# Flood 2020, Trigger Analysis Bangladesh

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# Contents

# 1 INTRODUCTION

Advances in predictive analytics, using data and scientific models, allow the humanitarian community to mount a response before a predictable shock manifests into humanitarian needs. Taking such an anticipatory approach where possible, will lead to a response that's faster, more efficient, and more dignified.

In late June 2020, the Resident Coordinator in Bangladesh and the Emergency Relief Coordinator pre-approved and endorsed an anticipatory action framework and the corresponding Central Emergency Response Fund (CERF) projects. Building on existing structures and experiences by the IFRC, WFP, and the Government, the pilot was set up within two months.

The framework pre-established when and on what basis financing and action will be triggered ahead of a specific monsoon flooding peak; how much funding would go to which agency; and what activities the funding is being used for in what timeframe.

On 4 July 2020, severe floods were forecasted for 18 July onwards, the framework triggered, and CERF funding was released to agencies, enabling humanitarian assistance to reach people before peak flood. With everything pre-agreed, CERF launched the fund's fastest-ever allocation within 4 hours.

By the time the water reached life-threatening levels, more than 220,000 people had already received assistance through WFP, FAO, and UNFPA, working together with the IFRC, 10 local NGOs, and the Government.

An integral part of the pilot was to document evidence and learning. This report is a contribution to that learning process on evaluating the forecast and triggers to contribute to learning.

Forecasts at different lead times tend to predict different variables (e.g., seasonal rainfall vs 3-day rainfall totals), and it is critical to understand the relationship between the forecast itself and the hazard of interest (e.g., floods).

A trigger should be based on the action the humanitarian community can take in advance of a disaster that mitigates the impact of the hazard. Based on this action, responders can determine both (1) which forecasted impact is the most relevant level to intervene, and (2) what probability of this impact should be used to trigger action.

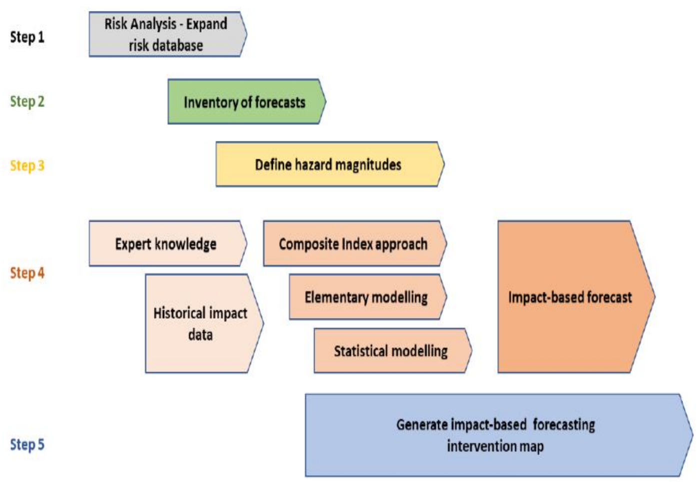



**Figure 1: Concept of Impact-based forecasting showing the five steps and the phasing.**

To determine this impact-based forecast, five steps are taken, as indicated in Figure 1. The first two steps are to create a risk analysis and an inventory of forecasts. The third step defines hazard magnitudes. The fourth step creates an impact-based forecast by either combining the risk analysis with the forecasts using expert knowledge or using elementary or more advanced modeling and historical impact data; the fourth generates an impact-based forecasting intervention map.

# 2 FORECASTS, TRIGGER AND IMPACT PREDICTIONS

Building on previous experience and scientific work, including from the IFRC Early Action Protocol, the forecast and trigger methodology for the pilot were also in line with the HCTT 2020 contingency plan which is activated for a humanitarian response to monsoon floods in Bangladesh. However, given the entirely anticipatory action approach and narrow geographic focus, the trigger is adapted for the collective pilot. [1]

## 2.1 FORECASTS

Disaster managers in the humanitarian sectors implementing anticipatory action need to know the following questions:

- What is the hazard? What is the threshold for the extreme event? What are the risks? What is the “danger/impact level”?
- How much lead-time can the forecast give us to take early action effectively? What is the probability of forecast?
- If we act based on this probability, how often will we act in vain?

