# Development and Implementation of the Myanmar Flash Flood Guidance System (MyanmarFFGS)

**Nay Pyi Taw, Myanmar, 26-28 February 2018**

## Initial Planning Meeting

## Final Report


**March 2018**

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# Development and Implementation of the Myanmar Flash Flood Guidance System (MyanmarFFGS)

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## 1. Background

In Myanmar, flash floods account for a significant portion of the lives lost and property damages that result from flooding. Given that flash floods can occur at any time or place with disastrous results, there is an urgent need to prioritize efforts that aim to improve early warnings capabilities. Improvements help society cope with flash flood threats by enabling the mandated national authorities to undertake appropriate measures, thereby contributing to protecting the population at risk from the disastrous effects of flash floods.

As part of WMO's Flood Forecasting Initiative and on the basis of a 4-party Memorandum of Understanding signed by the World Meteorological Organization (WMO), US NOAA National Weather Service, the Hydrologic Research Center (HRC), San Diego, USA, and U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA), the signatories have established a cooperative initiative for the Flash Flood Guidance System with Global Coverage Project. To attain global coverage, specific projects are planned and undertaken on a national and regional basis with countries that have committed in writing to participate actively in the implementation and operation of the forecast system.

## 2. Introduction and Opening of the Meeting

At the kind invitation of Myanmar, the Initial Planning Meeting on the development and implementation of the Myanmar Flash Flood Guidance System (MyanmarFFGS) was held in Nay Pyi Taw, Myanmar, 26-28 February 2018, and was organized by the WMO Secretariat. The meeting was hosted by the Department of Meteorology and Hydrology (DMH) of Myanmar and was held in its offices. As such, participants had an opportunity of visiting the premises of DMH to see operational weather analysis and forecasting capacities as well as activities undertaken in hydrology and water resources. A tour of its offices included seeing some of its IT infrastructure. Participants expressed their deep appreciation to DMH for its hosting of the Initial Planning Meeting and for providing a valuable visit of its facilities.

In opening the Initial Planning Meeting, the representatives of DMH, WMO, HRC and USAID/OFDA highlighted the importance of improving the timely delivery of flash flood information and guidance to the populations at risk and in the importance of providing forecasts and warnings to populations at risk from flash flooding and other hydrometeorological hazards. Although the core aspects of the project focus on the implementation of technology and scientific approaches undertaken mainly by DMH, it was highlighted that the guiding indicator for the ultimate success of the project is the effectiveness of the outreach to citizens and reducing their risk of being affected by flash floods in a disastrous way.

In his opening remarks, Dr Kyaw Moe Oo, Director-General of the Department of Meteorology and Hydrology (DMH) and the Permanent Representative of Myanmar with WMO, expressed

his sincere gratitude to, in particular, USAID/OFDA in agreeing to provide the necessary funds to develop and implement the Flash Flood Guidance System (FFGS) for Myanmar. He indicated that this would certainly assist in reducing the vulnerability of Myanmar to such events. He also pointed out that flash flooding can cause significant damages and loss of life. He recounted various historical events that had led to such losses. He noted that such flooding can occur during the monsoon season, but also noted that heavy, short duration rainfall can occur throughout the year that can lead to flash flooding. He concluded by indicating that the FFGS will help reduce losses within Myanmar and will allow improved information to be shared with the national disaster committee, thereby strengthening the linkages between provision of early warnings and mobilization of mitigation measures.

Dr Paul Pilon, on behalf of the Secretary-General of WMO, Mr. Petteri Taalas, welcomed everyone to the Initial Planning Meeting for the implementation and development of the Flash Flood Guidance System (FFGS) for Myanmar. He recalled that the FFGS was designed to improve the timely delivery of flash flood information and guidance to the populations at risk by strengthening national capabilities to forecast and warn populations at risk from flash flooding and other hydrometeorological hazards.

Dr Sezin Tokar (USAID/OFDA) indicated that OFDA is responsible for humanitarian assistance to victims of natural hazards, either through direct response to disasters or through efforts to reduce the recurring losses resulting from disasters, by investing, for example, in developing early warning capabilities. She stressed the need to of having an end-to-end early warning approach that results in moving people from harm's way. She noted that this remains a challenge for short-fuse events such as flash flooding. She expressed the hope that following this meeting, Myanmar will decide to join the FFGS family of more than 60 countries.

Dr Eylon Shamir (HRC) said that he was pleased to attend this meeting and to work closely with country experts to develop a system that will be able to meet their needs in providing early warnings of flash flooding. He indicated that he was looking forward to receiving data and developing the system. He hoped that he would have a prototype available in May for the training of staff on the operational use of the FFGS. Dr Paul Pilon (WMO) recalled the objectives of the meeting and its expected results and welcomed the participants to provide their active inputs into shaping this important national Flash Flood Guidance System project. He also thanked DMH for all its efforts in helping to organize and host the meeting, thereby helping to make a positive atmosphere for the event.

## 3. Organization of the Initial Planning Meeting

The meeting was attended by a broad range of experts from various ministries within Myanmar and the Myanmar Red Cross Society working in national to local disaster assistance. Representatives from WMO and HRC were also in attendance. The list of participants is provided in Annex 1, while the final agenda of the meeting is given in Annex 2. In general, in-depth information was provided by WMO and HRC to participants of the Initial Planning Meeting on the objectives and deliverables of the Flash Flood Guidance System (FFGS), its conceptual and operational set-up, and products that would be available from the FFGS. The Project Brief and the Implementation Requirements documents for the Myanmar Flash Flood Guidance System are attached as Annexes 3 and 4, respectively.

Information was provided by WMO on the purposes of the meeting. These included: to present and discuss the needs for flash flood forecasting and early warnings in Myanmar; to discuss dissemination procedures and protocols for warning populations at risk including the interaction

with and role of Disaster Management Agencies; to reach agreement with Myanmar officials on their intent to participate in the project; and to develop a common understanding of the roles and responsibilities of DMH, WMO and HRC in the project.

The meeting also allowed a platform for DMH to provide an overview of their flash flood forecasting and warning infrastructure. It also allowed an opportunity for other organizations to provide an overview of their activities in disaster mitigation activities. The meeting also provided participants an understanding of the concepts behind the Flash Flood Guidance System (FFGS), its implementation and data requirements. Presentations were also given on the roles and responsibilities of DMH for the Myanmar FFGS and on the organization and management aspects of the project's planning and implementation. As well, there were facilitated discussions that led to specific conclusions being made by the meeting.

All presentations are available on the WMO website (www.wmo.int)[1].

## 4. Proceedings of the Initial Planning Meeting

### *Myanmar Presentations – overview of flash flood forecasting and warning infrastructure*

Experts from Myanmar provided in-depth presentations on the current situation of their national services related to hydrometeorological forecasting capabilities, practices and development plans. As well, there were presentation from organizations on flood disaster management. The presentations are available on the WMO website (www.wmo.int). Myanmar does not presently have a dedicated system including the use of hydrological modelling to specifically address the provision of flash flood forecasts and warnings, making the FFGS an attractive option for consideration.

Dr. Zin Mie Mie provided an overview of the organizational structure of DMH, the areas that are prone to different types of hazards, the warnings that are typically generated, and various products issues. It was noted that hours of operation of DMH was 24/7. The disaster frequency for Myanmar from 1990 to 2014 has 54.8% for flooding and 12.9% for landslides. Most of Myanmar was shown to be at risk from flooding, while still a large portion of Myanmar was at risk due to landslides. She also provided a breakdown of meteorological observing networks, noting that 51 stations are reported on the WMO Global Telecommunication System (GTS). She indicated that Japan and the Republic of Korea were contributing approximately 50 new AWOSs, while IRM, World Bank Group (WBG) funded 90 in 2017. DMH anticipate another 79 AWOS becoming available through the WBG funded Ayeyarwady River basin project. She indicated that a further 121 climate stations were operated manually and reported monthly. She also noted that agriculture also has several meteorological stations.

Ms Khin Wah Wah Win provided an overview of the existing flood forecasting and warning infrastructure in Myanmar. She provided a summary of the current organizational structure and human resources dedicated to flood forecasting within DMH. She showed the current hydrological networks, which comprises approximately 72 hydrometric stations, 42 of which are read manually thrice daily and used for issuing warnings at these sites. Modelling approaches

[1] The cited material for the Myanmar Flash Flood Guidance System can be located by referring to the activities of the Flash Flood Guidance System within Floods/Flood Forecasting heading under the Hydrology and Water Resources Programme: http://www.wmo.int/pages/prog/hwrp/flood/ffgs/index_en.php and clicking on the location of the project on the map of the world.

used include the river-stage correlation method, multiple linear regression, and HEC HMS for three rivers, while HBV for Excel is being explored. Use is being made of the Integrated Flood Analysis System (IFAS) for research purposes. She also provided a summary of recent flood and flash flood events in Myanmar, as well as the early warning Information and dissemination system in Myanmar. She concluded by indicating that DMH is interested in cooperation and collaboration with local and international organizations to upgrade the flood forecasting system to reduce flood risk in Myanmar.

***Myanmar Presentations – roles and reeds of Disaster Management Agencies for forecasts and warnings***

Ms Su Nandar Myint of the Department of Disaster Management (DDM) provided a presentation on the activities that DDM is involved with concerning flash flooding. She also provided a brief summary of some recent flooding events. She summarized the needs in the flash flooding area as being: mapping of flash flood prone areas; provision of early warning for specific flood prone areas; development of hazard maps in each region having flood prone areas; maps showing safe areas from flash flooding in each region; and the need to conduct simulation exercises of emergency measures associated with flash flood events.

There was a complementary presentation given by the Kalay District, General Administration Department, detailing conditions leading up to and including the severe flooding that occurred in 2017 and comparing this with the flooding of 2015. Indications of activities needed to help preparedness and mitigation were given.

There was a second complementary presentation given by the Minbu District, General Administration Department, regarding flooding that occurred in early 2017 resulting from Maarutha Cyclone. The population of the district is approximately 709,000, and there were flash floods reported to have occurred in Mann Stream, resulting in losses. However, early warnings provided by DMH allowed evacuation and helped to significantly decrease losses. The presentation provided a summary of actions to be taken before, during and after the flash flood.

Mr Aung Thaung Shwe provided a presentation on the role and mandate of the Myanmar Red Cross Society (MRCS) in disaster management, which it views as being auxiliary to the Government of Myanmar in providing humanitarian services to all without discrimination. The presentation highlighted the various activities of MRCS, the various ministries it works with, and how it affects emergency relief during disasters. A few examples were cited showing work undertaken in the field. A path forward was presented on what further development was necessary to advance emergency notification and relief efforts through use of Emergency Operations Centres. Currently two such centres exist, one in Nay Pyi Taw, and the second in Yangon. MRCS monitors the DMH Facebook page for daily weather bulletins and are alerted by facsimile of any abnormal weather conditions. MRCS provides recommendations for early action to branches and communities.

