with national water resource management activities, other than the more limited flood forecasting activities.

The NWP found that the status of the DOM was worse than that of the DHRW in 2001. It was suffering continuous setbacks from the lack of support projects, frequent changes of leadership as well as relocation of office and shortage of professional staff. With no funding historically channelled to it, DOM did not have its own transportation for field work. That situation has improved somewhat.

5.5 Department Operations

MOWRAM's Socio-Economic Development Plan (SEDP) 2014-2018 records the following achievements related to the mandate of this Department in the previous planning period (2009-2013):

- Establishment of 3 meteorological stations and the repair of 5 stations
- Installation of rain gauge posts in 18 stations and the repair of 26 stations
- Provision of automatic equipment in 8 stations

For the period 2014-2018, MOWRAM's SEDP recognises that data and information are necessary for planning and construction of infrastructure for water resources management and development, for flood and drought forecast improvement, and the alleviation of flood and drought impacts, especially in river basins where water conflicts occur. The SEDP also recognises that data and information management on the amount of water used in sector is still limited, and that meteorological and information management, hydrology and budget for research are also still limited. The SEDP states that water resources and meteorology information indirectly contribute to the Rectangular Strategy, which enables MOWRAM to perform better.

In this context and the dire lack of water data identified in the NWP, the MOWRAM plan for 2014 to 2018 sets as targets the installation of 4 meteorological stations for each of the 5 years of the planning period (a total of 20 stations), bringing the total up to 41 stations, and the repair of 4 meteorological stations each year (a total of 20 stations). The combined budget for DHRW and DOM over the 5 years is nearly USD 19 million. However, despite all of this, no RGC funding is provided in the MOWRAM SEDP, nor is specific international support identified.

Some improvement in operational funding has occurred in the last two years, according to the Director of DOM. Without operational funding the Department cannot make progress against its mandate and water data management in Cambodia will continue to decline.

6 MOWRAM Provincial Departments

Provincial department of MOWRAM perform all field operations but have very limited staff and resource. Currently they cannot service existing networks and will be more incapable of servicing future expansion of the networks with additional stations. There may be a general tendency to mistrust automated equipment, much of which has fallen into disuse over time. Provincial offices could perform more advanced data functions in the future if support, development, and funding are made available.

6.1 Provincial Departments

The provincial department of water resources and meteorology (PDWRAM) is the provincial arm of MOWRAM. There is a total of 52 provinces with a PDWRAM in each province.

The structure of the PDWRAM follows the head office structure to some extent but the inter-departmental divisions are less defined. There are staff assigned to responsibilities related to hydrology and meteorology and the same staff member may have both responsibilities. Most provinces have only one member of staff with responsibility in these areas, and that staff member may have other responsibilities.

It is clear that the PDWRAM's ability to undertake work in hydrology and meteorology within its provincial territory is seriously limited.

6.1.1 Staff level and capacity

With respect to hydrology, provincial staff, for the most part, have limited knowledge to repair only the basic elements of AWL recorders. The provincial staff assigned responsibility for meteorology and hydrology (normally both responsibilities) usually have other responsibilities as well.

They collect hydrological data, water levels and where available rainfall data, and transmit these data to DHRW. They coordinate information from volunteers who read staff gauges. They also make meteorological observations, which are transmitted to DOM.

6.1.2 Current role of PDWRAMs in flood-related activities

At present, the PDWRAMs are limited to performing tasks related to the collection of data from weather stations and water level recorders (manually-read and automatic). Their capacity to maintain and repair automated equipment is believed to be very limited. It is normal for head office staff to visit a province when equipment has broken down.

Provincial staff are not capable of data analysis or forecasting and it is unrealistic to expect that they can be trained to the required level in the short or medium term. It may be a long-term objective to have (some) provincial interpret weather or hydrologic data locally.

This report discusses the role that provinces could best perform. Table 9 shows the current level of activity that the consultants believe occurs in provincial offices

Table 9: Tasks and roles of PDWRAM staff in hydrometeorology

Task/Responsibility	Current Capacity	Planned Goal
Operate and maintain AWLs for all routine breakdowns	Limited operation ability (if any?) Not capable: all equipment must be sent to head office	Build up larger PDWRAMs as centres for equipment repair and maintenance
Operate and maintain meteorological equipment	Basic weather station operation Maintenance not capable	Build up large PDWRAMs as centres for equipment repair and maintenance
Collect data and transmit	Routine function undertaken via manual systems	Increased reliability and coverage
Hydrometeorological data quality assessment	Not undertaken or possible	First rank data quality assessment preformed in province[3]
Hydrometeorological data archive or access	Archives not kept. No access to head office databases	Access to historical data enabled for use
Interpretation of water level data to assess flood risk	Not capable	Some interpretation of water levels in consultation with head office

[3] Meaning that staff are familiar enough with the data to detect obvious anomalies, investigate them and make corrections

Task/Responsibility	Current Capacity	Planned Goal
Access to regional weather/precipitation information	Only what is publicly available but not able to interpret it for flood risk assessment	Access to head office information and able to make general risk assessments in consultation
Interpretation of weather station data and other	Not undertaken – data transmitted only	Date interpreted in province
Monitoring of flood events	Not undertaken actively	Monitoring to verify forecasts and identify flood characteristics
Communication of flood risk	Undertaken on basis of information provided externally	As now, but including locally derived information
Flood warning	All formal warnings proceed from centre	Daily and hourly updates possible by province for local floods

Using Table 9 as a basis for capacity development and the expansion of provincial roles, a plan can be developed to move in the direction indicated. Initially, it would be more feasible to strengthen a few larger and more capable DPWRAMs and give them a role in supporting neighbouring provinces.

6.2 Hydrological and Meteorological Equipment

At present a number of donors are providing, or intend to provide, automatic water level recorders in various parts of Cambodia. The total number of AWLs is expected to increase by some 52. This will add significantly to the work burden for operation and maintenance. The number of staff needed to service the equipment will expand.

Provincial staff are capable only of routine maintenance, meaning general mechanical repairs that can be made without specialist knowledge. They repair staff gauges, for instance. They are not capable of making electronic repairs or replacing electronic parts. These repairs must be organised through head office.

When electronics equipment fails, these are replaced through suppliers. Retro-fitting reportedly causes compatibility problems at times, such as when new software is not consistent with pre-existent data-loggers or data formats. Compatibility problems have to be resolved through head office.

Equipment vandalism was a problem when recorders were first installed, but is reportedly less so now.

The number of AWLs is increasing significantly. It is difficult to see how existing staff can adequately maintain the increased in station numbers. Furthermore, enquiries indicated that beyond initial training by donor projects or supply companies, that focuses mainly on operation, Ministry staff do not receive support. In some cases (JICA), major maintenance and repair is expected to be done by donor-assigned staff or contractors, even over the longer term.

6.3 Data Transmission and Telemetry

Water levels obtain by staff reading staff gauges are transmitted manually by local observers to the PDWRAM, which reports the information by phone to DHRW. Data from AWLs is transmitted directly to MOWRAM or the MRC.

Provincial staff retain local records of staff gauge data, however the AWL data bypass the local office and are transmitted directly to head office. For this reason, provincial staff prefer to have manual records of flood levels to communicate to local people. They may also consider manual records to be more reliable than data form the automatic stations.

Provincial staff are taught how to check whether AWLs are working, how to re-boot the equipment, and how to use LCD-based menus. If there is a telemetry communication problem local staff check whether the telephone system is up and running (which may be due to sim cards running out of financial credit, for instance) or whether there is a problem with the water level equipment itself.

It is desirable, in the long term, that the Ministry increase provincial capacity (i) in equipment maintenance and operation (water level recorders, telemetry systems, weather station equipment), (ii) in the management of streamflow/water level data, (iii) in the management of weather observation data, (iv) in analysis of flood-related information, (v) in the local communication of flood risk, and (vi) in monitoring and documenting flood events.

6.4 Data Checking and Quality

Provincial staff keep a copy of manually and locally obtained water levels. At the province visited that archive was in both hard and soft copy.

No program of data matching, checking or quality assessment is conducted in the provinces. The data that is manually communicated to DHRW is matched against telemetry data from related locations. Provincial staff have very limited experience and knowledge of practice in data quality management. The senior staff member may have some understanding of data management.

PDWRAMs retain copies of the data that they communicate to head office. It is understood that these data are not actively used by PDWRAM staff for further understanding of flood. It is retained only as a back-up.

6.5 Staff Knowledge of Flood Behaviour

Staff in some provinces are aware of the general impacts of Mekong flood levels. For instance, if the flood reaches a particular recorded level, experienced provincial staff will know what areas are likely to be flooded as a result. That is because, annually, they record the districts, communes, and villages that are flooded. Although no records are kept of flood depths in settled areas, some province staff can estimate the location of flood waters for a specified river flood level.

This understanding would not apply in the same way to tributaries of the Mekong or tributaries of the Tone Sap, where flood levels are less regular and change faster.

6.6 Staff Communication of Flood Risk

No formal communication of flood risk is made by PDWRAMs. All official warnings come from MOWRAM head office or the NCDM and its branches. Provincial disaster management committees receive information from the National Committee and communicate it further down the line. The head of the PDWRAM sits on the provincial committee, but 'technical' staff are not directly involved.

PDWRAM may unofficially communicate with local authorities and agencies about flood levels and likely flood risk or timing. To what extent this happens is not known.

6.7 Regional Weather Forecast Information

Provincial staff have limited access to regional weather information or forecasts, beyond what is made public. It follows that they don't make any assessment of likely weather impacts on catchment saturation or streamflow.

6.8 Monitoring and Tracking Local Flood Events

Local flooding may be caused by the Mekong River level rise or there may be other contributing factors. Where the Mekong River flood level alone is responsible, flood advance is relatively predictable from year to year and prior to the flood event. Although much more could be known about the extent of flooding and its location. Some provinces send staff to document and record flood boundaries (geo-positioning and photo records). However, these records are limited.

Other factors can contribute to flooding. These are chiefly (i) local precipitation and (ii) other streamflow. There is no provincial responsibility or capacity to monitor either precipitation and its possible impacts, or streamflow in tributaries and smaller streams.

Tributary streamflow can alter rapidly to cause flash flooding. Such flood events are virtually impossible to predict reliably and difficult to track as they move, due to the rapidity of flow. However, some tracking and downstream warning could be possible for streams where upstream locations are able to provide a guide to expected downstream discharges. Presently there is no expectation that provincial staff will perform a warning function of this nature.

It is recommended that a program be initiated to obtain records of the extent of flood events with a combination of provincial staff and community members making records of flood waters. This information should add to the historical record and improve simulation models and flood predictions.

7 MOWRAM Institutional Capacity

The institutional capacity of MOWRAM requires strengthening in most areas. Institutional structures are not problematic except that the placement of related technical activities in different departments limits access to data because of the culture that is inimical to sharing it. Funding and resources are not adequate for the flood management function and staff are affected by challenge in their working conditions. Furthermore, finding staff with adequate competencies in technical areas is very difficult do to generational factors in Cambodia.

7.1 Introduction

Institutional capacity in flood forecasting and drought prediction within MOWRAM is limited by a number of factors. Factors that form barriers to greater performance are discussed later in this report. This section discusses those factors related to staffing and the facilities owned by the Ministry.

The two technical departments of MOWRAM with responsibilities related to flood management are DHRW and DOM. These departments both receive, generate, and use information and data that contributes to understanding events that influence surface water flow, river flow and river and lake levels. However, the departments are managed separately and there is no free flow of information or data between them at this time.

The program to develop the NFFC therefore must find ways to bring about coordinated assessments of precipitation and streamflow, and to incorporate that information into modelling activities that will generate forecasts which in turn result in timely and accurate flood warnings.

7.2 Institutional Capacity of DHRW and DOM

The work of the Office of Research and Flood Forecasting (ORFF) of DHRW possesses the functions that relate to the core activity of an NFFC. The consultants concluded that the technical capacity of DHRW is too limited for it to become effective as an NFFC at this time.

The qualifications, training and background in hydrology of recently recruited technical staff is very basic or in some cases non-existent and it is concluded that they are not able to usefully operate advanced flood models. There are generic problems in obtaining technical staff with appropriate qualifications and training. In fact, the capacity of the Department is likely to deteriorate as senior hydrologists retire.