Several global, regional and national flood forecasts are available for the major rivers in Bangladesh. For the pilot, two forecasts were selected based on a thorough study by the Red Cross Climate Center (RCCC) and previous experience triggering anticipatory action for monsoon floods for the Jamuna flood plain by the IFRC/BDRCS and WFP.

First, a 10-day probabilistic warning model based on the Global Flood Awareness System (GLOFAS), a global hydrological forecast, and a monitoring system that couples weather forecast with a hydrological model and is calibrated for the Jamuna river in Bangladesh.

Second, a 5-day deterministic action model, based on the Bangladesh Flood Forecast & Warning Center (FFCW), a national model.

### *2.1.1 Why use GLOFAS and FFWC?*

GLOFAS is a global hydrological probabilistic model using medium-range rang rainfall forecast from the European Centre for Medium-Range Weather Forecasts (ECMWF) with a lead time of 1 to 30 days for large basins in the world.

The FFWC uses GLOFAS for trend analysis in the forecast. GLOFAS is currently the only openly available model with 10 days lead time and prediction of the water flow to remain above the trigger for three

[1] The HCTT contingency plan triggers at a “water level at and above danger level up to 1 m in Jamuna river in at least 3 observation points including Bahadurabad” estimating an impact of a minimum of 2 million people exposed to inundation, 10% of people displaced and 5,000 hectares of crop land exposed to inundation.

consecutive days. GLOFAS also demonstrates good forecast skill with 10 days lead time. Hence GLOFS is used as a pre-activation trigger for readiness.

FFWC, center under the Bangladesh Water Development Board (BWDB) and though Joint River Commission (JRC) have access to the observed water level and forecasts (24 hours) at Dhubri in Assam India on the Brahmaputra river.

Dhubri is upstream in the Jamuna river and the flood wave traveling time is 4 -5 hours to reach Noonkhawa, Bangladesh.

In the Teesta river basin, the upstream Gozoldoba station adds additional lead time. In addition to the basin rainfall data, FFWC uses several stations upstream for the forecast.

FFWC 5 days the deterministic hydrodynamic model forecast is the only model available in the country. The FFWC forecasts the water level with respect to MSL (Mean Sea Level) and Danger Level along with the major river system in Bangladesh with an acceptable error range of +/- 30 cm. The model result was used by the Government of Bangladesh and for activation of early action.

### 2.1.2 Why use Bahadurabad?

Three are four main observation stations in Bangladesh: the Bhairab Bridge, Bahadurabad, Harding Bridge and Aricha are representing the Meghna, Brahmaputra-Jamuna, Ganges, and Padma rivers respectively. These four river systems provide a major source of flooding in Bangladesh. Except for the Bhairab bridge other stations measure at the entry point of the basin.

The Bahadurabad hydrological station of BWDB is in the upstream boundary of the Jamuna river and maintains long observation records of water levels, discharge, and flooding in the basin. Hence, Bahadurabad station has been considered and used as a threshold to represent the basin flooding and starting point to predict flood impacts. The impact calculation uses a flood depth map based on all the forecast stations along the Brahmaputra-Jamuna river.

## 2.2 TRIGGER

A trigger should be based on a set of criteria to help answer the questions of when and where to act before the disaster. It should determine when a hazard becomes an out-of-the-ordinary (or severe) shock and impact crosses a certain threshold for the exposed vulnerable community.

The trigger happens when a pre-identified forecast product, at a certain lead time, indicates a sufficient probability of impact. This means that the forecast shows a sufficient probability that an extreme event (hazard) will happen in an area where a certain level of vulnerability exists.