***Benefits of the FFGS implementation in Myanmar***

Dr Eylon Shamir provided a brief overview of the definition of flash floods, reviewed commonly used terminology associated with the Flash Flood Guidance System, and pointed out differences between riverine flooding and flash flooding. He also reviewed both the diagnostic and prognostic capabilities of the System. He noted that the System uses bias-corrected remotely-sensed precipitation estimates and real time soil moisture estimates to produce flash

flood guidance and flash flood threat for small catchments, and that these were not based on precipitation only. Of the various terminology used, two definitions were stressed. The first was Flash Flood Guidance (FFG) – the volume of rainfall of a given duration (1-6 hours) over a given small catchment that is just enough to cause bankfull flow at the outlet of the basin. The second was Flash Flood Threat (FFT) – the rainfall of a given duration in excess of the corresponding Flash Flood Guidance value. Usually forecasted quantitative precipitation from a high resolution Numerical Weather Prediction (NWP) model are used to produce the Forecasted FFT, or FFFT, for various forecast lead times.

The System Benefits were cited as being:

- Early awareness of impending local flash flood threats for all potentially vulnerable areas;
- Indications of flash flood potential and flash flood threat;
- Rapid assessments for the occurrence of a flash flood, assisting with early warnings; and
- More rapid mobilization of response agencies.

A brief discussion focused on possible benefits of the application of the FFGS to Myanmar. The discussion points are summarized as being:

- Forecaster-usable data and forecasted products are integrated from global, regional and local sources (including Quantitative Precipitation Estimation (QPE) and Quantitative Precipitation Forecasts (QPF)) and the ability to use these externally in other systems;
- Forecaster-usable products to permit real-time forecasting of potential areas having flash flood occurrence;
- Availability of extensive training;
- Relevant products such as soil moisture that could be of use to other areas, for example, agriculture and energy production; and
- Enhancements in processes relevant to water management (riverine forecasting and sub-seasonal to seasonal forecasting), landslide susceptibility assessments, and urban flash flood forecasting.

***Available mesoscale NWP models: spatial and temporal resolutions***

Dr Tin Mar Htay (DMH) provided an overview of various activities underway within Myanmar on mesoscale modelling using NWP. These included: WRF outputs; Diana tools and products; WARMS outputs; the AWS network; the Radar network; and future plan for data assimilation.

Work commenced on enabling use of the WRF model in 2012 with RIMES and ADPC. These efforts included training at DMH as well as secondments of DMH staff to both RIMES and ADPC. A WRF regional model is running at 30 km resolution, with a forecast lead time of 3 days by DMH and 9km resolution provided by RIMES. Some operational problems regarding intent speed and server problems were cited. As well, ECMWF Diana tools (Norway) are available at 11km resolution. The Shanghai Meteorological Service is making available WARMS (WRF-ADAS Real-time Modelling System), with ADAS being the Advanced Regional Prediction System Data Analysis System, output products over the internet at 3 km resolution, updated twice daily. It is anticipated that this might become an operational product though the tendering process associated with the WBG project.

Dr Tin Mar Htay also presented on the AWOS network that is under development. JICA had funded 30 AWOSs in 2016, while IRM, WBG funded 90 in 2017 and KMA/KMI are funding an additional 20 in 2017-2018. This brings the AWOS total to 140 sites, which includes the previously mentioned 51 manual stations that are reporting using the GTS. DMH anticipate another 79 AWOS becoming available through the WBG funded Ayeyarwady River basin project and 30 additional stations funded by the Republic of Korea, with these being available in 2019-2020. The plan is to have the 140 new stations reporting on the GTS later this year.

Dr. Tin Mar Htay mentioned that 3 new radars and a new multi-hazard early warning centre were being implemented under a Japanese Grant Aid Project entitled "Establishment of Disastrous Weather Monitoring System".

Dr. Tin Mar Htay indicated that the plan was to modernize the forecasting system (global NWP for routine forecasts from day 1 to day 10, and to adapt WRF for nowcasting and very short range forecasting running at high resolution (about 3km, if feasible) for up to 6 hours or more with assimilation of radar and surface observations (AWOSs, radar, radiosondes), including quality control procedures, by 2020.

Dr Shamir indicating that HRC is in the process of developing a WRF application for the Myanmar FFGS, to be run at either 6 or 4 km resolution, using the GFS boundary conditions. It was also mentioned that it was possible to have a GFS window for Myanmar to save download time. DMH participants mentioned that additional radars might eventually be available, with planning for an S-band radar in 2019 for southeast Myanmar, and proposals are being made for two C-band radars for the east and north possibly in 2019 or 2020. Dr Shamir indicated that delineations had already been made at around 80 $km^2$ and that feedback will be needed on these. There was not a need to have radar umbrellas for all potential radars.

***Overview of Myanmar FFGS***

Dr Eylon Shamir (HRC) provided an overview of development work being undertaken on the Myanmar FFGS. He indicated that the WRF modelling effort of HRC could be one of the 5 possible forecasted precipitation products that are ingested into the FFGS. He also explained Flash Flood Risk. He also indicated that 6,226 basins had been delineated for Myanmar using 3 rounds of quality control and that feedback on delineations was needed to allow additional modelling work to be undertaken. He noted that 3 radar locations were considered when undertaking the delineations and had used a compromise in sizing of delineations, which brought the average size of basins to about 80 $km^2$. He also indicated that HRC can access the GTS data and that it was excellent to learn that 140 stations would soon be available.

Dr Shamir also explained some key definitions and characteristics of the FFGS. He explained the following precipitation products:

- Global Hydro Estimator (GHE) precipitation, which is produced by US National Oceanic and Atmospheric Administration (NOAA) using Infrared (IR) channel (10.5 micrometre) of geostationary meteorological satellites;
- Micro Wave adjusted Global Hydro Estimator (MWGHE) precipitation, which is estimated by correcting GHE precipitation with Micro Wave satellite precipitation;
- Gauge Mean Areal Precipitation (Gauge MAP), which is estimated by using WMO synoptic reports obtained from the WMO GTS network; and

- Merged Mean Areal Precipitation (Merged MAP), which is derived from the best available mean areal precipitation estimates from GHE precipitation or MWGHE precipitation or Gauge MAP or Radar estimated precipitation.

He indicated that the Merged MAP is the bias adjusted precipitation product to be ingested into FFGS models; namely the SNOW 17, Sacramento Soil Moisture Accounting (SAC-SMA) and Flash Flood Threat models. The Forecast Mean Areal Precipitation (FMAP) is often generated using applications of numerical weather prediction Limited Area Models (LAMs), such as ALADIN and WRF. He continued by explaining other FFGS products:

- Average Soil Moisture (ASM), which indicates upper soil (20-30 cm) water content, including free and tension water;
- Flash Flood Guidance, which is an amount of actual rainfall that may cause bankfull flow conditions at the outlet of a sub-basin for a given duration (e.g., 1, 3, or 6 hours); and
- Three Flash Flood Threat products, which indicate the possibility of flash flood occurrences at the outlet of a particular sub-basin, including Imminent Flash Flood Threat (IFFT), Persistence Flash Flood Threat (PFFT), and Forecast Flash Flood Threat (FFFT).

Dr Shamir reiterated the efforts being undertaken to test a 6 and 4 km resolution WRF model, which of course would be extremely useful for the prognostic aspects of the FFGS, namely threat products. Dr Kyaw Moe Oo, Director-General of the Department of Meteorology and Hydrology (DMH) and the Permanent Representative of Myanmar with WMO, indicated that he would much prefer having the 4 km model over the 6 km one. He also indicated that he would like to see this model application becoming the operational model to be used by DMH, and, as such, it would be beneficial to have a back-up server. It was mentioned that USAID/OFDA might be able to arrange additional funding for this new requirement.

Dr Shamir also presented on some recent efforts to advance FFGS functionalities, such as Urban Flash Flood Warning, use of satellite inundation mapping to correct soil moisture, landslide susceptibility mapping, channel routing (riverine forecasting), sub-seasonal to seasonal forecasting, and the new Map Server Interface.

He also explained the importance of using local data in the FFGS to calibrate model parameters. He also emphasized the importance of providing available historical hydrometeorological data to HRC and in making real-time precipitation data accessible; otherwise, only global data with coarse resolution would be used. The importance of the use of real-time precipitation data to bias-adjust satellite and in future radar precipitation estimates was also stressed. He reviewed the various data types required for the FFGS, such as: precipitation, soil data, vegetation cover, evaporation, temperature, discharge, stream/river (locations) network, and quality controlled digital elevation data. Data requirements for the project are provided in Appendix B of Annex 4 of this document.

Dr Shamir stated that training was an integral part of all FFGS projects, and extensive training would be provided to forecasters. He showed the schematic diagram outlining the FFGS hydrometeorologist training programme, which is contained in Appendix A of Annex 4 of this report. He explained that it consisted of five steps:

- Step 1 introductory regional workshop;
- Step 2 eLearning hydrometeorologist training;
- Step 3 specialized training at HRC;

- Step 4 regional operations training workshop; and
- Step 5 regional operational sustainability workshop.

It was mentioned that the Step 4 training was where potential future FFGS trainers were tested and evaluated to become WMO certified FFGS trainers. The current phase of this project included training steps to the Step 3 level. He further articulated that when the training was completed, forecasters should be confident and competent to use FFGS products for flash flood forecasting and the provision of early warnings.

***Facilitated Discussions***

The Potential benefits from the Myanmar FFGS were also discussed. Ms Khon Ra (Irrigation and Water Utilization Management Department) mentioned that the System could assist in irrigation activities, by having improved forecasts of rainfall. As well upstream reservoirs and upstream catchments could be hydrologically modelled. Combining FFGS products with river and reservoir modelling systems would assist regulation of reservoirs for water resources management. Use of QPE and QPF products from the FFGS could assist as many catchments currently de not have these. For design purposes, there is a lot of historical rainfall data, which is linked to dam-site safety.

Mr Min Oo (Department of Hydropower Implementation (DHPI)) indicated that the annual inflow is roughly 5 times the current storage capacity. His organization needs to operate spillways that have the potential to flood downstream areas. They are currently looking into installing weather stations for real-time precipitation data. Work is underway on one specific basin, namely the Mon Rver.

Mr Mya Aye Aung (Department of Agriculture Land Management and Statistics) indicated that Myanmar had extensive flood protection works, with over 300 ponds, dams and weirs that also provide irrigation supply throughout the country. The protection works are for both river and sea flood-prone areas. There are many rivers in the delta region and several dyke and related embankments have been built. Several towns and cities are also protected from river and sea flooding. Sea dykes have also been built to prevent salt water intrusion onto agricultural lands. Many gates and embankments have been built to store water, including use of polders. Agriculture has found the DMH 3-day forecasts to be very useful.