The same was found in respect to meteorology in DOM. This is not as great a problem for the purposed NFFC, but competent meteorologists are needed for the comprehension and analysis of climate data and the operation of more advanced precipitation models need to support flood warning and disseminating forecast information.

The degree to which DHRW is capable of usefully operating the models being developed by the project, is uncertain. Perhaps the most telling indication was that the staff of DHRW who attended the MRC training course on the use of the Deltares model (FEWS) could not keep up with the training and were no better placed to make use of it afterwards.

DOM does not provide data directly to DHRW, who obtain some weather information from DOM's website. There is no electronic link between data or analysis outputs of DOM with the hydrologic flood information that DHRW generates. This obviously limits the up-to-date knowledge and forecasting information available to DHRW. A proper information exchange needs to be developed between the two departments.

7.3 Human Resources

Areas where human resources capacity needs upgrading are shown in Table 10. Some general assumptions are made regarding funding, based on comments received by the consultants.

Table 10: Some General Staff Capacity Requirements

Requirement	Staff Issues	HQ/Province	Funding
Office of Hydrologic Works			
Maintenance and repair of AWL recorders in light of increased numbers	Additional staff capable of attending sites and maintaining recorders	Increase staff Nos. HQ and provinces	Increased funding for site visits
Calibration and recalibration of AWL recorders for data reliability	Upgrading and more staff capacity	HQ staff increased capacity and availability	As above
Improve reliability of river discharge calculations – more frequent cross-sections and flow metering	Additional staff and training	HQ staff (seems unlikely that Provincial staff alone can be upgraded for this	Considerable funding required

Requirement	Staff Issues	HQ/Province	Funding
Office of Research and Flood Forecasting			
Improved flood modelling ability	Training and appropriate background	HQ	Not critical (?)
Mapping and flood risk identification			
Drought prediction	Additional long-term climate analysis and modelling	HQ	Funding for data (?)
Incorporation of meteorological data into flood models	Upgrading of modelling abilities	HQ	Not significant
Weather Observation Office			
Weather station data observation and collection	Upgrading of provincial skills and additional observers	Provincial staff to manage new existing stations	Additional funding (some recently forthcoming)
Weather Forecasting Office			
Interpretive skills using existing data to generate forecasts	Staff upgrading of skills and knowledge (cannot assess whether existing staff would be capable)	HQ	Not extensive once upgrading accomplished

7.4 Management of Technical Departments

Constraints on management in MOWRAM appear to the consultants to be limiting factor for professional improvement and the likelihood that more advanced technology will be used effectively to improve flood forecasting, and hydrology and meteorology in general.

The consultants did not conduct a review of management in MOWRAM or the technical departments as this was outside their terms of reference. However, during their investigations, a number of practical questions arose and some management challenges can be identified for further investigation and analysis.

In general, and based on prior knowledge of the Ministry, it can be observed that the management of departmental functions is not strong. By that we mean that managers appear not to be able or empowered to exercise the degree of control over staff and resources that is necessary to ensure that functions are performed effectively, continuously, and at a level where improvement is likely. They appear to be without the means to motivate staff to perform at a level that would be considered necessary for professionals in these fields.

The difficulties experienced by managers are believed to include the following:

- A widespread situation where staff are engaged in external work or other activities during the working week

- An observed lack of motivation among staff to perform professionally and lack of interest in achieving professional results
- Lack of the means to sanction poor attendance or to raise the level of practical performance (or inability to use such means if they exist)

That is not to say that all staff follow these descriptions, but observation of the staff in DHRW caused the consultants to conclude that:

- They attend the office for very short periods during the working week;
- They perform relatively basic tasks, that mainly involve obtaining and receiving data, entering it into basic databases, and sending data out or making it available
- They are not motivated to perform or improve their abilities
- The managers appeared to have little influence on the performance of the staff
- The managers were apparently unable to make significant decisions on operational matters and matters of staff and staffing
- There were few meetings or situations where managers communicated with staff or staff communicated among themselves at a professional level

While some managers were present for long hours, their subordinate staff were not present for much of the time. The impression gained was that most of the substantive work of the department was performed by a few staff in supervisory or management positions.

These are general observations, not based on detailed investigation. However, the consultants are convinced that decision-making is very heavily centralised, leaving senior officials without independence of action on operational matters. There may also be disincentives for staff to make suggestions or press for changes in light of the centralised system by which the Ministry works.

A management problem that arises in organisations due to lack of autonomy is that middle-level managers act more as facilitators than as managers. By this we mean that they coordinate but do not exercise authority, because that authority must come from much higher up. It means that, contrary to what one might assume, an autocratic system causes management to consist of passing down orders from above and of leaving decisions to be made or more likely not made at higher levels. A general lack of decision-making can result in such organisations. We believe this dynamic to be operating in MOWRAM.

The other dynamic is where staff are not motivated and managers have to perform much of the lower-level activity themselves. We observed indications of this.

Other areas of activity in the Ministry appear to show that where advances have been made in the past, those improvements depended very much on the efforts of a few active individuals. Once those individuals move on, the programs they promoted fall by the wayside. This seems to be the case with the Technical Institute in the Ministry, which now seems to be practically defunct, after being strongly promoted some eight years ago.

The Ministry works on a financing model where external funds create new assets and provide support and training, but the facilities and functions dry up when the external funds are no longer being provided. This applies to the maintenance of AWLs and AWSs. There seems to be no reason, at this time, why the same will not apply to the AWLs being installed by this project and other projects. If ongoing maintenance is not financially provided for then equipment may become inoperable over time and abandoned as has happened before.

There is a lack of practical information and data. For instance, it was not possible to obtain information about such matters as the numbers and qualifications of staff with responsibility for hydromet activities in all the provinces. These data ought to be readily available to head office management.

There is tension between the desire of the most senior figures to control and make decisions for all lower level activity, and the need for the Ministry to perform in areas such as flood forecasting and response.

The consultants conclude that the current management model in MOWRAM puts difficulties in the way of improving and developing more professional and active functions. Therefore, there could be a case for conducting a management review that investigates the management dynamics of the Ministry with a view to recommending improvements.

As this was not a core concern of the missions, the consultants did not investigate whether management reviews of MOWRAM have taken place, nor how deeply management structures and practices have been looked into. Nonetheless, the consultants recommend that a management review be considered, as the situation seems dire. Such a review would have to consider the whole of the Ministry and its dynamics, investigating such matters as:

- Decision-making levels and the scope of managers at all levels to make management and operational decisions
- The staff control rules available to managers at all management levels and impediments to these being acted on
- Communication practices within and between departments and at all levels, including the general subjects of communication
- The management 'ethos', meaning the view of managers as to what their role is or should be, their ability to carry it out and the changes required to strengthen it
- Financial control, locations of financial decision-making, and the availability of funds to perform assigned tasks and functions
- The state of information and information systems and whether managers are able to know what is occurring in order to make management decisions
- The motivational factors for both managers and staff and what factors affect these

7.5 Conclusions

The two departments of MOWRAM with flood and forecasting related roles have relatively few professionally qualified staff and overall staff capacity is low. Although the consultants were not able to directly view the work activities of the departments, it was clear that the level of qualifications, knowledge, and skill among the professional staff is limited by lack of tertiary level qualifications, lack of experience, and lack of training and in at least some cases, lack of basic ability in areas required to be proficient in hydrology or meteorology.

Limited funding also affects data collection and observation. This was claimed to be a bigger problem for hydrology than for meteorological. The departments have limited ability to deal with data coverage and data quality.

Provincial resources are very limited. In most provinces a single staff member is responsible for both meteorological and hydrological activities. This involves the undertaking or organising the collection of weather observation data and water level data from manual recorders. However, the staff member may also be responsible for other duties in the province. Provincial capacity is spread very

thinly and is the reason why head office departments have to undertake tasks that the provinces could do if they had the resources.

8 National Flood Forecasting Centre

The proposal for a national flood forecasting centre is admirable. The key to its success is less structural and more to do with improving the knowledge, skills, and capacities of staff, and introducing Ministry-wide systems to improve performance. Ideally such a unit would become a centre of technical excellence, but that is not possible for the time being.

8.1 Hydrology and Meteorology

Best practice in flood forecasting makes use of both meteorology and hydrology services. Both provide data and information that needs to be combined to produce predictions, forecasts, and warnings about the likelihood of flooding and its actual occurrence.

Therefore, a flood forecasting function needs to combine meteorology and hydrology. Presently, these functions are undertaken separately within MOWRAM and, to the knowledge of the consultants, there is no combined use of near real-time information to input to models that rely on both precipitation and water level information.

8.2 Organisational Models for Flood Forecasting

There is no 'best practice' institutional model for organising how hydrology and meteorology should be configured or located within government ministries or agencies, or in academic institutions and other independent organisations. For instance, in Australia, hydrology and meteorology were undertaken at two different levels of government, but were amalgamated at the national level until

recently. In some countries, hydrology and meteorology are placed in the same organisation. In other countries they are in different ministries.

There are a range of functions related to meteorology and hydrology. For example, the function of on-ground observation and measurement may be undertaken by regional organisations while modelling and interpretation, analysis and risk assessment may be done by centralised organisations.

While climate and weather observation and forecasting are devoted to 'normal' weather conditions, as well as flood and drought conditions, hydrologic data is also used for a range of purposes quite such as design of water works, irrigation, hydro-power, water supply and to estimate environmental water needs.

In fact, hydrology is usually associated with the dominant water use in a country, which is most commonly irrigation. It may then progress from being used chiefly in the design of projects to being used for water management. In countries where flooding is important, hydrology is usually associated with responsibility for flood warning. For such reasons, hydrological services are often housed separately from meteorology.

8.3 Flood Forecasting Centres Internationally

There are several examples of flood forecasting centres worldwide. Examples are the United Kingdom, flood warning and forecasting centres under the International Commission for the Protection of the Rhine (mainly located in Germany) and in Bangladesh (under the Bangladesh Water Development Board). However, it is more common for flood forecasting to be part of disaster management agencies or meteorological agencies.

Flood forecasting requires information about water level and movement as well as precipitation. In some countries (as in Australia recently) hydrologic data is transmitted to the meteorological agency and therefore available to weather forecasters who issue the initial food warnings.

Because hydrology and meteorology are both contributors to flood forecasts, the flood forecasting agency usually includes an element of both fields. However, in Cambodia the Department of Hydrology and River Works is the responsible department. This results from its connection with the MRC and the RFMMC, which have developed forecasting based on Mekong River flood levels.

A brief overview of the hydrometeorological service of Vietnam is given here because firstly it has a related organisational system (though not identical) and secondly it is close to Cambodia and produces meteorological information that is useful to this country.

The organisational setup for hydrology and meteorology in Vietnam is complex. The Government of Vietnam has established a National Centre for Hydro-Meteorological Forecasting (NCHMF). It comes under the umbrella of the Ministry of Natural Resources and Environment (MONRE). Its mandate is to:

> *"to protect man and society from the vagaries of weather, climate and water induced disasters and provide for ways the country can use weather, climate and hydrological information in pursuing sustainable economic development, through the timely provision and issuance of timely, accurate and reliable information"*

Note that its hydrology mandate extends to evaluation of economic projects that use water. It has regional hydro-meteorological centres throughout the country. Vietnam also has an Institute of Meteorology, Hydrology and Environment (IMHEN) that is responsible for research and development in hydrology and meteorology but also oceanography and the environment. It also issues crop yield forecasts. IMHEN is also under MONRE, not within an academic institution.

The National Hydro-Meteorological Service (NHMS) of Vietnam was established in 1976. It became NHCMF when it was incorporated into MONRE in 2003. MONRE has a Department of Hydrology, Meteorology and Climate Change (DHMCC) which is a policy making body that plans projects, strategies and programs for these activities. Vietnam is subject to frequent and severe flooding in all regions and therefore has paid attention to establishing a reliable hydro-met network.

8.4 Issues for a National Flood Forecasting Centre

Following on from MRC approach to flood warning systems, it has been assumed that the NFFC will be hydrology-based. For flood forecasting to be improved under this model, the NFFC would need to be located within MOWRAM and its core activity would be the same as the formal functions of the Office of Research and Flood Forecasting (ORFF) in DHRW. This office is the flood forecasting unit of MOWRAM and there is an existing communication system for publishing flood forecasts and warnings originating in this office.