For this pilot, a 1 in 5-year return period is considered a severe shock; and a vulnerability threshold is passed when more than 40% of a population are forecasted to be affected or 20% of household assets are predicted to be damaged.

To make the best use of available forecasts and increase time to prepare for activation, a two-step trigger system is used by this pilot:

- **Stage I: Pre-Activation (Readiness) trigger** is reached when the water flow at the Bahadurabad[2] gauging station over three days is forecasted by the GLOFAS forecast model with lead time 10 days to be more than 50% likely to cross 100 000 m3/s (1 in 5-year return period).
- **Stage II: Activation trigger** is reached when the water level at Bahadurabad[3] is forecasted by the FFWC 5-day lead time model to cross the government-defined "Danger Level" + 0.85 meters.

### *2.2.1 Why define the trigger point at 0.85 meters above the government danger level (DL)?*

The threshold for flood trigger is defined as the water level representing a 1 in 10-year return period at Bahadurabad on the Jamuna river. Using a Gumbel distribution of 55 years of historic records shows a 1 in 10-year return period of a Danger Level at + 1.0 m for Bahadurabad station. But the average error of the 5 days FFWC forecast is in the range of 15 -30 cm. Hence the trigger threshold was adjusted and defined as the danger level +0.85 m for the activation of anticipatory action.

The danger level defined by the government is the water level at a river location above which the flood may likely cause damages to nearby crops and homesteads. In a river having no embankment, the danger level is about the annual average flood level. In an embanked river, the danger level is fixed slightly below the design flood level of the embankment. The design level of a right embankment of the Brahmaputra-Jamuna river considers a 1 in 50-year return period as the danger level for the protected area.

To develop the impact threshold for anticipatory action – which should only occur for out-of-the-ordinary events - in 2015 a household leveling survey was conducted for four unions in the Bogra district. The idea is to set a threshold above the government danger level when the impact of floods is out of the ordinary.

The main challenge was to fix a threshold when the population is living at different house yard levels. For example, ward 3 of Vanderbari Union (not protected area) has a varying degree of the yard levels by any of the 450 rural houses. Yet 50% of houses are below 17 m PWD (Elevation Datum by Public Works Department) with the range from 15 m to 18 m PWD.

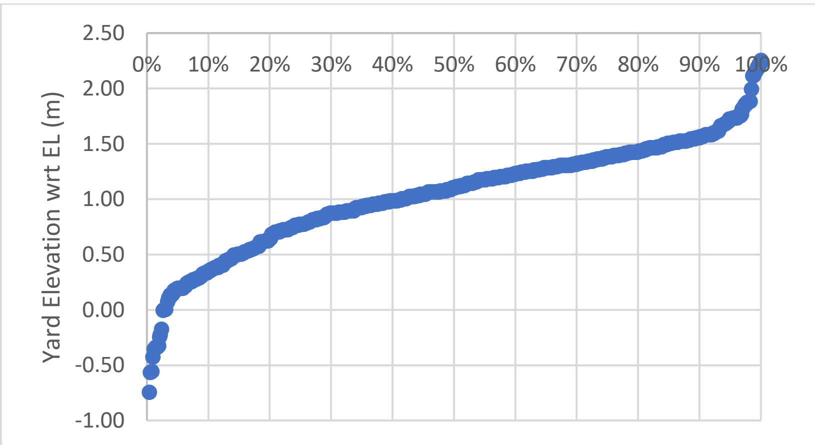



**Figure 2: Population Elevation Curve, Ward 3 Vanderbari Union, Bogra.**

[2] https://www.globalfloods.eu/accounts/login/?next=/glofas-forecasting/
[3] http://www.ffwc.gov.bd/ffwc_charts/index.php?stid=66

The annual average of the water level for Ward 3 of Vanderbari unions is 15.85 m PWD measured at the local gauge data, correlated with Sharikandi long time series. This is also considered as the Danger Level for the ward by the government.