Dr Pilon, mentioned that he had receive an e-mail form Mr Ata Hussain of the WMO WDS department, indicating Myanmar is officially part of the Severe Weather Forecast Demonstration Project (SWFDP)-Bay of Bengal, but not SWFDP-Southeast Asia (SeA). Mr Hussain had indicated that RSMC New Delhi is providing daily guidance and NWP products in graphical format through its password protected website. It also include NWP LAM graphics from WRF (9km) covering entire South Asia project domain. It was also mentioned that the India Meteorological Department (IMD) is also running a 3 km application over India that also covers a portion of Myanmar. Participants from DMH confirmed that they have access to this website and its products.

As these products are only available in graphical format, there would be the need of discussing with IMD the sharing of numerical data, possibly during a RSMT meeting for SWFDP-Bay of Bengal. Follow-up action is needed on this.

It was mentioned that Myanmar is not officially part of SWFDP-SeA, with this project developing and applying a NWP model at 5 km resolution. It is planned that model outputs should be available possibly in quarter 4 of 2018. Access to numerical products for the area of Myanmar would need to be discussed with the RFSC Ha Noi (Viet Nam).

The RIMES led effort of WRF modelling at 9 km resolution was also raised in terms of needing to confirm if Myanmar can make these data available to the FFGS. It was mentioned that there is currently no agreement on future activities with RIMES on the 9 km WRF application. The current WBG funded project was also discussed in terms of the possibility of making high resolution NWP products and data available to the FFGS. It was not certain at this time when and which products might be made available.

In summary, Dr Shamir mentioned that it was looking as though three NWP model results might be available for use in the Myanmar FFGS. One was the 4 km WRF model being developed by HRC, while the two others are the WRF models at 9k and the partial coverage of Myanmar at 3 km resolution.

There was a brief discussion on obtaining pan evaporation data for 20 hydrological stations from 2012. HRC would use these data to calibrate a potential evapotranspiration model for the country. It was mentioned that the agro-meteorological division in Yangon has evaporation maps and would provide these and their data from 17 stations to HRC, as well as soil temperature and moisture data.

***Roles and Responsibilities of DMH***

Dr Pion outlined the roles and responsibilities of DMH for the Myanmar FFGS. DMH has the following responsibilities: to provide historical and *in situ* data to the project developer, HRC; to participate actively in the flash flood hydrometeorological training programme; and to issue flash flood warnings and disseminate them to their national disaster management organization(s). He also indicated that DMH should: communicate effectively with WMO and HRC on FFGS activities; have good computer network connectivity including to the Internet for receiving data and sharing products with users (e.g., agriculture, water management); monitor routinely the availability of FFGS products; and conduct flash flood validation studies. Detailed information about roles and responsibilities of DMH is provided in Annex 4 (Appendix A) of this document.

Dr Pilon provided a brief overview of the organizational and managerial aspects of the project, reiterating the roles and responsibilities of DMH. He then introduced the concept of a Project Steering Group (PSG) and its composition, indicating that 3 experts from DMH would be represented on it, as well as HRC, USAID/OFDA, and US National Weather Service. Details of the PSG are found in Annex 5, while the Implementation Requirements are provided in Annex 4 of this document.

***Interest of Myanmar to participate in the FFGS***

During the facilitated discussions, participants asked a number of questions about the FFGS products and system operations. After clarifications were made by USAID/OFDA, HRC and WMO, participants indicated that implementation of the FFGS would be very useful for Myanmar, particularly given the importance and value of issuing flash flood warnings. As well, such implementation was seen as being an important contribution to enhancing national capabilities and would also help advance efforts on disaster risk reduction as well strengthening applications of advances in meteorology and hydrology with other ministries. Given the strong

interest expressed in the project, Dr Kyaw Moe Oo, Director-General of the Department of Meteorology and Hydrology (DMH) and the Permanent Representative of Myanmar with WMO provided the Letter of Commitment of Myanmar for the project during the meeting. This letter is provided in in Annex 6.

### *Project Implementation Plan*

Drs Shamir and Pilon described the project implementation plan, showing the major tasks, milestones, and schedule. The draft implementation plan was discussed, indicating that dates are usually somewhat flexible but are best estimates of when items will be delivered or completed. It was noted that the presented implementation plan needed some adjustments, which have been reflected in the draft implementation plan given in Annex 7. Participants agreed on the project implementation plan, saying that they would do their utmost to comply with the plan.

### *Closing of the Planning Workshop*

The Initial Planning Meeting agreed on a number of conclusions. These appear in Section 5 of this report.

Closing remarks were made by Dr Kyaw Moe Oo, Director-General of the Department of Meteorology and Hydrology (DMH) and the Permanent Representative of Myanmar with WMO. He expressed his appreciation to USAID/OFDA, HRC and WMO in bringing this project to Myanmar. He also thanked the participants especially those form other organizations for taking time to participate in this meeting and for their valuable contributions. Participants expressed that they were looking forward to working towards the successful implementation of the system

## 5. Conclusions from the Initial Planning Meeting

1. There was agreement among participants that the development and implementation of the Myanmar Flash Flood Guidance System will significantly improve the capabilities of the Department of Meteorology and Hydrology of Myanmar to produce timely and accurate warnings of flash flood induced hazards, thereby contributing to disaster risk reduction by saving lives and reducing property damages.

The objective of the Myanmar Flash Flood Guidance System project is to contribute towards reducing the vulnerability of Myanmar to hydrometeorological hazards, specifically flash floods, by developing and implementing a Flash Flood Guidance System to strengthen national capacity to develop timely and accurate flash flood warnings.

2. Participants agreed that the official name of this initiative will be the Myanmar Flash Flood Guidance System (MyanmarFFGS) project. This name will be used in all documents and communications.

3. Workshop participants noted that the FFGS has a global aspect and that it is being implemented as a component of the WMO Flood Forecasting Initiative (WMO-FFI). The intent is that the implemented FFGS will be fully integrated into the day-to-day operational activities

of the Department of Meteorology and Hydrology of Myanmar that is responsible for the provision of flash flood early warnings.

4. Workshop participants also noted that the products of the MyanmarFFGS would also be of benefit to a number of agencies and organizations, such as the Department of Disaster Management, Irrigation and Water Utilization Management Department, General Administration Department, Department of Agriculture, Department of Agricultural Land Management and Statistics, Department of Hydropower Implementation, Directorate of Water Resources and Improvement of River Systems, Myanmar Red Cross Society, Forest Department, Survey Department, Myanmar Radio and Television (MRTV), Department of Urban and Housing Development, Progress of Border Areas and National Races Department, and Department of Geological Survey and Mineral Explorer.

5. DMH agreed and participants expressed support in principle on the following core elements of this national project:

- Communication with and inclusion of national agencies and organizations in the use of products from the MyanmarFFGS;
- General concepts and technical approaches chosen to provide early warnings of flash flooding using the Myanmar Flash Flood Guidance System;
- Roles and responsibilities of the Department of Meteorology and Hydrology for project implementation;
- Project governance including the roles of all partners (DMH, WMO, US NWS, HRC and USAID/OFDA);
- Guiding principles for the implementation of the Myanmar Flash Flood Guidance System; and
- Concept of Operations/Standard Operating Procedures.

All items listed above are provided in the Project Brief document, which is Annex 3, and in the Implementation Requirements document, which is Annex 4. These are also supplemented through the discussions and conclusions arising from the Initial Planning Meeting held in Nay Pyi Taw, Myanmar, on 26-28 February 2018.

6. With regard to the governance of the project, participants agreed it would be beneficial to have the proposed structure and interim terms of reference of a Project Steering Group (PSG) as attached as Annex 5 of this report.

7. The Permanent Representative with WMO for Myanmar has provided to the Secretary-General of WMO a letter indicating DMH's commitment to fully participate in the MyanmarFFGS project. In this letter, the Permanent Representative with WMO for Myanmar has designated one focal point and two alternates to serve on the PSG, with the expectation that these designates would serve throughout the duration of the project. A copy of this letter is provided in Annex 6 of this report.

8. WMO and HRC will work with the Department of Meteorology and Hydrology of Myanmar to assist it in successfully implementing the Myanmar Flash Flood Guidance System, to facilitate data transfer for project implementation, to allow development of forecast products and their best use in the provision of early warnings of natural hazards including flash floods, and to facilitate the provision of products to a number of national agencies and organizations for their use.

9. WMO requested HRC and the designated focal point and two alternates to develop, at the earliest, direct communication links to facilitate project implementation.

10. The Permanent Representative with WMO for Myanmar recognized that the incorporation of local data and information are necessary to enhance system reliability, accuracy and effectiveness in the provision of flash flood early warnings and agreed that DMH would do its utmost to make its data available for use by the system.

11. With a view to a timely and successful implementation of the project, the Permanent Representative with WMO for Myanmar agreed that DMH would provide available data as specified in Appendix B of Annex 4 and transfer such data to HRC.

12. Participants agreed that the establishment of the system is a collaborative endeavour, based on the continuous feedback between development and testing, and among the National Centre, HRC and WMO. Participants recognized also that a successful design and reliable operation of the MyanmarFFGS requires quality data and metadata provided in a timely manner to the MyanmarFFGS. The real-time data of selected hydrometeorological stations need to be transferred to HRC as per the implementation plan.

13. Subject to the fulfilment of commitments by Myanmar, WMO in collaboration with HRC will strive to deliver the operational version of the system by September 2018.

14. Participants agreed on the revised proposed milestones for the implementation plan that are attached as Annex 7 to this report.

15. Participants noted that WMO, within the limitations of available resources, will provide overall project coordination and necessary support to activities that lead to the successful implementation of the project. This includes, inter alia, the development and provision of training programmes that will be undertaken by the National Centre, HRC and WMO.

16. Participants noted that there is a great benefit for the concurrent implementation of advanced numerical weather prediction activities through the on-going World Bank Project in Myanmar and the applicable Severe Weather Forecasting Demonstration Projects in Bay of Bengal and Southeast Asia. Additional efforts will be needed to make use of advances in numerical weather prediction products as they become available for incorporating them into the MyanmarFFGS to enhance further flash flood early warning capabilities for Myanmar.