A 'fully-fledged' NFFC should take on other activities and upgrade its modelling and forecasting capacity. Some meteorological data interpretation would have a bearing on an NFFC's forecasting ability, but this ought to be undertaken within DOM and made available to NFFC. There is a need to strengthen DOM in this area as well as to create data exchange links.

With respect to the question of flash flooding, the proposed Flash Flood Guidance System (FFGS) technology involves the interpretation of satellite weather data (primarily precipitation) provided by the National Atmospheric and Oceanic Administration (NOAA) of the United States. As a result, this activity should be undertaken by DOM. So far, training has been given to staff of DOM and also ORFF in DHRW.

9 Organisational Options

The organisational options for the flood forecasting centre range from a completely independent agency to the reconfiguration of an ORFF in DHRW and coordination with DOM. The minimal option is preferred by the Ministry and this is probably the most realistic. It will only work well if effective data interchanges between DHRW and DOM can be put into practice. This section discusses the functions of such a flood forecasting centre.

9.1 Introduction

In this section a number of potential organisational options are discussed. In the next section, the preferred option is described in more detail and explained.

Two important factors affect the organisational design of a flood forecasting centre. They are:

6. How 'independent' the centre needs to be for best outcomes
7. Whether the centre should include both meteorology and hydrology in the same organisation

The discussion in Section 10 - Proposed Scope of a Flood Forecasting Centre, explains the proposed model and the rationale for each proposed organizational model.

9.2 Independence of Forecasting Centre

As to the level of independence, the question is how readily can the Centre collect incoming real-time data, generate forecasts, and issue forecasts and warnings. Can this be done effectively from within a unit that is relatively low in the hierarchy or are there delays that result from the Centre's warnings having to go through higher channels?

A secondary question is whether a higher status for the centre would help it to obtain information or to promulgate it more effectively.

On both of these questions, the consultants concluded that a higher level in the organisation might give the Centre more profile, but that receipt of data and issue of flood information did not seem to be unduly hampered in the current setup, where hydrologic flood forecasting is done within DHRW.

The lines of communication have to go through the Minister and NCDM, but there are other lines of information to provincial offices and provincial authorities and other local governments.

9.3 Flood Forecasting Centre – National or Not?

Although the project was based on the expectation that there would be an entity known as the 'National' Flood Forecasting Centre, Ministry officials expressed the view that they prefer it to be known simply as the Flood Forecasting Centre, (FFC) without the 'national' label. This is because the label of National has connotations with respect to position and reporting relations within the Royal Government of Cambodia.

9.4 Meteorology and Hydrology

As discussed earlier, MOWRAM provides meteorological services through DOM and hydrological services through DHRW.

The two departments operate separately. They have access to each other's forecasts through their respective web pages but do not take advantage of forecast, incoming data, interpretation of these forecast, or modelled outputs to improve their own models and forecasting.

Flood forecasting requires information from both sources. River levels and discharges need to be known, along with actual and predicted precipitation, and ideally these are accompanied by catchment conditions (level of saturation in particular).

There is no ideal organisational break-down for flood forecasting. The two fields of meteorology and hydrology are required for purposes other than flood forecasting and drought prediction, although these are very important. Hydrologic analysis can be used for the design of roads, bridges, irrigation supply schemes, canals, protection works, dams and weirs, hydro-power stations and drainage works. As part of hydrologic analysis, probably maximum flood (PMF) discharges and levels may be modelled and calculated. However, PMF is based on probable maximum precipitation or climatic event (such as cyclone), and therefore must incorporate both sources of information.

The point is that a flood centre, even if based chiefly on hydrology cannot take over the whole of that function. The consultants did not investigate hydrology being undertaken beyond flood forecasting, but it was clear that most of the hydrology undertaken at the provincial level (such as it is) is for irrigation and related purposes.

Similarly, meteorology must cover early warning for flooding, but also other features, such as routine weather forecasts and updating climate change predictions need to establishing building codes and for climate related development purposes.

The question is whether it is important to offer meteorological services together with hydrological services or not.

Meteorology and hydrology are not normally located within a single organisation, although sometimes they are. The key is to coordinate professional activity and information between field data collection (weather observation and streamflow recording) meteorology and hydrology. Coordination is where improvement is possible within MOWRAM.

Therefore, we conclude that it is not necessary to take meteorological and hydrological functions from the existing departments to create a new Centre.

9.5 Change to Responsibilities of MOWRAM

There has been mention of efforts to reconfigure MOWRAM along lines similar to those of the Peoples Republic of China and other countries such as Vietnam, where the Ministry of Water Resources has a management and regulatory role and where irrigation is placed within an Agriculture Ministry. A question is whether such a change, if made, would affect the way in which the NFFC should be organised.

The consultants concluded that such changes to MOWRAM, for instance creating a Ministry of Natural Resources and Environment such as exists in China, Vietnam, and Lao PDR, would not affect the organisational structure or location of a Flood Forecasting Centre. The reason for this conclusion is because meteorology and hydrology would both continue to be part of the same Ministry and both would come under a technical division.

It is further suggested that if meteorology should ever be separated at an organisational level from water resources management, that includes hydrology, the communication problems between meteorology and hydrology would become greater than now.

9.6 Consultation

During the investigation the consultants held two meetings with the CPMU and other senior officials to discuss organisational options for the flood forecasting centre. At the first meeting (February 2017), the range of options described above was presented at the meeting. The outcome of the meetings, and later discussions, was that MOWRAM prefers the least independent model, where the forecasting centre is an office in DHRW.

A second meeting was held in July 2017, where the DHRW option was discussed further and the Ministry position confirmed. Therefore, the proposal presented in this report follows MOWRAM desired direction. There are believed to be good reasons why a more independent centre cannot realistically be established at this time.

9.7 Options Discussed with the MOWRAM

The Options discussed with MOWRAM were:

1. An independent organisation outside of MOWRAM
2. A flood forecasting centre as a department of MOWRAM. headed by a Director
3. A flood forecasting ‘centre’ within DHRW – at the level of Office

Option 1 was considered impractical, as the Government would have to create a new entity reporting to the Cabinet. An alternative would be to place it within or under the NCDM. However, that was considered impractical as the NCDM is a policy and communication entity, and is not technical in nature.

Option 2 would create a department separate from DOM and DHRW. The option may have the advantage of some autonomy but would duplicate technical work being undertaken in DHRW. Therefore, unless DHRW’s hydrology was radically reduced, an FFC as a separate department would duplicate work. In any case, it would fragment hydrology and perhaps meteorology within MOWRAM.

The same arguments apply to meteorology and DOM. There should be weather forecasting expertise within an FFC, if it is set up as a new department, but this would require staff to be taken from DOM.

An alternative to creating a new department would be to redesign DHRW as the centre. But that is not desirable because DHRW has functions that go well beyond flood forecasting and it would be an advance to put the whole of the department into a flood forecasting centre.

The Ministry is not in a position to establish a new department. It has enough difficult maintaining the staff for existing technical departments. Therefore, this option is not practical at present and was not supported by the CPMU meetings held to discuss the options.

Options 3 emerged as the most feasible option at the time of preparing this report. Option 3 is the least radical organisational option. It does not involve restructuring at a departmental level. However, it does involve restructuring the Office of Research and Flood Forecasting which is to become the Flood Forecasting Centre (FFC).

9.8 Preferred Option

Option 3 involves restructuring the Office of Research and Flood Forecasting within DHRW as the initial structure for a FFC. The restructuring will add some functions to the existing office and see the research unit dropped. The significance of this is minimal as the department is not undertaking research and has not done so for some time.

The proposal for restructuring is provided in Section 10 - Proposed Scope of a Flood Forecasting Centre. The proposal outlines a possible structure and staffing, with broad job descriptions and expected activities and outputs.

This option would help to advance the MOWRAM's flood forecasting role, provided that the following changes are also made, to link the work of DOM and DHRW:

- Communication on real-time flood information is established as a regular event between DOM and DHRW at the technical level
- A data exchange protocol is developed and applied to facilitate access to forecasts and model outputs between the two departments
- There is significant technology transfer from consultant modellers to staff of DHRW (FFC).

These three changes need to be made in order to enable flood simulation models to incorporate all available incoming data (meteorological and hydrological) and the for outputs to be made available to both departments.

Close cooperation between DOM and DHRW, at a technical level, needs to be established and significantly improved. Two-way communication is needed. Without these improvements in communication between DOM and DHRW, the effectiveness of the FFC will be constrained and the simulation models will lack important data.

The consultants do not consider it practical to place the FFC in DOM. The reasons are:

- Strong links currently exist between DHRW and RFMMC with respect to the Mekong and floodplain water level reporting and forecasting
- DHRW already has flood models based on water level/discharge data for the Mekong River and Tonle Sap
- Hydrology staff would have to be transferred from DHRW to DOM and this would be resisted because DHRW hydrological staff perform other functions

9.9 NFFC Functions and Scope

The scoping of the NFFC is based on current and projected activities, according to the expected outcomes of the Project. The consultants concluded that there were two functional areas where the ORFF was already operational, namely:

- Use of water level data with associated models to generate flood forecasts and warnings
- Dissemination of flood information, including warnings

Based on the proposed technical improvements and added activities, along with the need for an active forecasting unit, the consultants identified the following functional areas that could form the basis for a future NFFC:

- policy and strategy
- flood forecasting
- flood mapping
- flood risk hazard identification
- flash flood warning (as distinct from river flooding)
- community information and education

The rationale for these functional areas is present in the following sub-sections.

9.9.1 Policy and Strategy for Flood Forecasting and Warning

There needs to be an assigned responsibility for advising the Minister and the Government on the direction for flood forecasting and communication of flood information to the public. Although the NCDM is responsible for flood warnings through its provincial, district, and village branches, the sourcing of reliable flood information and the policy on data collection, data analysis, and forecast generation at the technical level needs to be undertaken actively. Policy and strategy should include both the hydrological and meteorological activity.

During discussions with MOWRAM officials, the consultants raised the idea of introducing a formal responsibility for advising the Minister on policy and strategy for flood forecasting and early warning. The response to this idea was generally positive.

The reason is to ensure that the Minister is able to receive prompt and professional advice on questions of policy that arise concerning the direction and effectiveness of flood forecasting in Cambodia. Flood forecasting and early warning is considered to be an important function of MOWRAM and is of interest to the performance of the Government.

Although it would be the NFFC that should investigate any question that involves professional knowledge and judgement, the Centre, as presently proposed, is not at a high enough level to be an effective advisory body by itself. Matters of policy and strategy need to be discussed at the highest levels in the Ministry and with the Minister.

Therefore, ideally, a senior official would be given formal responsibility for bringing advice on forecasting policy and strategy to the Minister. That advice should include matters connected with the practice of meteorology and hydrology within the Ministry and the organisation and communication aspects of those professions.

9.9.2 Flood Forecasting

Obviously, this is the core function of the NFFC. It is already undertaken by ORFF, but will be enhanced with the introduction of new technology. The challenge is to bring the capacity of the staff of ORFF up to the level required to make use of the technology.

9.9.3 Flood and Drought Risk Mapping

Flood maps identify the return period for flooding according to geographical location. Return periods are generated by identifying the extent of historic floodwaters, to produce a statistical mean. Reliable maps rely on data from earlier flood events, along with data on flood levels and extent and long-range climate trend predictions and weather forecasts.

Flood risk and drought hazard is an assessment of the likelihood of flood or drought occurring in a location, combined with the likely consequences. It adds factors such as likely economic, social and environmental damage and threat.

Flood hazard can increase over time with changes in settlement, for instance. It requires models and mapping technology that applies population, economic production and social threat to the assessment of floods occurring.

A limitation discovered by the project is the coarseness of topographic information. Contours one meter apart are not adequate for modelling flood behaviour in extended floodplain areas, where the topography is very even, but where very small changes in level can direct flood waters in one direction or another. Similarly, the configuration and location of development, settlement and transport lines can change the routing of flood waters in such terrain.

To improve the topographic base model, technology such as LIDAR is too costly to use on the broad scale. Drone-based surveying software is now available at much lower cost, though it can scan much smaller areas at any one time.