In the consultation with communities, the impact is most severe when water reaches the house floor – or water goes above the plinth level - and there is then no choice for people but to leave the house. This translates into a threshold of yard level plus 0.5 meters or danger level + 1.0 meter. For the example of Borgra, about 40% of people's yards are below this threshold (danger level + 1 meter) in this Union.

A house elevation survey in 2015 shows an average height of 0.25m, 0.30m, 0.45m, and 0.5m with respect to yard level to Cowshed, Toilet, Tubewell, and house floor level would expose these to a flood in the Unions (example, see Table 1). From the consultation, people start evacuating when the house floor goes underwater i.e. yard level + 0.5 meter or danger level + 1.0 m.

The health impact starts at the household level when the Tubewell and Toilet go underwater i.e. at yard level + 0.30m or more, but it also varies depending on the socio-economic condition of the area.

The livestock and rearing cows will be impacted by floods when grazing fields and cow shades go underwater. This means when water reaches the danger level and inundates the standing crop on the field with grazing field as well.

**Table 1: Impact thresholds of the house (example ward Vandarbari Union, Dhunot Upazila, Bogra).**

| Item description | Cow shade | Toilet | Tube well |
|---|---|---|---|
| **Height w.r.t. courtyard (m)** | 0.23 | 0.28 | 0.44 |
| **Sample no** | 130 | 54 | 174 |
| **Return period (year)** | 3-5 | 4-6 | 5-8 |

The inundation threshold for rural houses with reference to Bahadurabad gauging station is used in forecasting the impact for anticipatory action as shown in Table 2. The floor of the house/plinth level represents a danger level + 1.0 m and the corresponding return period is greater than 10 years.

**Table 2: Different magnitude of the flood (water level, discharge, return period) with respect to Danger level (BWDB) at Bahadurabad station on Jamuna River.**

| Reference Level | DL | DL+ 0.5m | DL + 1.0m | DL +1.5m | DL + 2.0m |
|---|---|---|---|---|---|
| **With respect to House** | Agriculture | Yard | Plinth | Half of wall | Full of wall |
| **Water level (m, pwd)** | 19.5 | 20 | 20.5 | 21.0 | 21.5 |
| **Discharge (m3/s)** | 63,400 | 72,200 | 84,900 | 98,600 | 105,500 |
| **Return period (year)** | 2 | 4 | 10 | 50 | 100 |

### 2.2.2 What about Flood depth and durations?

Depending on the exposure, flood depth and duration are the main drivers for impact. Statistics of the flood duration above the thresholds for two different exposure categories (Char land and mainland outside the embankment) using a 3 hourly time series water level data at six locations along the river Jamuna are shown in table 2. There is a difference in duration between the mainland and Char land. The flood duration above danger level plus one meter shows a maximum of 9 days but on average 3 days. Hence 50% of Unions in the Char land and outside the embankment remain flooded at least for 3 days.

### 2.2.3 Historical analysis of the trigger

Figure 3 shows the historical analysis of the trigger configuration proposed. The top panel shows the water discharge in Bahadurabad from GLOFAS and the 1 in 5-year threshold corresponding to 100,000 $m^3/s$. The bottom panel shows the water level data in Bahadurabad from FFWC. Blue markers represent water level below the threshold and red markers water level above threshold.