**ANNEX 1**

**Development and Implementation of**
**the Myanmar Flash Flood Guidance System (MyanmarFFGS)**

**Initial Planning Meeting**
(26-28 February 2018, Nay Pyi Taw, Myanmar)

## List of participants

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**ANNEX 2**

# Development and Implementation of the Myanmar Flash Flood Guidance System (FFGS)

**as part of the**

## Global Flash Flood Guidance System

## INITIAL PLANNING MEETING

**26–28 February 2018, Nay Pyi Taw, Myanmar**

# Agenda

## Day 1

08:45–09:00 Registration of participants
09:00–09:30 Opening of the Meeting (DMH, WMO, HRC)
09:30–09:45 Introduction of participants (All)
09:45–10:15 Overview and purposes of the Meeting (WMO)
10:15–10:30 Photo Session

**10:30-11:00 Tea Break**

11:00-11:15 Review of Agenda (All)
11:15-11:30 Overview of the global FFGS (WMO)
11:30-11:45 Role of WMO (WMO)
11:45-12:15 Role of HRC and NOAA (HRC)

**12:15-13:30 Lunch**

13:30-14:30 Overview of existing flash flood forecasting and warning infrastructures in Myanmar (Hydrometeorological Representatives of the DMH)

- National capacity for the provision of flash flood early warnings;
- National capacity for weather forecasting and nowcasting (high resolution Limited Area Models, meteorological data processing and visualization software);
- Current hydrometeorological networks (number and types of meteorological and hydrometric stations, Radar network, data dissemination methods, GTS reporting, databases);
- Availability of systematically observed hydrometeorological data (availability of the data, data types, digital or paper, periods of coverage) since May 2012;

- Any archives they have on past flash flood events that show the time and place (coordinates) of occurrence;
- Organizational structure and human resources (24/7 working, number of trained forecasters, forecasting department); and
- Collaboration with emergency management agencies other governmental and non-governmental (private sector, TV, Radio etc.) organizations;
    - Brief overview of products and services provided, and the form with which they are provided.

14:30-15:30 Needs of Disaster Management Agencies (DMA) for forecast and warning of hydrometeorological hazards (Representatives of the Disaster Management Agencies)

- Role of Disaster Management Agencies (DMA) with respect to flash floods, including urban flash floods, and landslides;
- Disaster Managements perspectives on requirements for forecast lead times, location, accuracy of forecast, and impacts of forecast;
- Need for closer collaboration or increased abilities of forecasting agencies.

**15:30-16:00 Tea Break**

16:00-16:30 Benefits of the Flash Flood Guidance System (FFGS) Implementation in Myanmar (HRC)

16:30-17:00 Available mesoscale NWP models: spatial and temporal resolution (DMH)

## Day 2

09:00-09:30 Summary of Day 1 (Chair)

09:30-10:30 Overview of the Myanmar Flash Flood Guidance System (FFGS) (HRC)

- Introduction to the Myanmar Flash Flood Guidance System
- Background and key components
- Delineations
- High Resolution Mesoscale QPF ingestion
- Nowcasting

**10:30-11:00 Tea Break**

11:00-11:30 Data requirements and data priorities for the Myanmar Flash Flood Guidance System (FFGS) (HRC)

11:30-12:30 Facilitated discussions on the availability and access to historical and real-time data and information (All)

**12:30–14:00 Lunch**

14:00 Visit to DMH (*TBC*)

19:00 Welcome Dinner (*TBC*)

## Day 3

09:00-09:30 Summary of Day 2 (Chair)

09:30-10:00 FFGS Advanced functionalities (HRC)

- Multi-NWP QPF ingestion
- Radar ingestion
- Landslide susceptibility mapping
- Riverine Routing
- Urban Flash Flood EWS
- Seasonal and sub-seasonal discharge prediction

10:00-10:30 Flash Flood Hydrometeorologist Training Programme (HRC)

**10:30-11:00 Tea Break**

11:00-11:30 Roles and responsibilities of the Department of Meteorology and Hydrology and Disaster Management Agencies in Myanmar FFGS (WMO)

11:30-12:00 Facilitated discussions on the national professional and technical capacities needed for national project operations (All)

12:00-12:30 Organizational and management aspects of project planning and implementation (WMO)

**12:30–14:00 Lunch**

14:00-15:00 Facilitated discussion and expression of interest of Myanmar to participate in the project (All)

15:00 -15:30 Next steps and work plan (HRC)

**15:30-16:00 Tea Break**

16:00-16:30 Review and adoption of decisions and recommendations (All)

16:30-17:00 Final remarks and closing of the Meeting

------End of Meeting------

# Development and Implementation of International and Regional Flash Flood Guidance (FFG) and Early Warning Systems

## Project Brief

# Myanmar

# Flash Flood Guidance System

**June 2017**

## SUMMARY

The purpose of this project is the development and implementation of a national flash flood guidance and early warning system. The approach will entail development and implementation of national technology, training, protocols and procedures to address the issues of mitigating the impacts of flash floods and the application of such a system allowing the provision of critical and timely information by the Department of Meteorology and Hydrology (DMH) of Myanmar.

To accomplish this, the World Meteorological Organization (WMO) will cooperate with the Hydrologic Research Center (HRC), San Diego, USA to implement a flash flood guidance and early warning system designed along the lines of similar systems that have been made operational in different parts of the world. In cooperation with the DMH of Myanmar, the project will be developed and implemented by the HRC with support from the DMH. Support will be provided by the NOAA/National Weather Service for the system global data needs and training; and WMO providing technical backstopping and supervisory services including Monitoring and Evaluation of the project. USAID/OFDA is providing funding support for the system development and implementation. Additional financial resources will be needed to fund travel-related costs of Myanmar government employees. WMO may provide some support or possibly this additional funding might be made available through other on-going projects within Myanmar.

Based on estimation of rainfall from satellite imagery and available gauges, the system will provide the DMH of Myanmar with an estimate of the precipitation amount and an indication (guidance), based on physically-based hydrological modelling, as whether it would generate a bankfull discharge (e.g., minor flooding) at the outlets of small, flash flood prone basins throughout the country. DMH will integrate local knowledge from other sources (their national networks, observers report, etc.) to validate the guidance and issue as required a warning through channels proper to Myanmar.

As technical developer, the role of HRC includes the development and implementation of the flash flood guidance and warning system as well as research and development into system enhancements, including inclusion of infrared and microwave technology for satellite rainfall estimates, as needed for the different implementations, and training and capacity building on system operations and applications to disaster risk reduction (i.e., an end-to-end system approach). The approach will provide a tool for DMH to access the data and information needed to develop alerts and warnings for flash floods.

***The main objective of this project is, therefore, to contribute towards reducing the vulnerability of Myanmar to hydrometeorological hazards, specifically flash floods, by developing and implementing a flash flood guidance system to strengthen national capacity to develop timely and accurate flash flood warnings.***

## 1. Beneficiaries

In many areas of the world, flash floods are a regular phenomenon accounting for loss of human life and significant economic and social damages, adding up to hundreds of millions of dollars for a single event. Flash floods can affect not only mountainous and hilly rural areas with sparse settlements but also major urban areas. In addition, an increase in their frequency and magnitude is anticipated as a consequence of climate change. Implementation of a flash flood guidance system would provide benefits to all societal and economic stakeholders of Myanmar.

A key benefit of the proposed system is that it is capable of providing early awareness of impending local flash flood threats for all potentially vulnerable communities. A true value of the system will be to provide rapid assessments of the potential of flash floods allowing improvement of the early warnings for the occurrence of a flash flood and therefore allowing for more rapid mobilization of response agencies.

The system implementation also provides capacity building and cooperation for effectively mitigating disasters from flash floods. Training and capacity building will be a strong component of the implementation of this programme. There will be opportunities in cross-training of hydrologists and meteorologists from Myanmar and with different backgrounds and skills in hydrometeorology, which forms the basis of flash flood detection and prediction.

The availability of the system guidance products will also help to improve the way flash flood events on rivers are addressed, encouraging preparing public awareness campaigns and response strategies.

Primarily aiming to improve national service delivery capabilities to deal with flash flood threats, the implementation of the flash flood guidance system will also provide the opportunity for enhancement of national collaboration of disaster mitigation and response agencies and improvement of community awareness of flash flood disaster threat and mitigation.

Training programs will be designed to include experts from DMH to develop strong scientific and technical capabilities to use the FFG system and further to include disaster management agencies where the responsible agencies will be involved in system validation programs which will require determinations of where flooding did or did not occur. The issuing of warnings based on flash flood guidance and flash flood threat products will conform to established national practices, if existing; alternatively, the project could provide support to a national dialogue for their development. The establishment of such criteria requires understanding of the hydrometeorological processes and prediction uncertainties, as well as capabilities of the population to take effective action.

## 2. Sector-Level Coordination

Through implementation of the project, DMH can collaborate with agencies and organizations involved in disaster risk reduction to enable operational engagement of technical and disaster risk reduction agencies for implementation of the system. This effort will provide the opportunity for enhancement of national collaboration of disaster risk management agencies leading to improvement of community awareness of flash flood disaster threat and mitigation. Depending on sector-level discussion, in-country training programmes may be designed to allow disaster management agencies make best use of DMH forecast and warning products.

## 3. Technical Design

Flash floods are a hydrometeorological phenomenon that requires (a) assessment of both meteorological and hydrologic conditions in real time and (b) ingestion of local information and expertise for reliable warnings. The system design aims to allow for both. This system will serve as a catalyst to develop protocols in line with country norms pertaining to other event warnings. The system will allow the DMH to develop its own manner of system configuration and use adapted to local requirements as a tool for developing flash flood warnings and watches together with other local timely information.

Important technical elements of the Flash Flood Guidance and Warning System for Myanmar are the development and use of a bias-corrected satellite precipitation estimate field, high-resolution numerical weather prediction model outputs (the system will include implementation of the WRF mesoscale model for the Myanmar domain, noting the system can also make use of other high resolution mesoscale model outputs as they become available), and physically-based hydrological modelling to determine flash flood guidance and flash flood threat. Global real-time estimates of high resolution precipitation data from satellite will be the primary source of precipitation for forcing the hydrological model and determining the flash flood threat. The real-time satellite precipitation estimates will be obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA) NESDIS and CPC via the internet. Local, available precipitation gauge data from DMH or other agencies will be used to supplement the satellite precipitation estimates and provide the data needed for bias correction. DMH gauge data will need to be made available for ingest into the FFG system. Global digital terrain elevation databases and geographic information systems will be used to delineate small basins and their stream network topology. In addition, global soil and land cover spatial databases will be used to support the development of a physically-based soil moisture accounting hydrological model (see flow chart in Figure 1). If higher resolution and more accurate local soil and land cover data bases are available, these will be applied rather than the global databases.