Flood mapping is to provide flood return maps, which identify the relative risk of flooding on a geographical basis. More information is required than what is available at present to develop more specific flood maps. Currently the mapping function derives its flood information from the hydrologic data generated by DHRW and MRC.

Flood risk mapping and flood hazard identification was originally included as a functional area but later downgraded to a program area. The reasoning for this is that mapping and identification of flood risk and hazard is expected to be a finite program. As a program it can be incorporated under the mapping function. Nonetheless, as a program it could extend for some years (perhaps intermittently), given the need for improved terrain data (DEM) and analysis of historical information on the extent of past flood events.

9.9.4 Flash Flood Warning

It is intended that new technology be introduced for flash flood warning. The flash Flood Guidance System (FFGS) using weather data from NOAA satellites can provide forecast information on the probability of severe weather events at a local scale. However, for this information to be useful, knowledge of local hydrological conditions must be considered to predict the potential for flash flooding. The process and procedures are distinct from those used to forecast flooding in the large river systems.

Flash flood warning also requires shorter-term monitoring, action and reaction than other flooding. It involves maintaining close watch on the progress of flood waters, receiving rapid updates and

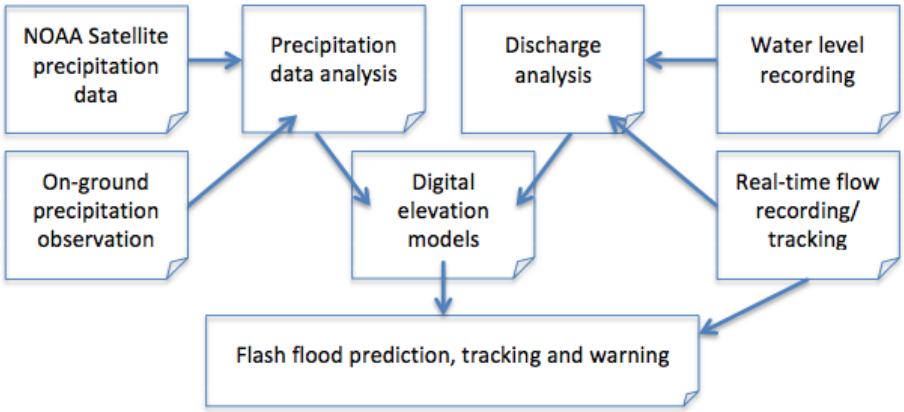
responding promptly round the clock. Therefore, a flash flood unit would need to operate at all hours during critical periods.

Similar a rapid response flood watch could be required where dams are critically affected by flood discharges.

Forecasting and warnings for flash floods would be improved where on-ground flow or water level monitoring is available, in order that flood flows can be tracked in real time (or near real-time). Both precipitation observation (DOM) and water level observations (DHRW) are required.

The components for flash flood risk assessment and warning are shown in Figure 3.

Figure 3: Components for flash flood risk assessment and warning



Flash flooding is seen as a function where it is necessary to develop a clear protocol that defines the respective responsibilities of DHRW and DOM.

From Figure 3 it is apparent that the precipitation data and analysis are functions of DOM as is real-time observation of rainfall in flood affected areas or areas where flash flooding is highly likely.

There should be an immediate information link between incoming precipitation data and on-ground water level and flow information. These are both required in order to provide location-specific warnings and updates rather than general, regional warnings.

While it is DOM responsibility to issue warnings about severe weather and heavy rainfall events, it is suggested that it is the NFFC's responsibility to develop the warnings related to flows and water levels. However, as noted elsewhere, specific flood forecasting of this nature will depend on elevation models and streamflow modelling to provide reasonably accurate predictions of flood discharge and flood levels.

9.9.5 Communication, Information and Education

There is already a communication line from DHRW to PDWRAMs, to the Minister, and subsequently to the NCDM and NCDM's provincial and district committees. However, it is important that a NFFC unit be developed to provide specific warning information that includes the actions that should be taken, such as where people should relocate to for safety from floodwaters. As well, educational material on flood preparedness and flood warning response needs to be developed and disseminated. This can also be developed and distributed by the NCDM, but the NFFC should have a key role in developing specific information about flood risk and flood preparedness.

Table 11: Desirable Outcomes of an Effective NFFC

	Function	Outcome
1	**Policy and strategy advice**	A clear focal point for advice that is technically sound, to be delivered to the minister and government on flood forecasting and warning
		Plans to coordinate and improve functioning of relevant departments within MOWRAM
		Flood information issues identified in advance and planned for
2	**Flood forecasting and warning (river and lake flooding)**	Forecasting information significantly more accurate based on three dimensional models and timely meteorological and hydrological inputs
3	**Flood mapping**	Flood maps identifying flood return periods in all locations produced to guide local authorities and communities
4	**Flood risk and flood hazard identification**	Identification of flood return periods and the risk of flood damage in economic terms, using GIS and hydrologic data
		Maps identifying the extent of flooding at nominated flood heights
5	**Flash flood warning**	Use of weather satellite information combined with models for terrain, allow warnings of likely flooding at prek and village scale
		Flood warnings issued immediately data becomes available
		Flash floods tracked in real time and information given to affected people
6	**Communication and dissemination**	Clear standard operating procedures (SOP) to define flood risk and severity
		Lines of communication that reach affected communities rapidly with adequate warning time
		Educational information transmitted throughout Cambodia to help communities prepare for flood and know how to respond to flood forecasts and warnings

9.10 Flood Forecasting Functions of the FCC

After the second discussion meeting it was agreed that two functions, which were identified in the initial scoping for the NFFC, would not be included in the organisation proposal that involves restructuring of the Office of Research and Flood Forecasting within DHRW.

They are:

- Policy and strategy advice
- Flash flood warning

9.10.1 Policy and Strategy Advice

In February there was apparent support for identifying the responsibility for advising the Minister on flood policy and strategy. But, the FCC would not be at a high enough level (headed by a departmental Deputy-Director) to engage directly with the Minister, other senior officials, and agencies in this sphere.

Therefore, the consultants recommended that a senior official be given formal responsibility for providing advice on policy and strategy to the Ministry. That official might draw on the FFC for information and opinion in formulating advice, but the FFC will not be formally responsible for high-level strategy or policy.

It is important to note that the policy and strategy role should be broad enough to include advice on the data and information related to weather observation and streamflow as these are critical inputs to the forecasting function.

9.10.2 Flash Flood Warning

Responsibility for early warning on the likelihood of flash flooding should remain with the Department of Meteorology. Flash flooding is chiefly driven by intense or extended precipitation events, although the addition of information about water levels and discharges would help DOM refine its evaluation of the flash flood hazard and associated risk. Therefore, the FFC will not have a primary responsibility for issuing flash flood warnings.

Under the NFFC proposal, staff are identified with responsibilities related to flash flooding. These staff are to identify water level stations which will have a function prior to or during a flash flood event, and to developed the information and communication systems to ensure that real-time data is analysed effectively to produce estimates of discharge in locations with a high risk of flooding. These data and analysis outputs would be transmitted promptly to DOM to be considered with incoming weather data.

River flooding has been and is mainly a hydrologic function, largely relying on information about river levels and understanding where the flood impact will occur. Such flooding is normally gradual and predictable, based on knowledge of topography and the extent of previous floods in connection with river flood levels.

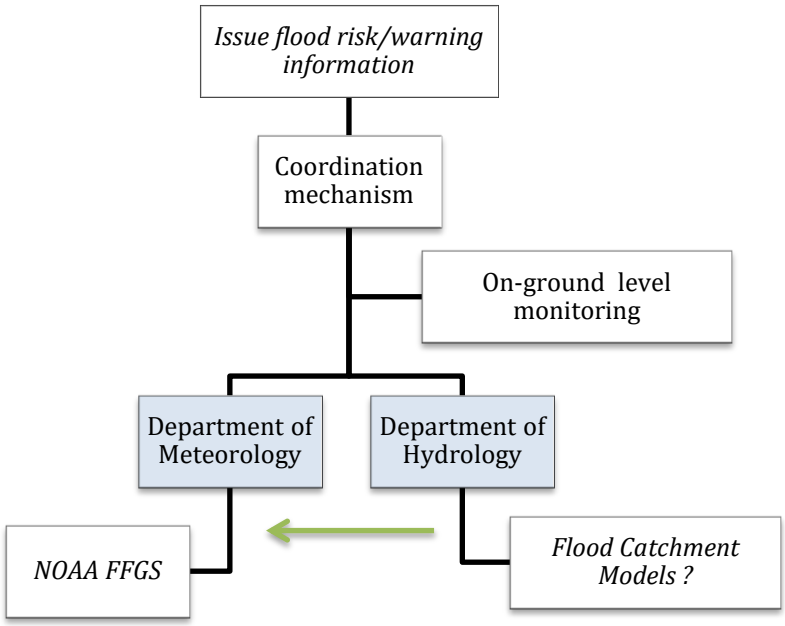
Other flooding is precipitation based or results from (intense) precipitation into circumstances where river flooding is about to occur or is already occurring. The inputs to understanding the flood risk here are based on forecasts of precipitation in connection with ground saturation or already flooded condition.

For instance, flooding in Phnom Penh in 2011 was not caused only by the normal rise in the level of the Mekong River, along with rise in level of the Bassac and Tone Sap rivers. Intense rainfall also was a contributing factor.

The reason for this brief description is to explain why the coordination of river level and precipitation data are important for creating forecasts of localised floods that result from rainfall events, or that are increased by such rain events.

As a consequence, both hydrology and meteorology must work together in real time (or as close to real-time as possible) to predict (i) the likelihood of flooding, (ii) the likely duration of an impending or actual flood, (iii) other flood event characteristics such as the rate of fall of flood levels, flood velocity, discharge, direction, and depth. Figure 4 illustrates the need for coordination.

Figure 4: Coordination for flash flood risk and warning



10 Proposed Scope of a Flood Forecasting Centre

The Flood Forecasting Centre proposals identifies the function and programs that a full-fledged flood forecasting centre could undertake. Some existing activity will require upgrading but other activities need to be introduced, such as flood mapping and risk identification. Flash flooding is a major concern, and that function needs to be improved, mainly through DOM. The Centre proposal can be used as a starting point to implement the flood forecasting function in an improved state.

10.1 Scope of Flood Forecasting Centre

The Ministry asked the consultants to 'paint a picture' of a full-fledged flood forecasting centre that could be established in Cambodia. Accordingly, this section outlines the features of such a centre while recognising that the full scope of the Centre cannot be established at this time.

10.1.1 Functions and Capability

A comprehensive flood forecasting centre would have the following major areas of activity:

- Meteorology, including advanced use and interpretation of global and regional weather data, climate data and trending, and identification of flash flood hotspots, with the ability to make reasonable risk assessments of flash flood danger down to sub-catchment level
- Hydrology using 3D models owned by the centre to track and predict streamflow, discharge and likely flood heights
- The use of historic data and flood maps to identify the spatial extent of current and likely floodwaters and to understand the flood dynamics

- Integrated use of weather and flood models to assess the likely impact of precipitation, evaporation and other climatic factors on flood levels
- Real-time operational data for both weather and streamflow models for early warning, flood forecasting, and drought prediction
- Integrated networks of AWLs in significant sub-basins and AWSs throughout Cambodia, with immediate data links to the forecast centre
- A data unit which undertakes operational receipt of data and input these data to predictive models, and also archives, or has access to, historical data on streamflow and precipitation/climate events
- A communication unit which distributes the outputs of hydrological and meteorological analysis/data interpretation directly to national, provincial agencies and authorities and communicates with government officials responsible for flood and drought response at province and district levels
- The communication unit should also become a centre of information dissemination during serious flood events and be linked to all incoming data sources from affected localities

In addition, it would have a policy and strategy advisory role with staff assigned to this function to promote the development of technology, including streamflow and weather stations, and would be expected to advise the government on strategies to minimise the impacts of flooding. The centre should be involved in developing guidelines for development planning and infrastructure design in locations subject to flood risk.

The proposed centre would follow the outline present in Section 9.9.

10.2 Hydrology in the Ministry

A forecasting agency as an autonomous agency under the relevant minister would have an independent head who communicates directly with the ministerial level and related line Ministries

While meteorology is undertaken almost exclusively to inform about weather, forecasts and climate trends, hydrology has several purposes, importantly as the basis for designing water works of all kinds and designing structure which require the passage of water (roads, bridges, culverts, and the like).