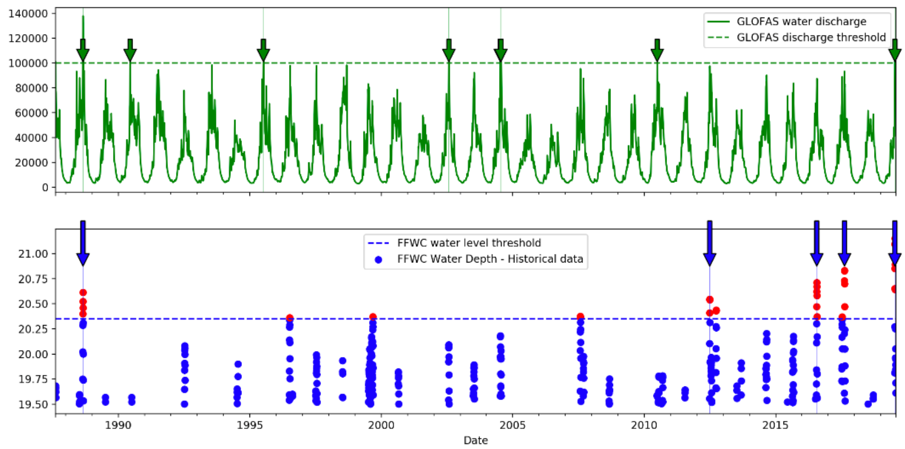



**Figure 3 : Historical analysis of triggers.**

The green and blue vertical arrows correspond to historical simulated activations of the GFAS pre-activation and the FFWC activation triggers, corresponding to 3 consecutive days above the threshold.

Water discharge from GloFAS has overall a good correlation with water level from FFWC. However, since 1987 our historical analysis shows that:

The GLOFAS pre-activation was followed by the FFWC activation two times (1988 and 2019)

- Three times (in 1995, 2003, and 2004) the GloFAS pre-activation level was reached but the FFWC water level remained below the trigger level
- Three times (in 2013, 2016, and 2017) the FFWC water level went above the trigger level, but the GloFAS water discharge didn't reach the threshold.

This analysis highlights that:

- A pre-activation is 30% likely to be followed by activation. In the remaining cases, the water level reported by FFWC is above the danger level, but it doesn't reach the threshold for the related activation trigger.
- Some historical events like 2012, 2016, and 2017 floods, were characterized by high water levels reported by FFWC with relatively low water discharge reported by GLOFAS. For these events, the pre-activation trigger will not be activated before the activation trigger. The analysis of historic

events since 1987 suggests that 2 out of 5 (i.e. 40%) of the activation triggers were preceded by a pre-activation trigger.

- A pre-activation is 40% likely to be followed by activation. The floods in the remaining 60% are likely to be below the activation threshold from FFWC.
- GloFAS is expected to miss 60% of the activations from FFWC.

Finding the acceptable tradeoff frequency of pre-activations and their accuracy will be one of the main challenges moving forward.

### *2.2.4 Trigger governance*

The following is a table summarizing roles and responsibilities in monitoring the forecasts and establishing when a trigger is reached.

**Table 3: Roles and responsibilities in forecast monitoring and triggering.**

| Who | What | How | When |
|---|---|---|---|
| **The BDRCS-led forecast monitoring team** | Monitors flood forecasts (GLOFAS and FFWC) | Populates (twice a day) the forecast and observation in the log sheet[4] | From June 2020 |
| **The BDRCS-led forecast monitoring team** | Confirms that 10-day pre-activation trigger is reached<br><br>or 5-day activation trigger is reached<br><br>➔ Related agreed interventions by agencies can commence immediately | Communicates status of 10-day pre-activation (readiness) or 5-day activation trigger to the RC/RCO as well as concerned UN Agencies, OCHA, and other partners (See annex 1) through email and a WhatsApp Group.<br><br>The communication includes an intervention map. | As triggers are reached |
| **CERF** | When a 10-day warning is issued (or a 5-day trigger without a previous 10-day warning), CERF will immediately send the approval letters to the agencies. | Endorsed pilot and CERF application by RC and Emergency Relief Coordinator (ERC)<br><br>Pre-approved CERF approval letter | |

[4] https://drive.google.com/file/d/1J5B9pktZYnlBwAtb8n907A8P6xFVlCCd/view

| Who | What | How | When |
|---|---|---|---|
| **RC/RCO** | The Resident Coordinator may call for a meeting. Invitees include the BDRCS-led working group on forecast-based action, Red Cross Red Crescent, BDRCS, WFP, FAO, UNFPA, OCHA, and government (e.g. MoDMR) immediately after the 10-day pre-activation or 5-day activation trigger is reached. | This meeting is to discuss the situation, including coordination of actions with government efforts. | As applicable |