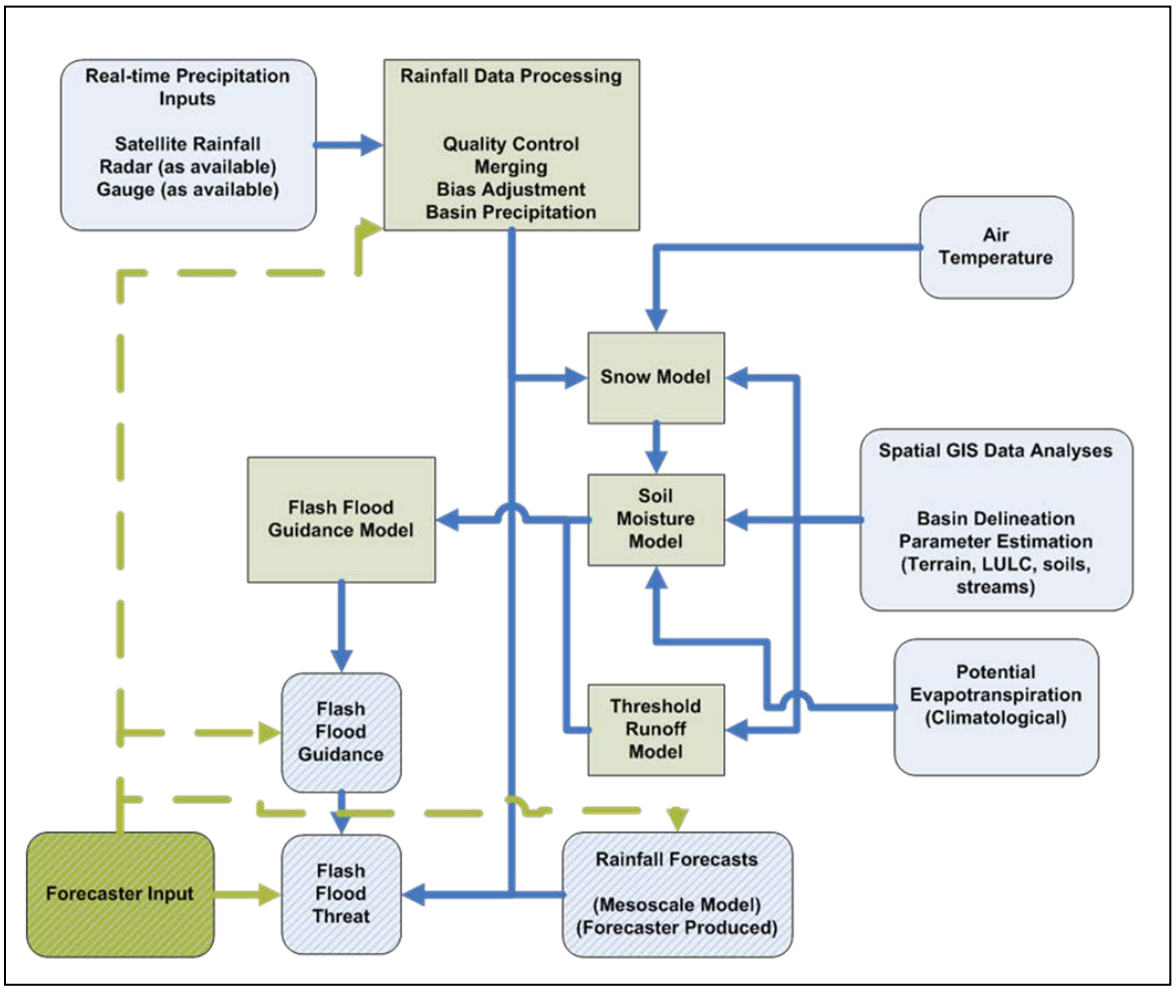


**Figure-1 Schematic Flow Chart of the Flash Flood Guidance System**

With training, forecaster will be able to provide adjustments to the FFGS products based on local knowledge or supplemental data. The system design allows this coupling with the system outputs and existing or developing DMH knowledge on a national or even local scale.

System flexibility and system capability to engage local forecasters should help greatly towards the development of national/local protocols for integration within existing warning dissemination systems.

The system will provide evaluations for the threat of flash flooding over time scales of one to six hours and for basins on the order of 150 $km^2$. Given the computational burden and depending on available computational resources, it is very likely that the most valuable lead times for system use will be 3 - 6 hours. A product displaying basin flash flood risk out to 36 hours through the application of the WRF model will also be provided.

## 4. Implementation Approach

The system design is such that it allows for efficient global data ingest and it supports use of local data. The design is characterized by distributed operations and functions. All computations and product dissemination will be done locally at the DMH offices and is made possible through the timely use of national data, as well as project software, hardware and training. Two servers will be provided through the project and installed at a location determined by DMH. One server will be used to run the FFG software, ingest any available local data including WRF mesoscale model output, ingest global data and disseminate FFG system products. The second server will be used to run the WRF mesoscale model implemented for the FFG program. It should be noted that there are no on-going license fees or other related costs associated with the use of the software following completion of the project. The overall organizational structure is shown in Figure-2.

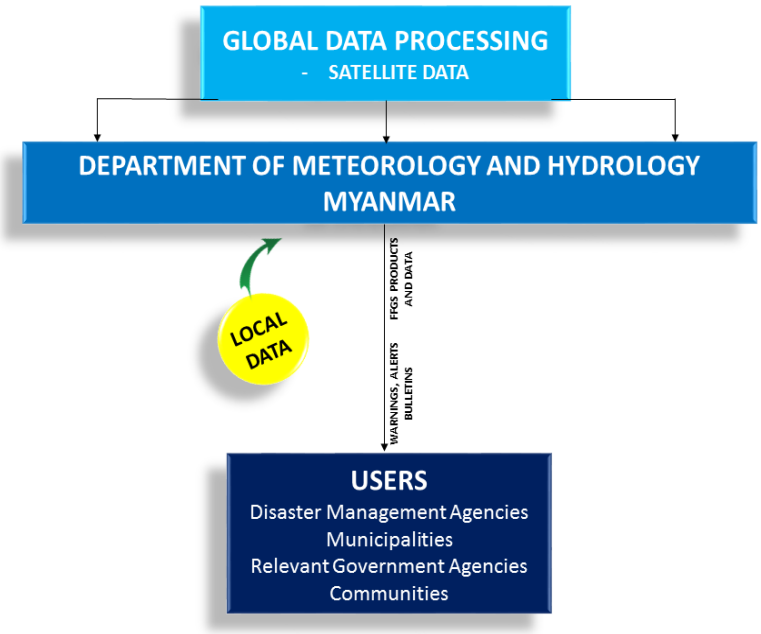


**Figure-2 Flash Flood Guidance and Warning System using global satellite data with local computer hardware, data and information to support DMH of Myanmar to issue warnings to users.**

The interface with global information is the link to real-time global satellite precipitation estimates via internet from NOAA NESDIS and CPC. Other global observations will be through one or more of the World Meteorological Organization (WMO) Global Centres (e.g., gauge precipitation data through the WMO GTS).

All requisite real-time data (global and local) are ingested by the FFG software server located at the Department of Meteorology and Hydrology of Myanmar. Graphical and text products are then available directly to DMH forecasters via a PC and to any other authorized users through a secure internet connection.

It is necessary in such projects that a national institution be designated as the project focal institution for the country, in this case the Department of Meteorology and Hydrology, which has proven technical capabilities. Key operational responsibilities of the DMH would include:

- Disseminate products derived from the FFG system and data to the users in the country such as Disaster Management Agency and Municipalities per user requirements and needs;
- Collect available real-time in situ meteorological data for ingest to the FFGS for the development of the FFG products;
    - Support national flash flood operations by developing national validation of products and ideas for system improvements.
- Develop an historical archive of the system products;

- Support WMO and the system developer with training activities to be provided to the hydrometeorological forecasters of Myanmar by assisting in organizing local training events and in provision of staff to be trained; and
- Coordinate with the system developer for their support regarding any routine maintenance and IT issues for the FFGS and WRF servers.

DMH functions pertaining to the use of the flash flood guidance and warning system will include: country-wide hydrometeorological analysis using the system products and information and other local products and information; any forecaster modifications of FFG products; evaluation of WRF-generated precipitation forecasts; development of local flash flood watches and warnings; monitoring of system performance (availability and effectiveness); providing feedback to WMO and the system developer on system operations/issues; and developing links to country disaster management agencies for effective disaster risk reduction. DMH working with the system developer during training will evaluate the needs and requirements of its users in order to provide timely and accurate information for the potential impact of flash floods.

It is expected that the products available from the DMH of Myanmar will support a range of other uses for a variety of additional agencies within the country. Outputs from the FFG system can be used to support the needs and requirements of other agencies such as agriculture or transportation.

One key to sustainability is confidence in a reliable, accurate system. To accomplish this, reliability evaluations will be included in the concept of operations.

## 5. Transition and Exit Strategy

Upon completion of the project, the DMH of Myanmar will have the computational hardware and software along with suitably trained staff to allow its hydrometeorological forecasters to access the flash flood guidance and early warning system data and products via LAN/WAN and the internet. The required data will be accessed and processed through the DMH national facilities. At the national level, only a PC and internet connectivity will be required to access the data and products required to evaluate potential flash flood threat, making the system very sustainable. The DMH of Myanmar will be the national designated institution and would need to ensure continued access to national meteorological data and work with the system developer to ensure that the FFG system and WRF servers remain on-line and functioning.

Much of the effort to ensure sustainability of the flash flood guidance and early warning system will be through training of staff and cooperative development efforts. This approach is intended to ensure ownership and full responsibility for system operations. In addition, a concept for the operation of the system within the existing operations protocols of the responsible agencies within the Myanmar will be outlined for each agency during training. A User Guide will be developed for the Myanmar Department of Meteorology and Hydrology for system operations and maintenance.

## 6. Project Implementation

Project implementation is based on the Project Implementation Plan (PIP) that will be discussed during the initial planning meeting. The Plan will provide information with regard to essential requirements and criteria that need to be met for the successful implementation of the project. These requirements include: Availability and accessibility of critical input data and information

including geo-spatial information, historical and near real-time meteorological and hydrological data, basic institutional infrastructure and technical/professional expertise of Department of Meteorology and Hydrology of Myanmar.

WMO in collaboration with its partners, as a first step to project implementation, would organize with DMH the initial planning meeting. Participants at the meeting including the Permanent Representative of Myanmar and the Permanent Representative's Hydrological Advisor and other participants. They are expected to discuss all aspects of the proposed project and express how they will be explicitly be cooperating and participating in the project activities. Participants will be asked at the meeting to agree with and arrange for providing technical information and data that are crucial for the successful implementation of the project in Myanmar. During the planning meeting, the following will be discussed:

- Myanmar experts to see first-hand the technical components of the FFG system;
- Myanmar experts and senior management to assess the potential utility of adopting such a system within their operations;
- Understanding of the requirements of DMH of Myanmar and other responsible agencies within the country**;**
- Understanding of Myanmar implementation requirements including professional staff; and
- Understanding of the primary data collection and access to such data required for the initiation of the project.

The project will be phased over a period of approximately one year. The scheduling of the various project activities will be discussed and agreed upon during the initial planning meeting.

The Requirements Document, which is complementary to this document, provides a comprehensive list of the types of data required for project initiation. It also describes in detail the in-kind contributions required by Myanmar for the successful implementation and continued use of the Flash Flood Guidance System for Myanmar.

## 7. Institutional status

In February 2009, WMO signed a Memorandum of Understanding (MoU) with USAID, HRC, and NOAA on the implementation of the Flash Flood Guidance System with global coverage.


## GLOBAL FLASH FLOOD GUIDANCE SYSTEM

# Implementation Requirements

## Myanmar Flash Flood Guidance System

**June 2017**

## Document Purpose

This document provides guidance to project participant, in particular Department of Meteorology and Hydrology (DMH) of Myanmar on minimum requirements with respect to professional capabilities, availability of data and information as well as computational and communication infrastructure to implement a **Flash Flood Guidance System (FFGS)** for Myanmar. In addition, the document provides information of the functions of the DMH leading to the delivery of flash flood guidance products on national level.