The government's capacity in hydrology, therefore, should not be limited to a flood forecasting and should consider including responsibility for design of works, in particular irrigation schemes and drainage works. A future looking strategy needs to be developed on how professional hydrologic analysis will be performed. This is a discussion outside the question of flood forecasting, but some brief points are made here for consideration.

The reasons for having hydrology in the Ministry needs to be clarified and its role specified. That is whether:

- the Ministry should undertake hydrologic analysis itself or expect the private sector to do this or some of this work, and where the Ministry does hydrology, it must determine the scope of the hydrology it will do with respect to types of schemes, projects and works
- the Ministry should exercise a regulatory function, to ensure that hydrologic studies for public and private projects are technically sound
- the Ministry should specify guidelines and/or regulations for hydrologic criteria to be followed in project design, for instance the discharge capacity of works that cut across drainage lines

These decisions also must consider what should be the balance between government hydrological work and that of the private sector. What is the 'common good' role of the Ministry versus private interest in developing works and structures for individual and private companies.

The answers to these questions will determine the scope and extent of hydrological services in autonomous agency, apart from flood-related analysis and information.

10.3 Relation of the Forecast Centre to other Agencies

In the long term, a flood forecasting centre could be an autonomous agency coming under the umbrella of MOWRAM. For operational functions, including developing flood forecasts, drought predictions, and following extreme weather events, the Centre should be directly connected to national agencies such as NCDM, and to provincial centres and offices of the Ministry.

On matters of strategy and policy, long-term financing, and program development, the Centre actions would be subject to the approval of the Minister.

On questions of issuing early warnings the Centre should be capable of issuing warnings directly, as well as to NCDM. This would obviously be subject to the defined responsibility of the Minister with respect to making announcements with the authority of the Government.

10.4 Structure and Functions

10.4.1 Proposed Divisions

Figure 5 shows an FFC with three units/offices, (i) Administration and Communication, (ii) Flood Forecasting and (iii) Mapping and Knowledge Management. The total staff, when fully developed would be four [4] managers (head of Centre and three office heads), and 18 staff, totalling 22 personnel. The unit with the largest staff complement would be flood forecasting. Administration staff are assumed to total two.

The consultants arrived at the proposal structure shown in Figure 5 through discussions with the CPMU and DHRW. Note that flood and drought risk mapping and flood hazard identification have been incorporated into the Flood and Drought Mapping Unit. Information technology and knowledge base functions have been added. The structure of the FFC proposal is briefly described below.

10.4.2 Administration and Communication

This office would be responsible for the administrative as well as the communication and education function. Communication and Education Unit would have the following responsibilities:

- To draft and disseminate flood forecasts and flood warnings
- To communicate with agencies and provincial/district offices of MOWRAM and NCDM in order to verify the receipt of information and to provide explanatory background where needed
- To develop educational and awareness material for flood response and to modify that material for specific flood situations, such as flash flooding

The office would have one senior official and three staff.

Administration is included on the assumption that one of the staff would cover this responsibility. It is recognised that the number of administrative staff at the departmental level is usually much more numerous.

10.4.3 Flood Forecasting

This office has two forecasting units: (i) flood forecasting and (ii) flash flood information. This distinction is based on the earlier view that flash flood risk assessment and warning has distinct characteristics and would require the participation of staff who have different skills and tools then

those doing flood forecasting for the larger systems. Flash flood identification also uses different technology, relying to a greater degree on meteorological data.

Two staff are assigned to the Flash Flood Information unit. However, at critical times, there could be a need to co-opt additional staff, to cover round-the-clock emergencies. This unit should have one member of staff with a meteorological background, capable of interpreting satellite weather data and assessing the impacts of intensive precipitation.

The Flash Flood Information Unit would not issue early warnings or predictions of flash flooding. Its role is to provide discharge and water level data and possibly catchment saturation data for locations where flash flooding is possible. That data would be transmitted in real time to DOM, which has the precipitation data and models. FFC would also analyse data after flood events to provide improved assessment of flash flood threats.

The Flood Forecasting unit would be responsible for flood forecasting as is presently undertaken by ORFF. It will require six staff, a supervisor and five hydrologists and flood modellers. The upgrading of flood models would also require an upgrading of current skills. Therefore, although this function is already in operation in DHRW, it would require considerable human resources development to become operational at the required level.

10.4.4 Mapping and Knowledge Base

This office will have two units, (i) Flood and Drought Mapping and (ii) Information Technology and Knowledge Base.

The Flood and Drought Mapping unit would be responsible for:

- developing flood return maps
- geographical identification of flood risk, for planning purposes to avoid unnecessary development and settlement in highly flood prone areas
- mapping predicted drought risk, based on historic data

Flood risk and flood hazard mapping would be undertaken by this unit. In theory, a nationwide program would be completed and updated on a regular frequency.

The information and data for mapping flood and drought prediction are located in the hydrologic, climate, and weather data archives and digital terrain models. The skills required in this unit are primarily GIS-based. Three staff are assigned to this unit, a mapping expert and two assistants.

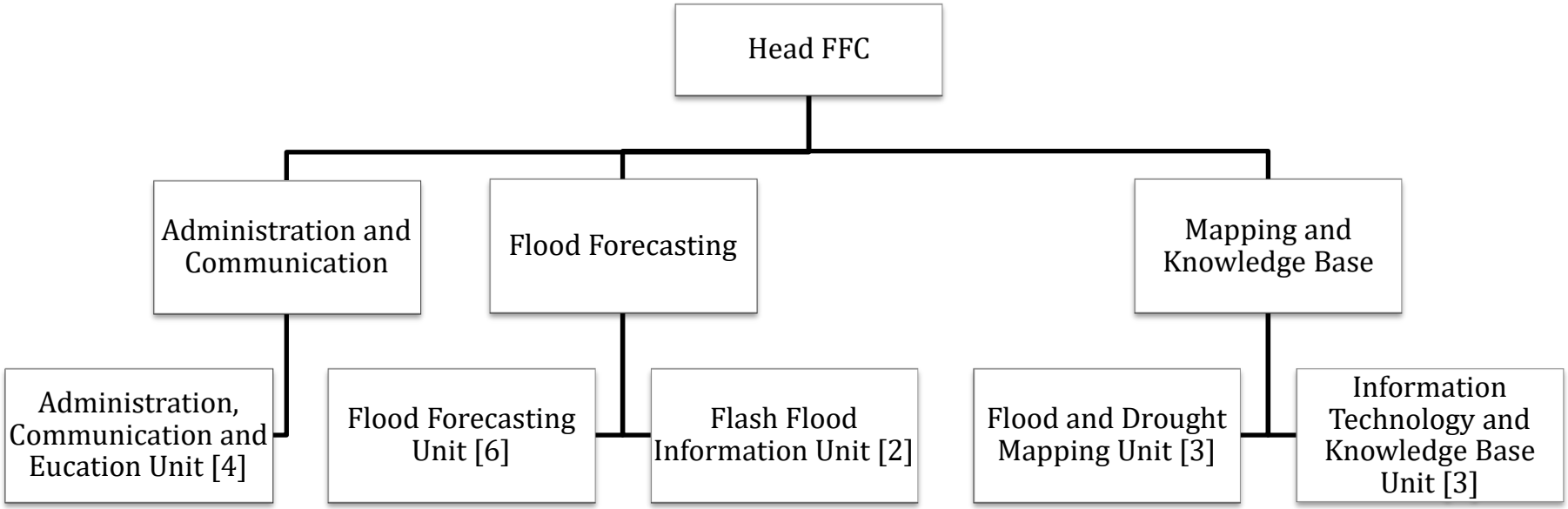
The Information Technology and Knowledge Base unit would be responsible for:

- providing IT support for the whole of the NFFC (computing and associated linkages)
- developing and maintaining data bases (hydrologic and associated flood data)
- maintaining effective electronic links to related databases, archive data, and real-time data, in particular meteorological data

Three staff are assigned to this unit, one senior database official, one IT generalist, and one database assistant.

This outline is a starting point for developing an FFC within MOWRAM.

Figure 5: Structure Option for Fully-Developed FFC with Staffing Numbers



11 Barriers and Challenges

The key barrier to immediate improvement is with the staff of MOWRAM. The qualifications, experience, practice, and motivation of junior staff is problematic and more senior staff who have knowledge and competencies suited to meteorology and hydrology are facing retirement in the next ten years. Some aspects of staffing are also closely linked to working conditions and management within the Ministry.

11.1 Introduction

The primary barrier to developing an effective FFC is staff capacity. Advanced hardware and software can be easily supplied by donors, however skilled staff cannot. The human resource deficiencies lie in several areas:

- Lack of formal qualifications in hydrology and recruitment of staff without either engineering of science qualifications into hydrology positions
- General lack of further development due to (i) basic models being used, (ii) inadequacy for development of short courses given to staff, (iii) scarcity of senior staff to teach junior staff
- Culture where some staff are absent from the office, engaged in external pursuits

Recruitment does not involve the input of the directors of the technical departments. There is also a lack of interest among the tertiary student population in technical areas such as meteorology and hydrology, evidenced by the difficulty that tertiary institutions have in maintaining courses in these subjects.

Addressing the human and staff development question is therefore key to obtaining professional staff to effectively operate the upgraded the flood forecasting function. Building human resource capacity needs to involve DHRW and DOM as well as be considered a long-term objective at the Ministry level.

11.2 MOWRAM Staff Capacity

The capacity of MOWRAM in meteorology and hydrology is low, as discussed in Section 7. The consultant concluded that the MOWRAM is not able to recruit suitable professionals to staff a flood foresting centre at this time. By suitable, the consultants mean (i) adequately and appropriately qualified at the tertiary level, (ii) having enough experience and ability to use analytical hydrological tools. For this reason alone, a full-fledge flood forecasting centre is unrealistic at this time.

To summarise the human resources barrier, there is a gradual drain of professional capacity in meteorology and hydrology, as senior, qualified staff approach retirement. Meanwhile junior and middle level staff lack the same level of qualifications and ability. Some lack even basic competency in mathematical analysis because they have been inappropriately recruited.

Senior officials in MOWRAM have said they understand the problem and have discussed it many times, but see it as intractable because:

- At present there is a lack of interest among university students to study sciences, engineering and mathematics
- Ministry recruitment procedures have not always selected the most appropriate staff for professional positions

The consultants believe that MOWRAM faces a reduction in capacity in these technical and professional fields over the next ten years unless ways can be found to attract and develop suitable staff. In other words, things will get worse before they improve, because all possible solutions are long-term.

11.3 Technological Change

The Project is attempting to introduce more advanced models and digital tools for flood forecasting, mapping, and drought prediction, with the following characteristics:

- models that combine data inputs from meteorological and hydrologic sources (water flow and precipitation)
- meteorological analysis of the observed data
- location-specific predictive tools to indicate severity, duration, location or precipitation events and extent, depth, velocity of flood waters;
- three-dimensional flood modelling that makes use of digital elevation models (DEM) to provide predictive flood tools hazard identification for select return periods
- dynamic models and early warning systems with frequent and regular updating using near real-time water level, discharge, and weather data.

To date, the flood models being used by MOWRAM (DHRW) are simple one-dimensional or regression based tools. These require less understanding of the hydrologic system and are less demanding with respect to the interpretive skills required to analyse hydrologic and other data.

This is a key institutional issue for flood forecasting, early warning and drought prediction as new technology will be only useful if the organisation and human capacity are available to effectively use the new tools and technologies.

11.4 Factors Affecting Technical Staff Performance

There are several factors combining to negatively affect technical staff performance. The consultants cannot provide potential solutions with confidence. The problems are reportedly well known and being discussed within MOWRAM. Solutions have not been found internally, so far.

There are a few measures that, in theory, could help MOWRAM, but the greater problems are external generational culture, internal management, and internal culture affecting junior to middle-level staff.

The external 'culture' barrier in Cambodia is one where there is a very low level of interest among tertiary level students in subjects such as meteorology, hydrology and engineering. Subjects such as business, accounting, financial, and legal studies are competing with subjects that require science and mathematical ability. The present generation of tertiary-aged Cambodians, are interested in studying subjects that will help them to start successful businesses or make money. At present many government positions are simply not attractive to them.[4] This is a generational problem.