These requirements reflect a system that provides timely and useful data and information based on robust communication infrastructure in a form that is consistent with the operations in place in many of the National Meteorological and Hydrological Services (NMHSs) throughout the world. Of primary importance is to establish a system that becomes part of NMHS operations and is used as the primary tool by these services for providing flash flood alerts/warnings to the appropriate agencies and/or the public.

## Overview of the FFGS

The primary purpose of the FFGS is to provide real-time informational guidance products pertaining to the threat of potential flash flooding. The system is designed to address the reduction in devastation caused by flash floods in terms of reductions in the loss of life, suffering and property damage. The system provides the necessary products to support the development of warnings for flash floods from rainfall events through the use of remote sensing-based rainfall estimates (primarily satellite).

The system products outputs are made available to forecasters as a diagnostic tool to analyze weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then to make a rapid evaluation of the potential for a flash flood at a location. The system empowers users with readily accessible observed data and products and other information to produce flash flood warnings over small flash flood prone basins. The system is designed to allow the addition of experience with local conditions, incorporate other data and information (e.g., Numerical Weather Prediction output) and any last minute local observations (e.g., non-traditional gauge data), to assess the threat of a local flash flood. Generally, evaluations of the threat of flash flooding are done over hourly to six-hourly time scales for sub-basins from 100 - 150 $km^2$ in size.

Important technical elements of the FFGS are the development and use of a precipitation gauge-based bias-corrected satellite precipitation estimate field and the use of hydrological modelling. The system then provides information on rainfall and hydrological response, the two important factors in determining the potential for a flash flood. The system is based on the concept of **Flash Flood Guidance** and **Flash Flood Threat.** Both indices provide the user with the information needed to evaluate the potential for a flash flood, including assessing the uncertainty associated with the data.

The flash flood guidance approach to developing flash flood warnings rests on the comparison in real time of observed or forecast rainfall volume of a given duration and over a given catchment to a characteristic volume of rainfall for that duration and catchment that generates bank full flow conditions at the catchment outlet. **Flash Flood Guidance** (FFG) is that

characteristic rainfall volume for the given duration over the small catchment that generates bank full flow conditions at the catchment outlet. FFG is updated in time based on current soil water deficit (as determined by antecedent soil moisture conditions), rainfall, evaporation, and groundwater losses. If the observed or forecast rainfall volume exceeds the FFG of the same duration, this excess is termed the **Flash Flood Threat (FFT)** and flooding at or near the catchment outlet may be likely . Figure 1 provides output products from an earlier development of the FFG in Southeast Asia that included Myanmar. Products would be similar for the FFG system being proposed for this project.

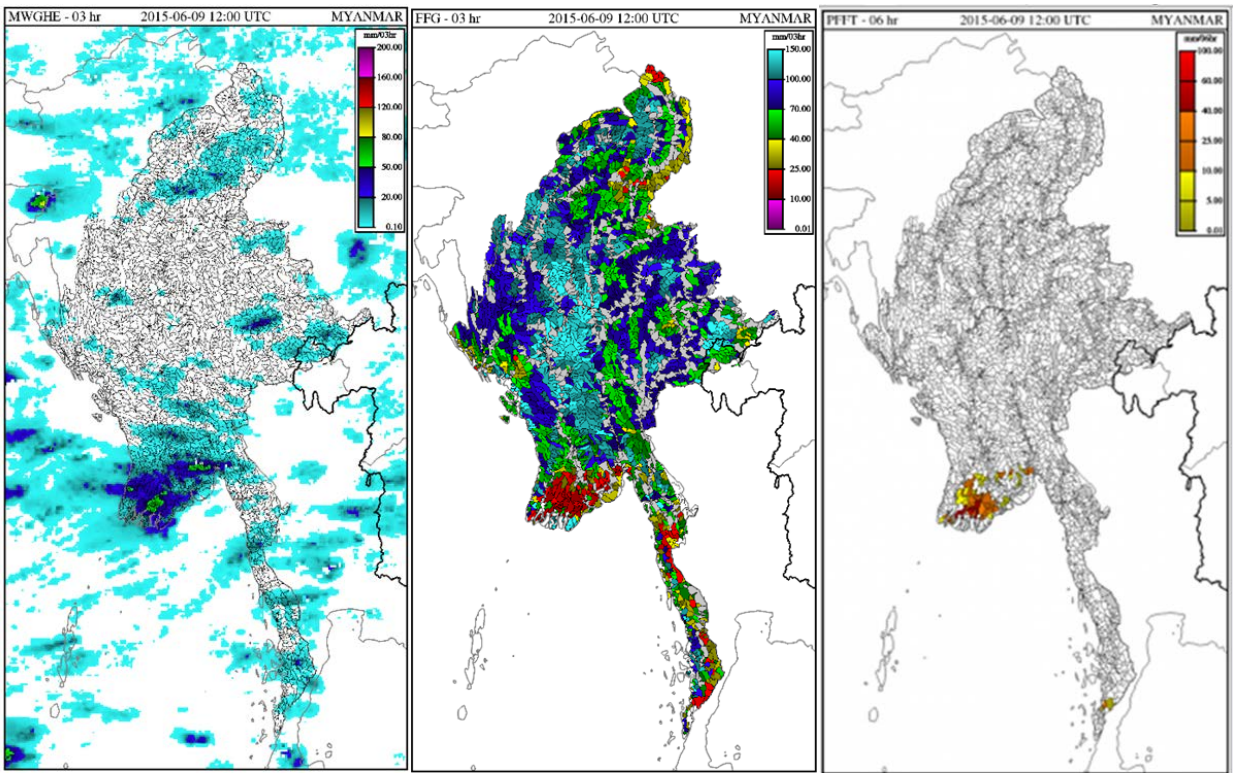


**Figure 1. Output Products from the FFG System for Myanmar (from left to right, microwave adjusted satellite rainfall estimates, flash flood guidance, flash flood threat)**

## Global Flash Flood Guidance System Program Background

The purpose of the Global FFGS (GFFGS) program is the development and implementation of regional and national flash flood guidance and early warning systems. The approach entails development of infrastructure on a global scale to then support the development and implementation of regional and national flash flood guidance projects comprising of technology, training, protocols and procedures components to address the issues of mitigating the impacts of flash floods.

Regional flash flood guidance and early warning systems are designed based on programs in Central America, Southeast Asia, Black Sea Middle East, Southeast Europe, and Southern Africa. The project approach is to provide a tool for each country within a specified region to access the data and information needed to develop alerts and warnings for flash floods. The main objective of this project is, therefore, to contribute towards reducing the vulnerability of

people around the world to hydrometeorological hazards, specifically flash floods, by developing and implementing flash flood guidance systems to strengthen regional and national capacity to develop timely and accurate flash flood warnings.

The data and information part of the requirements also provides guidance with respect to the selection of areas/basins on national level that can be covered with a flash flood guidance system based on the availability of critical data and information.

Implementation of this program is in concert with the World Meteorological Organization's Flood Forecasting Initiative guided by the Hydrology and Water Resources Branch of the Climate and Water Department of WMO. In the context of this initiative, the World Meteorological Congress has endorsed the implementation of a Flood Forecasting Initiative. A goal of this initiative is to develop and implement programs that encourage hydrologists and meteorologists to work together towards the improvement of operational flood forecasting services.

The Global FFGS program is being accomplished under the Memorandum of Understanding (MoU) noted below[2] through funding by the U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA).

The system design is such that it allows for efficient global data ingest and support of national cooperation amongst relevant national agencies. The system design is characterized by distributed operations and functions on global and national levels. Centres of computation and product dissemination will support the operational functions of the NMHSs through the timely provision of data, ancillary information, software, hardware and training. A schematic of the FFGS operational process for Myanmar is shown in Figure-2.

[2]MoU "Establishing a Cooperative Initiative among the World Meteorological Organization, Hydrologic Research Centres, U.S. National Oceanic and Atmospheric Administration/National Weather Service and the U.S. Agency for International Development/ Office of U.S. Foreign Disaster Assistance for the Flash Flood Guidance System with Global Coverage Project"

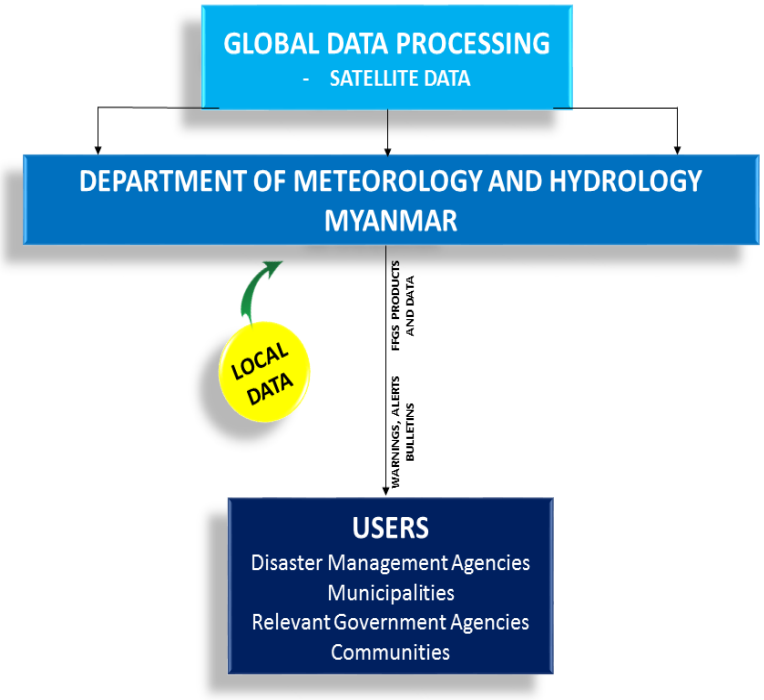


Figure-2: GFFG System Process for Myanmar

The interface with global information is the link to real-time global satellite precipitation estimates and global in situ observations will be through one or more of the World Meteorological Organization (WMO) Global Centres.

The DMH of Myanmar will require appropriate communications and infrastructure facilities to support operations. The proposed responsibilities of the DMH are outlined in Appendix A.

**In summary, to the extent possible, responsibilities of the DMH are to:**

- Allow any other, trained and authorized users outside of the DMH access to the FFG products and/or data (outside dissemination of raw products should be limited as appropriate);
- Provide routine national hydrometeorological analysis and guidance to users;
- Provide communications for system analyses to the national users;
- Provide communications of the national system modifications necessary to the system technical developers;
- Provide national flash flood hazard information per protocols;
- Provide national *validation of products* and formulation of plans for operational improvements;

- Collect available *real-time meteorological data* for ingest to the FFG system and the development of national products;
- Provide *training to the users*;
- Provide a *computational platform* for Myanmar real-time computations and modifications of flash flood guidance products;
- Coordinate with the system developer for their support regarding any routine maintenance and IT issues for the FFGS and WRF servers;
- Develop *a historical archive* of the system products and data;
- Develop adaptations of the flash flood guidance and precipitation forecasts on the basis of within-country most-recent data and information;
- Prepare local *flash flood watches and warnings* as required;
- Monitor system (products) performance (availability and effectiveness), conduct *verification studies; and*
- Communicate with national agencies for effective disaster risk reduction.