Another problem is the difficulty to attract professionally qualified people to take up positions in provincial centres. Phnom Penh is the attractive hub and provincial locations are seen as undesirable work locations by professional people. Although the flood forecasting centre is not directly affected by this problem, the supporting data functions suffer from a lack of newly qualified people. The reliable and comprehensive flow of weather observation and streamflow data are essential for analysis and modelling.

MOWRAM has missed opportunities to recruit larger numbers of graduates of the ADB Cambodian scholarship program who would have appropriate tertiary qualifications related to hydrology and meteorology. As a result, staff without suitable tertiary qualifications have been recruited to positions in meteorology and hydrology. There is doubt whether people without knowledge of meteorology and hydrology, and lacking mathematical and associated analytical ability can be trained to undertake complex modelling tasks or to understand the dynamics and behaviour of climate, weather, catchment conditions, and streamflow.

Other staff may be capable of improving their capacity to undertake modelling functions. However, this will require substantial training at the tertiary level and would most likely require staff to study outside of Cambodia. In which case, there is a danger they will decide to leave MOWRAM and seek more attractive work elsewhere.

The internal working and culture of MOWRAM is not supportive of effort outside normal working hours. Some staff are reportedly asking for transfers out of DHRW because they are required to spend long hours and weekends at the office during the flood season. If MOWRAM cannot institute shift work in these situations, this will continue to be a motivational problem. Shift work, of course, demands a larger number of staff.

As to management related barriers, there is a very hierarchical decision-making system in MOWRAM, where operational decisions are made at very high levels. This impedes the advancement of professional performance because it eliminates the capacity to grow and innovate, and to respond quickly to changes in the external environment.

The consultants have made some recommendations that may improve the recruitment and staffing situation, although other larger factors also need to change before real improvements will be realized.

[4] A colleague has informed the consultants that the same situation applies in Laos

All of these factors, taken together, lead to a demotivating scenario for technical professions in the MOWRAM. Reversal of this situation is a long-term process that is not easily accomplished.

11.5 Management Challenges

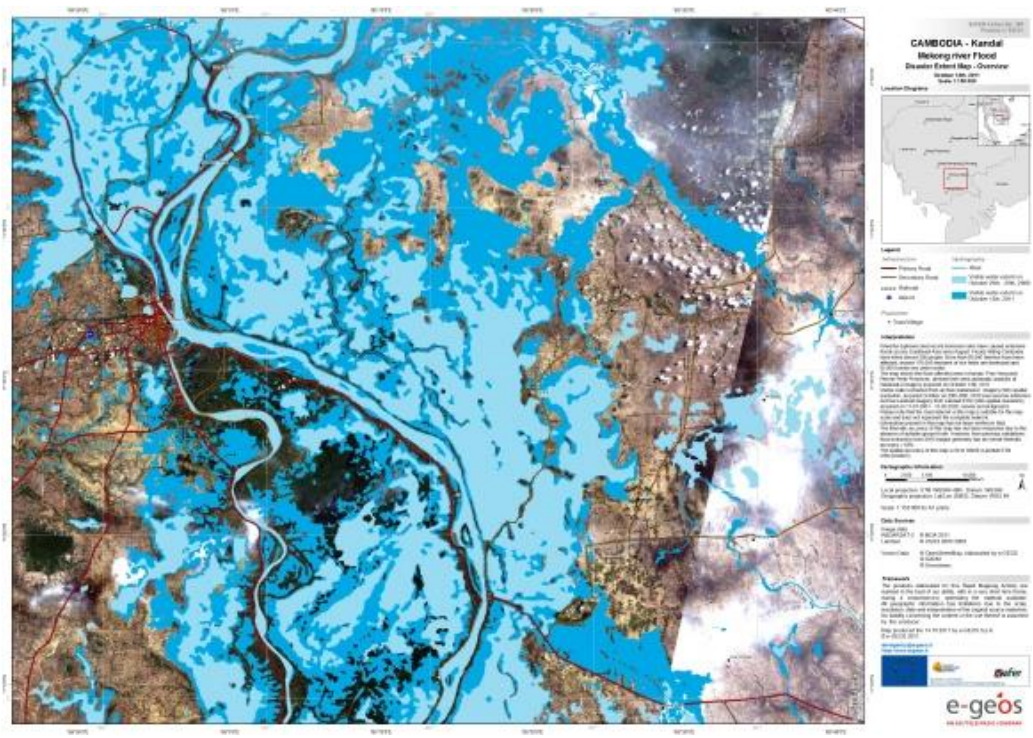
This topic was discussed under Section 7.4 and a summary is provided here for reference.

Managers in head office and in the provinces, face considerable challenges. Funding and resources are limited and ongoing maintenance, calibration of streamflow equipment, access to available data and baseline data for modelling are not at desirable standards. Attention to these aspects is required.

The capacity of managers within technical departments is believed to require strengthening. Management systems also require either improvement or consistent implementation. Even if technical staff qualifications and abilities are upgraded, weak supportive management systems may work against performance outcomes.

12 Data Questions

Immediacy of data access and exchange is critical for flood forecasting. Inter-agency data sharing is extremely limited in Cambodia. Furthermore, departments in MOWRAM are reluctant to exchange data and information. Data exchange does not occur between DHRW and DOM to any useful extent. The proposal to set up a 'global' data archive in MOWRAM, introduces the spectre of greater complexity and difficulty in data sharing.



12.1 Data Collection and Exchange

Information exchange refers to the regular and guaranteed exchange and open discussion of technical information. Whereas, data exchange refers to transmitting or allowing access to electronic data between departments or agencies.

It appears that AWL data for a number of hydrologic field stations are not delivered directly to DHRW, but is collected by another part of MOWRAM for a future data archive. For example, at the time of preparing this report, DHRW was not receiving data from the upgraded auto-upland stations. Accordingly, a data policy needs to be established that ensures all relevant data from stations installed by various donors and programs is consistently collected and stored, and that near real-time data are available to DHRW for flood tracking and forecasting.

12.2 The Global Data Archive in MOWRAM

There is discussion within MOWRAM of creating a 'global data archive' or central data management unit, for the management and archiving of data under a new department. The rationale seems to be

that collecting and storing all data in one place will ensure consistency and allow a comprehensive understanding of all the data and information under MOWRAM control.

The centralized data approach may hold for archived data, but is not desirable for the management of real-time data required for operational activities such as forecasting. The reason is that a central data management unit will cause delay in obtaining data for real-time analysis, if the central data management unit does not immediately transfer the required to the operational forecasting unit.

Even if the data is intended to become immediately available from the central data management unit to the forecasters, experience shows that inter-departmental communication and adding data transmission steps always causes delays in getting data to where it is needed in critical situations. This is a reality, not only for MOWRAM, but in virtually all cases. Even now, there are some AWL stations whose data is collected by staff not under DHRW and which is not readily available to DHRW. Therefore, the consultants warn that to divert AWL data and AWS data directly to a central data management unit who manage a global data archive will significantly limit meteorological and hydrological analysis in real-time. In doing so, it will weaken the ability of MOWRAM to prepare reliable forecasts and to generate early warnings for flood events.

Therefore, it is vital to keep open direct lines of data transmission between recording stations and DOM and DHRW (FCC). As mentioned before, real-time data must be directly available from data sources to the departments who use the data in operational models and for the generation of forecasts. For this reason, it is critical that no intermediary intervenes be placed between the generation of real-time weather and streamflow/level data (or near real-time data) and the forecasters. A well, it is important to recognized that data archiving needs are secondary to real-time information for flood tracking and forecasting.

12.3 Information and Data Exchange

Information exchange in the context of this report means regular briefings involving the two departments, to inform each other and the senior level or levels of shared activities. To give a practical example, during the flood season, a weekly joint briefing between DHRW and DOM would reveal such information such as (i) the Mekong River level and areas already flooded or about to be flooded, (ii) information gained from provincial staff about catchment dryness or wetness, (iii) short-term rainfall forecasts, expected intensity of precipitation for the following 3-7 days.

Real-time information is critical to improving the analysis of water level and precipitation impacts. The ultimate objective of hydrologic and meteorologic data observation, interpretation, and analysis is to understand the likely on-ground impact of what is happening, as well as the immediate and short-term impacts.

It appears that there is no frequent exchange of information between the two Departments, DHRW and DOM. As a historical background, DOM used to be separate and semi-autonomous before becoming a department under the Technical Division. In the period prior to joining the division, DOM did not freely provide information or data to other agencies. Some of this outlook may continue to influence DOM's orientation.

Information exchange means regular updates during the flood season, where the flood situation is discussed, along with updates on the latest weather and precipitation forecasts. In this way the effect of both weather and river flow can be compared and the likely flood impacts better understood.

Accordingly, information and data exchange between DHRW and DOM is one of the most critical improvements needed in regard to flood forecasting. Such exchanges would help both DOM and DHRW to generate more reliable forecasts and warnings.

The question of data and information exchange between DHRW and DOM, identified by the consultants, was raised by senior officials at the meeting of 26 July. There is acknowledgement that the exchange of information between the two departments is not as good as it could be and should be.

There is a historical reason for this. DOM was at one time relatively independent and located apart from the rest of MOWRAM. At the time it was brought into MOWRAM, the meteorological service had been self-sufficient and an independent organisation.

Flood forecasting and early warning would benefit from closer cooperation between the two departments. This should happen in two ways:

- Regular exchange of information about the current flood situation
- Access to and use of data and analyses generated by one department for enhancement of predictive capacity in the other department

It is not necessary that the departments merge in order to ensure the needed cooperation. It is common for agencies responsible for meteorology and hydrology to be separate. In some cases, they are merged into a single organisation but either model can work.

The important factor is ensuring that information and data are effectively exchanged. Therefore, it is recommended that the relevant Deputy Director (or Director) from DHRW and DOM meet, with the DD-GTS at least once a week during the flood season and more frequently if circumstances require, to discuss the latest information they have and what is proposed for the coming three-to-seven days.

12.4 Electronic Data Exchange

In addition to information exchange, involving the sharing and cooperating with respect to forecast related information, it is important to establish data exchange links for the transfer of hydrological and meteorological data between the two departments for the data required to support models and forecasting tools. No such exchange was occurring at the time of preparing this report.

The models being developed for DHRW require meteorological data the outputs of the models should be available to DOM, to support real-time interpretation of precipitation data and other weather parameters. Therefore, an effective data links need to be established.

Data exchange protocols are becoming more commonplace. They specify what data is to be shared, on what terms, for what purposes, and with whom. To date, data exchange has not been voluntarily agreed to, and a formal data exchange protocol will be required in the form of an order from the Minister

There should be no financial aspect to data exchange within MOWRAM. Data exchange should be two-way and with benefit realized by both sides. The issue of data exchange is regarded as one of the most important recommendations that needs to be action in the immediate term.

12.5 Recommendations:

12.5.1 Information Exchange between DHRW and DOM

- That regular meetings be set up at technical level, Director or Deputy Director, for the exchange of current and longer-term information and to foster cooperation between DOM and DHRW
- That the information exchange between DHRW and DOM consider river levels, areas flooding or flooded, precipitation, and other weather information relevant to flood and flood forecasting

- That an electronic links be established for information transfer between the two departments

12.5.2 Data Exchange Protocol

- That a data exchange protocol be established between DOM and DHRW, in the form of a formal order, that describes what data should be made available, for what purposes, under what conditions, how the data are to be used, and the mutual access conditions
- That the responsibilities of DOM and DHRW in relation to forecasting data be formally defined (in the protocol or in another way) and guide the implementation of data exchange
- That an electronic data links defined in the data exchange protocol be developed and made operational.
- That the ability to access data archives held by the two departments, under the conditions specified in the protocol, be considered

Given the potential for the establishment of the global data archive in MOWRAM, there should be a data protocol that specifies data access for all departments. The protocol should specify the responsibilities of the data archive manager, such as delivery or access in a timely manner. Flood-related data is critical to forecasting.

12.5.3 Data in General

- That an inventory be made of all AWL and AWS installations with complete meta-data for each site that have an operational value for forecasting flood and critical weather events
- That data for flood forecasting and early warning purposes which is collected in real-time from the inventoried stations be transmitted directly to DHRW (FCC) or DOM, depending on the nature of the data

13 Flood Centre Staffing

The qualifications for staff in key roles in the flood forecasting centre are specified. They may be used as the starting point for the restructuring of the existing office to create the elements of the flood forecasting centre.

13.1 Staff Qualifications and Responsibilities

The consultants have identified a number of key positions required to operationalize the FFC. Additional positions will be required to fully develop the FFC, however, the following five positions provide an initial capacity to perform the functions of the FFC, with support from junior staff. It may be that some of the positions can be filled by staff already available in DHRW. If so, these staff can be assigned to these new positions and recruitment initiated for the staffing of the remaining positions.

The following sub-section present the key FFC positions. Note that a meteorologist is included, with a view to including meteorological understanding in the flash flood sub-unit. Assuming that catchment/streamflow models are developed for the FFC, the meteorologist would assist in providing interpreted weather data for use by the models to generate discharge and flood predictions as well as support the needs of DOM to incorporate hydrologic information into its early warning system.

13.1.1 Leading Hydrologic Forecaster

The Leading Hydrologic Forecaster must have:

- Bachelor's degree in natural resources science with a specialization in hydrology or open channel flow; or the equivalent of five to ten years of experience with a technical diploma in earth or natural resources science

- Two years' experience in conducting hydrometric surveys
- Two years' experience in hydrologic/hydraulic modelling applications
- Basic understanding of meteorological observational techniques
- Ability to effectively communicate in both written and spoken form
- Demonstrated technical report writing skills and experience in presenting technical information in multi-disciplinary public forums and technical workshops
- Demonstrated ability to work in a technical team environment

13.1.2 Leading Meteorological Forecaster

The Leading Meteorological Forecaster must have:

- Bachelor's degree in applied science with a specialization in meteorology; or the equivalent of five to ten years of experience with a technical diploma in applied or natural resources science
- Two years' experience in operating manual or automatic meteorological stations
- Ability to effectively communicate in both written and spoken form.
- Demonstrated technical report writing skills and experience in presenting technical information in multi-disciplinary public forums and technical workshops
- Demonstrated ability to work in a technical team environment

13.1.3 Database and Data System Management Leader

The Database and Data System Management Leader must have:

- Bachelor's degree in computer science; or the equivalent of five to ten years of work experience with a technical diploma in electronics or information management including GIS or natural resources management.
- Experience in working with SQL database systems is an asset
- Experience working with hydrometeorological data management systems is an asset
- Ability to effectively communicate in both written and spoken form.
- Demonstrated technical report writing skills and experience in presenting technical information in multi-disciplinary public forums and technical workshops
- Demonstrated ability to work in a technical team environment

13.1.4 Client Products and Services Leader

The Client Products and Services Leader must have:

- Bachelor's degree in earth or natural resources science; or the equivalent of five to ten years of work experience with a technical diploma in information management including GIS or natural resources management
- Experience in conducting analysis of hydrometeorological data and the development of standard information products
- Experience in working with Web-based interfaces and portals is an asset
- Experience working with hydrometeorological data management systems is an asset
- Ability to effectively communicate in in both written and spoken form
- Demonstrated technical report writing skills and experience in presenting technical information in multi-disciplinary public forums and technical workshops

- Demonstrated ability to work in a technical team environment

13.1.5 Flood Risk and Hazard Mapping Leader

The Flood Risk and Hazard Mapping Leader must have:

- Bachelor's degree in earth or natural resources science; or the equivalent of five to ten years of work experience with a technical diploma in information management including GIS or natural resources management
- A demonstrated aptitude in understanding and working with GIS-based mapping technology
- Two or more years' experience in use of DEM and creating GIS-based maps
- An understanding of flood characteristics and behaviour, with sound knowledge of factors contributing to flood impact and risk
- Ability to effectively communicate in both written and spoken form
- Demonstrated technical report writing skills and experience in presenting technical information in technical workshops
- Demonstrated ability to work in a technical team environment

13.1.6 Hydrologist - Intermediate Modeller

The Hydrologist - Intermediate Modeller must have:

- Bachelor's degree in natural resources science with a specialization in hydrology or open channel flow; or the equivalent of five to ten years of experience with a technical diploma in earth or natural resources science.
- A demonstrated aptitude in understanding and working with hydrologic and hydrodynamic models
- Two or more years' experience in conducting modelling studies or supporting a senior modeller
- Ability to effectively communicate in both written and spoken form
- Demonstrated technical report writing skills and experience in presenting technical information in technical workshops
- Demonstrated ability to work in a technical team environment

The first five positions are key positions in the FFC, meaning that they would be in charge of sub-units.

14 Roadmap and Actions

The actions suggested attempt to lay out an immediate set of decision and action that will move towards the establishment of a more expert unit for flood forecasting within MOWRAM. Some longer-term actions are also set out. Both institutional and staffing decision have to be made. In particular, the data exchange protocol is considered important and should be implemented immediately.

14.1 Proposed Actions

14.1.1 Immediate actions

Based on the consultants' assessment and the discussions with MOWRAM, there are a number of actions that MOWRAM can take in immediately to move towards the establishment of the FFC. These are shown in Table 12. Some actions lie within the authority of the Technical Service General Directorate but other actions would require a Ministry-level approach to be taken.

Table 12: Immediate Actions

	Action	Comment
1	Initiate FFC within DHRW (Office of Research and Flood Forecasting to be reconfigured)	For MOWRAM to authorise and Deputy Director General of Technical Service to supervise; renaming ORFF initial step
2	Restructure ORFF as FFC	Adopt proposal reflecting FFC functions with proposed structure as guide
3	Identify and assign staff to key supervisory positions in FFC	Identify and approve positions in key positions (sub-unit heads) and further seek supporting staff with appropriate qualifications (as suggested)

	Action	Comment
4	Establish technical briefings on hydrology and meteorology during flood season and flood events	No need for TOR. Deputy-Directors of DOM and DHRW to confer on latest information available to each department and consider implications at least weekly or more frequently
5	Develop protocol on data and information exchange between DOM and DHRW/FFC and other units in MOWRAM with relevant data	Data exchange protocol should lead to actual data exchange from models and incoming weather and streamflow/level information and predictions
6	Create direct electronic data linkages between DOM and DHRW	Data access to be defined and governed by the protocol and established as a regular interchange of information
7	Set minimum technical qualifications for professional positions	Departments need to promote stated minimal tertiary background that includes skills related to hydrologic modelling and climate modelling
8	Involve technical department directors in recruiting professional and technical staff	MOWRAM needs to authorise change in procedure, in particular, positions of hydrologist, meteorologist and scientific instrumentation – minimum academic requirements
9	Make progressive staffing plan for FFC	Identify positions not able to be covered by current staff and develop proposals for upgrading or recruitment
10	Identify short-term staff development needs	Further input required
11	Provide on-job support for use of advanced flood models and mapping technology provided by ADB project	External (consultant support required to work with FFC staff to make models operational and generate forecast outputs
12	Operationalise FFC within DHRW	For MOWRAM to authorise and ADGTS to supervise; renaming ORFF initial step.
13	Start digital mapping of high priority flood-prone areas	

14.2 Discussion of Actions

A number of actions may be taken in the short term, to prepare and plan for the establishment of the FFC.

14.2.1 Initiate the FFC within DHRW

The proposed action is classified the Office of Research and Flood Forecasting as the FFC, and to modify its responsibilities in line with the functions of the FFC. The Office would then operate as the FFC and would be enhanced progressively to establish the full functioning of the Centre.

Although the name change alone would not advance the FFC significantly, it would identify the location of the Centre and hopefully focus attention on the Centre and provide a platform for developing the capacities required.

14.2.2 Identify Specific Staffing Requirements

Based on the projected activities of the FFC, the Project can identify the technical capacities required for the models and tools being developed. In addition, the Project can identify other technical capacity requirements.

Training in the models and tools will be provided by the Project, but longer-term development is likely required, given the level of knowledge of some staff at this time.

14.2.3 Involve Technical Department Heads in Recruitment Procedures

The exclusive involvement of the Human Resources Department (HRD) of MOWRAM in recruitment decisions has not been ideal. Staff without appropriate background have been recruited to positions requiring a level of expertise in mathematics, engineering or science. Department Directors should be allowed to reject unsuitable candidates, particularly those without basic levels of technical knowledge.

14.2.4 Set Minimum Tertiary Qualifications for New Staff

For the professional hydrologist and meteorologist positions there should be formally stated fields of tertiary study, which would be an essential requirement for recruitment. This could cause difficulty because of the lack of suitably qualified applicants. If that is the case, there should be a back-up strategy whereby applicants are required to undergo formal cadetships in required subjects at tertiary levels. The cadetships should apply to staff already recruited and their tenure should be conditional on passing the required subjects. This might overcome the problem caused when student scholarships do not lead to positions in the Ministry.

14.2.5 Identify Short-Term Staff Development Needs

For existing staff, some upgrading of knowledge and skills are required. In cases where staff in positions of hydrologist, hydrologic modeller or meteorologist do not have adequate computational, mathematical or scientific ability, alternative options need to be considered. Understanding of the hydrologic system, the behaviour of water in rivers, floodplains and water bodies is also a requirement for these positions, as is the understanding of climate and weather patterns, wind, humidity, and precipitation for example.

14.2.6 Hands-on Support for Existing Staff

Opportunities should be explored for upgrading the capabilities and qualifications of staff who are not able to perform the more advanced functions of hydrologists, hydrological modeller, meteorologist, and climatologist. There should also be some sanction for those who do not participate or do not progress in the required studies.

Note that some of these actions might require revisions in MOWRAM policy and may have implications for MOWRAM staffing and recruitment approaches in general.

14.2.7 Inter-departmental Briefings

The consultants recommend that, during the flood season, regular technical briefings be established between DOM and DHRW. The briefings should cover current state of weather, precipitation and coming weather forecasts, on the one hand, and current state of flood levels with immediate predictions from all sources.

As far as the consultants could tell, each department gains access to data from the other by going to the internet. Proper communication needs to be set up during the flood season, which needs to occur at least once a week, or more frequently depending on the situation and weather events.

Briefings should be given by Deputy Directors from each department. Additionally, monthly meetings should occur between the department Directors. It would seem appropriate that briefings and monthly meetings were presided over by the Deputy Director General of Technical Services.

The following schedule is proposed, based on experience on other ministries of Cambodia, such as the Ministry of Foreign Affairs, and International Cooperation where there is a constant need to ensure that all divisions are kept up to date with international developments. Similar imperatives apply to flood forecasting during the flood season and during severe weather events.

Table 13: Proposed inter-departmental schedule

Event	Frequency	Subject of event
Directors meeting	Monthly	To discuss upcoming forecasts and proposed activities, information requirements and cooperation
Deputy-Director briefings	Every week or 3 days	To share information on flood predictions and incoming weather events and patterns, to develop common access to models

14.2.8 Establish Direct Data Links between DOM and DHRW

This has been identified as a prerequisite for the flood forecasting function, to provide the required hydrological and meteorological data for the flood forecasting models. A data exchange protocol and direct data links need to be established.

15 Recommendations

The recommendations fall into a number of categories. The institutional recommendations accept a minimal structural change at this time, but promote an internal structure change that reflects the activities and functions of the flood forecasting centre. Other recommendations are designed to effect improved communication between meteorology and hydrology. Further recommendations consider support to better ensure that the new technology will be effectively used. Finally, there is consideration of ways to improve the recruitment and staffing levels, although this is an intractable problem in Cambodia at present.

15.1 Institutional recommendations

The institutional recommendations of the consultants are:

- t the Flood Forecasting Centre (FFC) not be established as a new department, but may commence by adopting that title for the Office of Research and Flood Forecasting in DHRW
- that the FFC be given the scope (five functions) identified by the consultants, and that its structure ultimately reflects those functions
- that structure and staffing of the FFC be guided by the institutional and structural proposals in this report
- that recruitment and development of professional staff be undertaken over time according to the staff profiles put forward by the consultants
- that Ministry recruitment for professional positions involve consultation with the Directors of DHRW and DOM
- that at the appropriate time an arrangement be made with MRC-Regional Flood Mitigation and Management Centre to strengthen on-job experience for staff of FFC
- that other on-job training and capacity improvement be pursued with the intention that external professionals work with MOWRAM staff to improve their capacity

15.2 Policy and Strategy

The study recommends that:

- A senior official of MOWRAM should be assigned formal responsibility for developing policy and strategy proposals for flood forecasting and other flood-related functions of MOWRAM and for advising the Minister accordingly
- The FFC, in association with DOM should investigate matters of policy or strategy as required by the senior official, and should provide information and professional judgement as necessary

These recommendations do not require the FFC to have a policy and strategy function, but would require the FFC and its head to respond to matters dealing with policy and strategy when requested.