It is expected that the products available from the DMH will be adequate to support a range of desk top computer-based processing capabilities at the national agencies, from using simple spreadsheet software to those computational facilities that support interactive graphical generation of user-related products.

## Data and Information Requirements

To ensure that the FFGS provides the highest quality data and information to forecasters, various historical and real-time hydrometeorological data and other information are required in order to develop, implement and operate the flash flood guidance systems. Historical data and information are needed for the development of the system and calibration of the models. Real-time data are needed for system operations. Terrain and other spatial-database information are used to delineate the small catchments for which flash flood guidance will be computed, to calibrate the models and to operationalize the flash flood guidance information.

It cannot be emphasized enough that quality data and information are needed to provide the optimum system for use by forecasters for the development of flash flood warnings.

Data and information needs are detailed in Appendix B. Appendix C is a survey of automatic rain gauges and weather stations. This information is important to fully understand the current status of these systems.

## Resource Requirements

## Personnel

The system is designed to be used operationally and jointly by meteorologists and hydrologists. The following expertise is recommended at the DMH mainly for the system use and operations. Recommended minimal available expertise are given in Table-1.

Table-1: Recommended Minimal personnel Expertise for the Department of Meteorology and Hydrology

| Area of Expertise | DMH |
|---|---|
| Have a meteorological and/or hydrological technical background. | Both meteorological and hydrological forecast expertise. |
| Have experience in operational weather and/or hydrological forecasting specific to the region or country. | Priority |
| Have experience in weather-related hazard emergency management operations | Priority |
| Have experience in or knowledge of quantitative analysis of satellite-based rainfall estimates. | Priority |
| IT capability for server system administration, network connectivity, and product availability. | Priority |

## Computers and Communications

High performance servers with the LINUX operating system will be run at the DMH through the project. To obtain system products, the DMH is required to have current-generation PCs and an internet connection with periphery devices in order to access products from the internet. On the other hand, the DMH will need hi-speed internet service and, potentially, access to GTS/WIS.

## Training Program

During the course of the FFG System implementation for the DMH, training will be provided to forecasters on the scientific basis and operations of the system. The training program is a blended learning model - known as the Flash Flood Hydrometeorologist Training (FFHT) Programme. The training program includes:

1. Introductory training workshop;

2. eLearning program to support system operations, product interpretation, system validation, including the use, management, and interpretation of output from the system, and the development of protocols to alert response agencies and the public of an impending or existing threat. For each completed course learners earn an HRC Course Certification, once they have completed the core curriculum they are eligible for Step Three;

3. Advanced Operations and Interactive Simulator Training at the Hydrologic Research Center in San Diego, California USA to assist with reviewing and assessing the operating versions of the system. Included is the Interactive Simulator training to provide the user with the skill to interpret and validate skill using real flash flood events. Upon successful completion of the Advanced Operations Training each learner earns an HRC Advanced Training Operations Certification; once they have completed this step they are eligible for Step Four;

## Appendix A

# Roles and Responsibilities of the Department of Meteorology and Hydrology (DMH) of Myanmar

### System Development

The Department of Meteorology and Hydrology (DMH) of Myanmar has the responsibility to assist with tasks during the regional FFGS development and implementation. These responsibilities include:

- The DMH will be the focal point for the collection of the required available spatial and historic hydrometeorological data needed for system development; and
- The DMH will assist the FFGS developer in coordinating specific reviews of various products created and data sets used during system development.

### System Operations Responsibilities

In meeting its responsibility to maintain the base node of the FFGS system, DMH will have the following roles, responsibilities, and operations to the extent possible, reasonable and within approved, standard protocols:

- For any available hydrometeorological data, the DMH will develop and maintain a local database and real-time input products and make available those products to the automated acquisition processes of the FFGS Server. This will require that the DMH work with the relevant national agencies that may collect these data to develop a set format of the data to be transferred to the DMH for use in developing this real-time database that feeds the FFGS;
- The DMH will provide access via the internet (as primary) to all FFGS products to all key relevant and authorized national agencies in-real time;
- DMH forecasters will evaluate and apply the FFGS products and will provide critical hydrometeorological expertise to users outside of the DMH when required;
- When appropriate, the DMH will be available for the briefings and discussions needed to properly evaluate flash flood potential using the FFGS tool. The DMH forecasters will work with other users to ensure that they understand the weather forecasts and to provide consistency, including evaluating and interpreting the applicability of current and forecast precipitation events;

- The DMH will evaluate the FFGS products from a national perspective and will communicate this perspective to the other user agencies as appropriate. The DMH will ensure consistency of FFGS products throughout the country;
- The DMH will provide national validation of system results and will advise the other user agencies of the presence of noted biases in system outputs;

- Where appropriate, the DMH will coordinate the issuance of flash flood watches and warnings (as applicable per protocols) in a consistent format using the FFGS tool as well as incorporating other information and tools available;

- The DMH will support routine training/workshops on system operations, product interpretation and development, product verification, etc. to forecasters; and

- The DMH will coordinate with the FFGS technical developer for conveying information regarding potential improvements that will affect the national products.

## System Management/Maintenance Roles and Responsibilities

The DMH will maintain and operate the two Linux servers which computes and disseminates national FFGS products (text and/or images) and executes the WRF model. These two servers using the LINUX operating system will be provided to the DMH through the project.

Even though the FFGS servers are designed to be fully automated, there will always remain a critical need for ongoing observation and quality control of their processing tasks and data products. This requires expertise from two basic categories: systems administration and operational quality control of the data products. Skills in both areas of expertise are needed to properly monitor and confirm the overall performance of the system. This can be fully achieved only through the cooperative efforts of both IT Staff and Forecasters. In fulfilling its system maintenance responsibilities, the DMH needs to perform the following activities:

- Maintain Network Connectivity and Data Availability – This relates primarily to the systems administration efforts of IT staff. Of concern are potential problems related to internet and/or GTS service availability, adequate communications throughput to ensure timely data downloads and access by the national agencies, network cabling, switches, or any one of numerous hardware and security issues related to the servers themselves. The assessment and correction of potential problems relating to any of these areas requires specific technical skill and an understanding of the systems and technologies involved;

- Product Quality Control – This relates to the function of the forecasters at the DMH. Their expertise in hydrology and meteorology is required to properly understand the relative quality of the FFGS input and output products at any given time. Accordingly,

DMH's forecasters must perform quality control procedures on the data and outputs and determine whether or not any perceived problems are the result of a parametric shortcoming, a failure in one of the FFGS models, or if it might relate to the quality or availability of the real-time input data that drives the system; and

- Operational Process Monitoring – In order to successfully fulfill the specific responsibilities of IT staff and forecasters identified above, both groups must engage in a necessarily cooperative effort of routine and systematic review of system processing activity. This involves regular inspection of system image products, data products, status indicators and log files as a means to confirm the proper operation and health of the system while maintaining a keen familiarity with the status quo in order to immediately recognize any deviation from it.

## Training Responsibilities

The DMH of Myanmar will be directly involved in the various training programs during implementation and operations. Training programs can involve both DMH staff and relevant national agencies staff. DMH Representatives will be equipped to play a fundamental part in the training of all DMH staff and any other user agency staff, especially during system operations. The primary purpose of training is for DMH representatives to familiarize themselves and develop a level of competency in the FFGS system basics (physical principle, components, operation, and validations), product interpretation and use, and collaboration for prediction and warning. Particular emphasis for the DMH will be placed on validation, operations, trouble shooting and maintenance, data management, communications, realistic scenarios, and preparedness for unusual circumstances or errors. The DMH may offer opportunities for national agencies personnel to serve at the DMH for hands-on training and to support the DMH operations.

## Centre Personnel Recommendations

Staff that supports the operations of the DMH of Myanmar should possess the following qualifications to the extent possible.

## Staff

The following expertise is recommended for the staff supporting the Department of Meteorology and Hydrology.

| Area of Expertise | Department of Meteorology and Hydrology of Myanmar |
|---|---|
| Have a meteorological or hydrologic technical background | Both meteorological and hydrologic expertise |
| Have experience in operational quantitative weather or hydrologic forecasting specific to the region or country | Priority |
| Have experience in weather-related hazard emergency management operations | Priority |
| Have experience in or knowledge of quantitative analysis of satellite-based rainfall estimates | Priority |
| IT capability for server system administration, network connectivity, and product availability | Priority |

## Focal Point

It is recommended that the DMH of Myanmar maintains a focal point for all operations and activities. This focal point should meet the following qualifications and responsibilities:

### *Qualifications*

The qualifications for the DMH Focal Point are recommended to be as follows:

- Have good knowledge and background in operational meteorology and hydrology;
- Have appropriate experience in providing technical training in hydrometeorology; and
- Have undergone advanced training in the theory and operations of the FFG system from the system technical developer and implementer.

### *Responsibilities*

The responsibilities for the DMH Focal Point are recommended to be as follows:

- Assist the system technical developer in the collection of required regional spatial and hydrometeorological data needed for system development;

- Be directly involved in the various training programs provided by the Global FFG Program partners during FFG system implementation and operations;
- Provide national validation of FFG System results (with and without forecaster adjustments) to the responsible national agencies ; and, on the basis of such regular feedback, coordinate with the technical developer for potential improvement and to review system products;
- Develop a detailed report annually based on:
    - Number of major events of flash flooding in Myanmar,
    - Deaths/property losses estimates for those events,
    - Performance of the national FFG, and
    - Operations information (percent of hours of system downtime and percent of hours with lack of remotely-sensed and in-situ rain gauge data).

### Operation Schedule

Both the DMH and relevant national agencies should operate on a round-the-clock basis either continuously year-round or at the minimum during seasons with significant flash flood risk.

### Summary

In summary, key responsibilities of the DMH of Myanmar are:

- Disseminate real-time country graphical products from the FFGS to the users;
- Collect available real-time meteorological data for ingest to the FFGS for the development of national products;
- Support national flash flood operations by:
    - Provide routine national hydrometeorological analysis,
    - Provide daily guidance discussion to Departments and Divisions within DMH and other responsible national agencies from a national perspective,
    - Provide national flash flood hazard information,
    - Provide national validation of products and formulation of plans for improvements, and
    - Provide communications for system analyses to responsible agencies in Myanmar.
- Provide communications of national system modifications necessary to developers;

- Collect spatial and historical hydrometeorological data needed for system development;
- Develop a historical archive of the system products;
- Support national training of DMH's Departments and Divisions representatives and representatives from other responsible national agencies; and
- Coordinate with the system developer for their support regarding any routine maintenance and IT issues for the FFGS and WRF servers.