15.3 Flood Mapping

The study recommends that:

- A flood mapping program be initiated, over a three-to-five-year period, to cover all areas of significant flood threat in Cambodia

15.4 Flash flood Risk Assessment and Warning

Flash flooding is likely to become a greater problem in the future than now, because of vegetation stripping and other development. Flash floods cannot be predicted with precision but flood risk can be assigned to locations and sub-catchments. Risk assessment should be improved by marrying information on catchment condition, precipitation and other weather parameters and observed and recorded streamflow/discharge.

The study recommends that:

- Output from the flood models of FFC be available to DOM under the data exchange protocol, to contribute to risk assessment and flash flood warning.

15.5 Data Collection and Storage

A data policy needs to be established that ensures that all relevant data from stations installed by various donors and programs is consistently collected, stored, and more importantly made available DHRW and DOM for in flood event tracking and forecasting.

The study recommends that:

- Data from all AWLs be transmitted directly to FFC and data from all AWSs be transmitted directly to DOM, for operational and database purposes
- Data held by DOM and DHRW for operational requirements be located with them, in addition to being held by any other unit of MOWRAM
- Immediate database access by DOM and DHRW be maintained or facilitated for the purposes of updating models and predictive tools, without restriction
- Data interchange between DOM and DHRW be implemented as defined by the data exchange protocol developed for that purpose

Note that it will be desirable to develop other data exchange and access protocols within MOWRAM if other units of MOWRAM receive or hold data on weather, climate, streamflow, or flooding.

See also the data recommendations in sub-section 12.5.

15.6 Provincial Resources

The state of provincial office and their performance is not strictly a matter for establishing an FFC, but the FFC will rely on the generation and transmission of data from stations maintained by provincial offices and on communication with provinces on flood-related matters. Therefore, some attention has been paid to this level of operation.

The study recommends that:

- Upgrading of technical training in provincial offices be a Ministry priority for staff development, in areas related to the maintenance and repair of AWLs and AWS equipment, given the expansion of the networks through various projects
- The generation, collection, recording and archiving of flood-related data in provincial offices be strengthened, to provide real-time and historical time-series data for flood risk evaluation and forecasting
- That community recording of floodwaters be further encouraged and if necessary funded, to broaden the data available for modelling and assessment, as well as for operational warning and response purposes

15.7 Technical Advisors

As an interim measure, MOWRAM could consider engaging retired professional staff to maintain meteorology and hydrology via mentorship. Such staff, who would have been in senior positions in the past, would be most useful supporting middle-level technical roles and engaging with modelling and analysis, data interpretation and the like.

A potential downside is that to engage such people might allow the Ministry to delay dealing with core staff deficiencies.

15.8 Support for Application of Flood Models

The consultants conclude that there is a real risk that the modelling prepared by the Project Support to the National Flood Forecasting Centre will not be used, or become an effective flood simulation tool, because of the low capacity of existing staff hydrologists.

Although training in the operation and use of flood simulation models is to be provided by the project under its terms of reference, the institutional consultants believe that staff of DHRW will require further hands-on support. This should involve an advisor providing on-job working support intermittently over a period of three years.

The precondition of this support would be to identify suitable staff for modelling. At present, not all staff in hydrologist positions would be capable of using models and updating them with new data.

Terms of Reference have been provided by the consultants in Annex 3.

The study recommends that:

- MOWRAM seek external assistance to support the flood modelling function in the FFC during an initial three-year period

Annex 1

Meetings Held by Consultants

Date	With Whom	What Discussed
16/02/17	Mr Piseth Long, ADB	*Related ADB projects, NFFC investigation*
17/02/17	People in Need (PIN)	*Briefing on PIN flood warning project with NCDM and village level*
17/02/17	Watt Botkosal, CNMC	*Related World Bank projects (3S,4P)*
21/02/17	Directors DHRW and DOM	*NFFC options and Department information*
21/02/17	Director DOM, Oum Ryna	*DOM structure, staffing, activities, capacity*
22/02/17	Chief of the Office of Research and Flood Forecasting	*Office structure, staffing, activities and capacity*
22/02/17	Director DHRW,	*DHRW structure, staffing, activities, capacity*
23/02/17	Assistant Director-General Technical Services, Mao Hak,	*NFFC options and recommendations. CPMU meeting*
28/02/17	CPMU of MOWRAM	*Consultant present NFFC institutional options and HR challenges*
02/03/17	Suy Sovann, DHRW	*Installation of hydromet stations and progress of JICA project*
03/03/17	Ms Ratana Norng, UNDP project officer	*Progress of UNDP project. This meeting attended but abortive (see note)*[5]
18/07/17	Deputy Director-General Technical Services, Mao Hak,	Discussion of proposed working session with MOWRAM officials and other related matters
26/07/17	Chaired by Director-General TS Ponh Sachak, with Deputy Director-General TS, Mao Hak, CPMU members, Director of DHRW and Deputy-Director DOM	Presentation and discussion of scope of NFFC, location of NFFC organisation, capacity challenges, provincial roles and capabilities, data access and exchange for flood event early warning
27/07/17	Mr Ishikawa Masayuki JICA technical expert	JICA hydrologic network and training activities

[5] The project officer at UNDP was absent from the UNDP office, later apologizing for electronic diary malfunction – sent written information on follow-up.

Date	With Whom	What Discussed
27/07/17	Deputy Director Hydrological Works	AWL network, maintenance and capacity of provincial staff
31/07/17	Director and staff of PDWRAM Kratie Province	Operation and maintenance of AWL stations, meteorological and hydrologic staff and capacity at province level
01/08/17	Permanent Secretary of PCDM Kratia Province	Communication and roles between PDWRAM and PCDM
03/08/17	Mr Oum Ryna, Director DOM	DOM communication systems and DOM activities related to data collection and management
07/08/17	Mr Piseth Long, ADB	Progress on institutional development, further follow up for capacity strengthening
07/08/17	Mr Mao Hak, Deputy Director-General Technical Services, MOWRAM	Current progress and issues of interest in establishing FCC, communication steps and roadmap to improvement, staffing

Annex 2

Related Projects and Equipment Installations

Many projects are installing automatic water level recorders and automatic rain gauges in Cambodia. Related donor projects were found to be:

- ADB: no further related projects identified
- World Bank: Phase II of 3S and 4P basin project, proposed installation of 10 AWL recording stations and 3 met stations in the 3P basins, linked to operation of Sesan II and upstream dams, and 2-3 AWL stations in the 4P basins. Work not commenced. EOI expected shortly.
- UNDP: this project has been delayed but will include AWL recording stations
- JICA, some 33 AWL recording stations and other manual stations in six provinces to the south and west of Tonle Sap Lake. So far, 27 stations installed with six being installed in 2017. Project continues to 2019 with river basin organisations to be set up.
- European Union: EU funding supports People in Need (PIN) which has started rolling out a mobile phone-based flood information and warning system at village level, connected with NCDM and its branches, which should be coordinated with flood information from MOWRAM. Locally operated water level sensors which trigger at pre-determined water levels, being installed in Pursat Province (2 so far as pilot) with more to be installed in future (no details available).

The number of automated water level recorders is set to double over the next two years, but the Office of Hydrology is not set to increase its staff and in fact it will lose MRC funding for work associated with the MRC installed stations – a squeeze from both ends.

Annex 3

Terms of Reference for Ongoing Support for Flood Simulation and Forecast Model Use and Development

The Ministry of Water Resources and Meteorology (MOWRAM) is being supported with improved hydrologic modelling capacity through the project 'Support to the National Flood Forecasting Centre'. The flood forecasting technology is in hydrologic models developed for the Mekong-Tonle Sap waterways and floodplains and a linked model for the adjoining Pursat River sub-basin. Modelling is intended to enable the Ministry to simulate flood flows with greater accuracy and therefore better predict flood levels. The models enable precipitation and forecast weather events to be combined with streamflow and discharge data, to create a comprehensive prediction of stream and floodplain flow.

The capacity of the staff of the Department of Hydrology and River Works (DHRW) is in general low, and the Project has identified a need to support modelling activity for an extended period. As noted in the institutional report of the project, a limited number of staff have the current capacity to take up, use and develop the models being provided by the Project.

This proposal assumes that the Flood Forecasting Centre will be established within DHRW and that its staff will be the recipients of on-job support, training, and mentoring to build capacity over the medium term.

Although training is given to Ministry staff on new technology, in this case, flood simulation models, it is common for such training to cover operation of the technology only to a level that enables staff to perform operational tasks under the supervision of the trainers. Afterwards, such staff do not continue to use the technology as they are not confident in the technical disciplines or they are capable of dealing only with routine aspects.

For this reason, it is considered vital that extended on-job support be provided to staff of the Flood Forecasting Centre (FFC), who will be using the flood simulation models. The core of that support would involve professional hands-on support to operate, calibrate, and develop modelling software and to identify issues with the verification, quality-checking, and interpretation of incoming data.

Requirements: One international hydrologic/hydraulic and one national hydrologic/hydraulic modeller to provide on-the-job mentoring and technical guidance as consultants.

Consultant	Total input	Period
International hydrologic/hydraulic modeller (flood)	7 months intermittent	36 months
National hydrologic/hydraulic modeller (flood)	18 months intermittent	36 months

This proposal assumes that the Flood Forecasting Centre will be established as an Office of the Department of Hydrology and River Works.

Consultant - Terms of Reference

I. International hydrologic/hydraulic modeller and trainer:
   a. Conduct assessment of capacity of FFC staff to operate, calibrate and develop flood simulation models
   b. Design training modules for FFC staff to improve flood simulation modelling capacity
   c. Develop performance indicators for FFC flood modelling staff

d. Propose a schedule of training and on-the-job mentoring for the FFC staff
e. Conduct on-the-job mentoring and provide technical support engaging FFC staff
f. Support joint development of one new sub-basin flood simulation model using technology already provided
g. Report on on-the-job mentoring activities
h. Provide progress reports on staff capacities and improvements
i. Recommend further support if considered warranted
j. Provide advice on need for further formal training for FFC staff as appropriate
k. Draft inception report, quarterly progress reports, and final report

II. National hydrologic/hydraulic modeller and trainer
a. Assist international hydrologic/hydraulic modeller
b. Assist in assessment of modelling capacity of FFC staff
c. Assist in design of performance indicators for FFC modelling staff
d. Conduct on-the-job work assistance and support, engaging FFC staff
e. Provide technical guidance in support of the development of three new sub-basin flood simulation model with FFC staff
f. Contribute to progress reports on capabilities of FFC modellers
g. Conduct training as per the schedule of training
h. Report on on-the-job mentoring activities
i. Assist international hydrologic/hydraulic modeller to draft inception report, quarterly progress reports, and final report

Reporting

I. Four weeks from start of project, provide an Inception report, to include:
- Initial assessment of capacity of FFC staff in flood simulation and forecast modelling and associated tasks
- Plan for the training and on-the-job mentoring schedule with an outline of the training modules
- Performance indicators for flood simulation and forecasting modelling capabilities
- Identify any potential barriers to FFC staff improvement

At quarterly intervals provide **progress reports**, to include:

- Report on activities and training events conducted
- Report on progress of staff towards meeting performance indicators
- Progress on new sub-basin(s) modelling
- Recommendations on adjustment to the training and on-the-job mentoring schedule

After 18 months provide a **mid-term report**, to include:

- Assessment of progress to date as compared to planned performance improvements
- Review and assessment of mentoring and training schedule and activities completed
- Recommendations for adjustment for the next 18-month period of support

After 36 months provide a **final report**, to include:

- Record and reporting on -job support and training activities
- Performance assessment against indicators for FFC staff
- Description of progress and outcomes of new sub-basin model(s) developed
- Evaluation of level of capability of Flood Forecasting Centre in flood simulation and forecast modelling
- Identification of any barriers to further improvement
- Recommendations as to further interventions