# Appendix B

# Data and Information Requirements

For each area or basins where flash flood guidance will be provided, various historical, real-time and state variable data and information are needed for the development and operation of the flash flood guidance system. As much of the following data and information as possible should be collected and/or made available from each responsible agencies within Myanmar. Note that the following items represent the optimum data and information requirements; system development and operations designs will consider which data are available for use.

## Logistical Data (Metadata)

- Longitude and latitude coordinates (in decimal degrees) and elevation (in meters) of all sensors providing real time data and historical data, type of data, units of measurement and sensor;
- Longitude and latitude coordinates (in decimal degrees) of dams and reservoirs;
- Evaluation of basin delineation: initial delineations based on hydrologic processing of the SRTM (90-m) resolution digital elevation data and hydrographic information from the Digital Chart of the World;
    - Evaluation of the delineation results with local knowledge and expertise is required for final quality assurance; and
    - Delineation maps may be provided in GIS format; shapefiles are preferred.

## Spatial Digital Data or Maps (for areas of interest)

- Digitized stream network data;
- Digitized country catchment boundaries data;
- Land-use and land-cover data;
- Soils data to include soil texture or FAO soil classification or soil properties data, and depth of upper soil and sub-soil;
- Local stream cross-sectional survey data for natural streams draining 10-2000km$^2$, including any reports of regional relationships between channel cross-sectional characteristics and catchment characteristics;
- GIS map of bedrock and alluvial channels;

- Population distribution data.

**Reports**

- Flood Frequency Analysis (regional and local);
- Flash Flood Occurrence (regional and local);
- Stream geometry studies for small streams;
- Climatological precipitation and flood studies.

**Historical Data**

Precipitation data (hourly, daily, monthly, climatology);

- Air temperature data (hourly, daily, monthly, climatology);
- Pan evaporation data (daily, monthly, climatology);
- Soil moisture data for top 1 meter of soil (weekly, monthly, climatology);
- Streamflow discharge data for local streams with drainage areas less than 2000 $km^2$ (hourly, daily, monthly, climatology);
- Spring discharge data;
- Stream stage data (hourly, daily, monthly, climatology) and associated stage-discharge curves (rating curves), also for local streams;
- Radiation data for computation of potential evapotranspiration (daily, monthly, climatology);
- Wind, humidity data for computation of potential evapotranspiration (daily, monthly, climatology);
- Historical radar data, once radars become operational, and satellite data;
- Groundwater recharge rates, channel transmission losses, and groundwater level data for surficial aquifer; and
- Snow water equivalent data.

**Real Time Data**

- Surface precipitation and weather data (hourly or 6hourly) (**important**);
- River stage + rating curves, or discharge data (hourly, 6-hourly or daily); and
- Snow water equivalent or depth (daily or weekly data) for mountainous areas with snowfall.

# Appendix C

## Real-Time Data Specifications and Information

Please provide the following information for each real-time rain gauge and automatic weather station:

- Location of the station as latitude and longitude in decimal degrees and elevation in meters;

- Deployment status – e.g., in place and operational, in place but not yet operational, planned for installation. If known, please specify the start date of operation;

- Current operational status (for all in-place stations) – e.g., fully operational, operating but intermittent, operating but erroneous or unreliable, offline for maintenance/repair, etc. Current status should be provided for each sensor of multi-sensor stations. Any additional information relating to problematic stations/sensors will be helpful;

- Method of data transmission – e.g. Internet, satellite, telephone landline, telephone cellular, telephone SMS, telephone fax, microwave radio, HF/VHF radio (voice or data), etc.;

- Period of observation (data recording resolution, per sensor) – This is the duration of time over which data is accumulated or averaged, as provided, e.g., 15-minute, 1-hourly, 6-hourly, 12-hourly, daily. For any instantaneous measurements, such as temperature, please indicate the interval between recordings;

- Frequency of data transmission/collection (on what interval is the data received by the responsible agency?) – e.g. randomly, 5-minute, 15-minute, 1-hourly, 3-hourly, daily or manual data logger collection;

- Survey information;

    - What is the functionality and adequacy of the data-reception and storage systems in Myanmar?

    - What preventive maintenance, calibration or repair needs to be performed on the gauges/stations? What is the typical schedule for routine, operational maintenance of gauges/stations?

    - What is the perceived level of institutional support for the agencies responsible for monitoring?

    - How can real-time data from the currently operating rain gauges and weather stations be accessed for use by the FFGS?

**ANNEX 5**

# Project Steering Group (PSG)

**Preamble:** The Project Steering Group (PSG) provides overall governance of the project and its related activities throughout the duration of the project. Its membership and the terms of reference would be confirmed and amended as deemed necessary during the first constituting session of the PSG.

## 1. Standing Core Members of the PSG

The PSG consists of the following members for the Myanmar Flash Flood Guidance System (Myanmar FFGS) project.

Table-1 Composition of Project Steering Group

| Organization | No of Representatives |
|---|---|
| Focal Point | 1 |
| Focal Point Alternate 1 | 1 |
| Focal Point Alternate 2 | 1 |
| Partner (US NWS) | 1 |
| Development Partner (HRC) | 1 |
| Donor (USAID/OFDA) | 1 |
| WMO | 1 |

Additional experts/representatives may be invited by the PSG as needed on an ad-hoc basis, and observers may also be invited by the PSG to participate in meetings.

## 2. Terms of Reference

The (intermediate) principle terms of reference of the PSG are as follows:

- Ensure smooth and timely implementation of project activities and achievement of the project purpose and its expected outcomes based on regular summary reports from the Myanmar National Centre;
- Provide technical and administrative guidance to the implementation of the project;
- Establish an adequate *monitoring and evaluation* (M&E) system for the project and implement findings from the M&E process;
- Review and update the *project implementation plan* (PIP);
- Promote benefits of the project on a national level;
- Facilitate links with other regional and national relevant projects, including Severe Weather Forecast Demonstration Projects (SWFDPs), regional World Bank hydrometeorological early warning projects;
- Ensure cross-sector linkages with relevant national and international organizations; and
- Seek additional expertise and financial support to supplement project activities.

## 3. Communication

Meetings of the Project Steering Group will be initially organized annually. In addition, tele-conferences may be organized on a tri-semester basis or as needed to monitor project progress and solve upcoming issues. Other communication means of the PSG will include a dedicated e-mail list and/or a web-based e-forum. Operational communications will be established between the National Centre and Myanmar Focal Points and the technical development partner (HRC).

## 4. Guiding Principles for the Myanmar FFGS Implementation

The guiding principles listed below provide an overall framework for the implementation of the Myanmar FFGS and may be specified in more detail by the first session of the Project Steering Group (PSG):

- Data providers remain owners of data. Data provided to the Technical Development Partner (Hydrologic Research Center, HRC), will be used solely for the purpose of building the FFGS components and such data will not be re-distributed other than to the Myanmar National Centre that provided the data;
- Equal, non-hierarchical access to data and information generated by the project for project partners and beyond are consistent with Resolution 40 (WMO CG-XII) WMO policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities (https://www.wmo.int/pages/about/Resolution40_en.html) and Resolution 25 (WMO CG-XIII) Exchange of hydrological data and products (https://www.wmo.int/pages/about/Resolution25_en.html);
- Services provided by the technical development partner (HRC) are of an advisory nature; and
- Full responsibility for provision of national flash flood guidance and warnings remains with the Department of Meteorology and Hydrology of Myanmar.

**Annex 6**

# Letter of Commitment


Government of The Republic of the Union of Myanmar
Ministry of Transport and Communication
Department of Meteorology and Hydrology
Nay Pyi Taw, MYANMAR

Office No.5
Ministry of Transport and Communications
Department of Meteorology and Hydrology
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Web Site : www.dmh.gov.mm


Ref.: 06942/2018-LO CLW/HFWR

Date: 28 February 2018

**Letter of Commitment**

To

Secretary-General
World Meteorological Organization
Geneva, Switzerland

**Subject:** **Letter of Commitment regarding the Myanmar Flash Flood Guidance System (MyanmarFFGS) project**

Dear Mr. Taalas,

Reference is made to the Initial Planning Meeting of the Myanmar FFGS held in Nay Pyi Taw, Myanmar, from 26 to 28 February 2018. This event was organized by the World Meteorological Organization (WMO) in cooperation with the Hydrologic Research Center (HRC), the U.S. National Weather Service and the U.S. Agency for International Development/Office of the U.S. Foreign Disaster Assistance (USAID/OFDA) and co-organized and hosted by theDepartment of Meteorology and Hydrology (DMH) of Myanmar.

I am pleased to inform you that the meeting had successful outcomes and conclusions, which constitute a milestone for the initiation of the implementation of this important project.

In this regard, I would like to confirm the commitment of Myanmar to actively participate in all project activities towards the achievement of the project objectives.

I would also like to inform you that Ms. Htay Htay Than has been designated as the focal point and Dr. Tin Mar Htay and Ms Khin Wah Wah Win as alternate for all related technical activities of the project. The designated officer will represent Myanmar on the Project Steering Committee. Their coordinates are given below.

Focal Point

| | |
|---|---|
| Name: | Ms Htay Htay Than |
| Function/Role | Director of Hydrological Division (Head of Division) |
| Address | Office No.5, Department of Meteorology and Hydrology, Ministry of Transport and Communications |
| Phone | +95 67 411528/+95 9250954638 |
| E-mail | HHThan.DMH@gmail.com |

Alternate 1

| | |
|---|---|
| Name: | Dr. Tin Mar Htay |
| Function/Role | Staff Officer (Forecaster of Meteorological Division |
| Address | Office No.5, Department of Meteorology and Hydrology, Ministry of Transport and Communications |
| Phone | +95 67 411527/+95 9250954664 |
| E-mail | tmarhtay@gmail.com/tmarhtay@googlemail.com |

Alternate 2

| | |
|---|---|
| Name: | Ms Khin Wah Wah Win |
| Function/Role | Staff Officer (Forecaster of Hydrological Division |
| Address | Office No.5, Department of Meteorology and Hydrology, Ministry of Transport and Communications |
| Phone | +95 67 411523/+95 9402574150 |
| E-mail | khinwah.sovereign30@gmail.com |

Ref.: 06942/2018-1.0 CLW/HFWR

It is my pleasure to inform you that we have designated DMH to act as the National Centre for the Myanmar FFGS, and it will be responsible for the implementation of the project for Myanmar.

I would like to express our appreciation for the efforts so far undertaken by WMO, NOAA National Weather Service, and HRC, as well as the generous financial support of USAID/OFDA.

Let me assure you of our full support and cooperation with the WMO Secretariat and the project partners for the successful implementation of this project.

Yours sincerely,

Dr. Kyaw Moe Oo
Director General
Department of Meteorology and Hydrology
Nay Pyi Taw, Myanmar
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**ANNEX 7**

# Milestones for the Draft Implementation Plan