## 2.3 IMPACT PREDICTIONS

The concept of anticipatory action is not to wait for the disaster, but to act before an event based on the forecast to save lives and livelihoods from hazards. Two critical components are thus needed to enable anticipatory action (see figure 4): A trigger to establish when and where to activate early action based on the impact-based forecast of a hazard. Thus, there is a need to describes what, who, and when anticipatory activities may reduce human sufferings for a predicted hazard's impact.

Anticipatory actions can take place in any location forecast to experience severe humanitarian impact. Hence, need to translate the forecast - what a hazard could be to what a hazard could do. Going beyond hazard forecasting towards impact-based forecasting requires linking forecasts with vulnerability and exposure data.

The hazard forecast is combined with the vulnerability and exposure layers to create an impact-based forecast output that will indicate where there is an increased risk of different levels of impacts to different populations.


**Figure 4: From forecast to impact**

A rapid impact forecast tool has been developed for the national level using 47 FFWC forecasting stations. The national-level impact forecast tool includes (i) the FFWC station representing the district's flooding; (ii) the thresholds of the severity of impacts based on the danger level: Normal, low, medium, and high; (iii) prioritization of the response activities based on impact score and the vulnerability.

However, the FFWC flood depth forecast map is not regularly produced because of resource limitations.

A flood alert tool has been developed by the German Red Cross and BDRCS with technical guidance from the Red Cross Climate Center (RCCC) to produce flood depth maps using 8 FFWC forecasting stations along the Jamuna river and considering embankments. The tool uses a 1 in 10-year return period flood depth map to estimate the impacts for prioritizing the intervene Unions for anticipatory action.

This tool can be supplemented with local knowledge and validation, the use of remote sensing data, exposure elements such as protected areas (Table 4), and most importantly the vulnerability data at the Upazila or union level.

The government from the 1960s started implementing flood control drainage and irrigation projects to assure safe agricultural production from flooding. Since, the BWDB, under the Ministry of Water Resources, constructed embankments to protect the area from floods of which about 50% are in the coastal area to protect from tidal flooding. In the Jamuna flood plain (pilot study area), there about 800 km of a constructed embankment to protect 40% of the land area from floods.

There are thus three exposure categories: (1) Protected areas from a flood (ii) unprotected Chars/island in the Jamuna, and (ii) unprotected mainland (shown in Table 2).

**Table 4: Exposure Categories in Jamuna flood plain (pilot study area)**

| Exposure type | Area (sq.km) | Percentage |
|---|---|---|
| **Protected area** | 9,461 | 40 |
| **Unprotected Charland area** | 2,710 | 11 |
| **Unprotected Mainland area** | 11,772 | 49 |
| **Total area** | 23,943 | |

Embankment 800 km, source BWDB

## 2.4 INTERVENTION MAP

To support the geographic prioritization of the anticipatory action framework, an intervention map is produced, to identify the unions where the forecasted flood impact crosses a specific limit. This map builds on the flood depth and population data.

To identify where to activate, as shown in figure 5, at the first stage, the unions will be identified where the impact crosses the limit. Following steps are undertaken to identify the unions where impact crosses the limit:

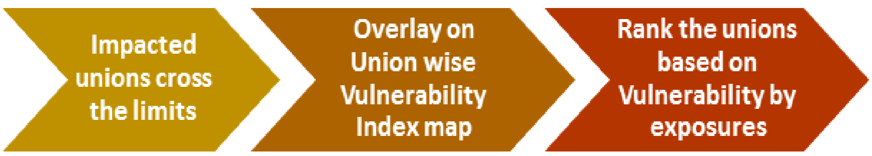
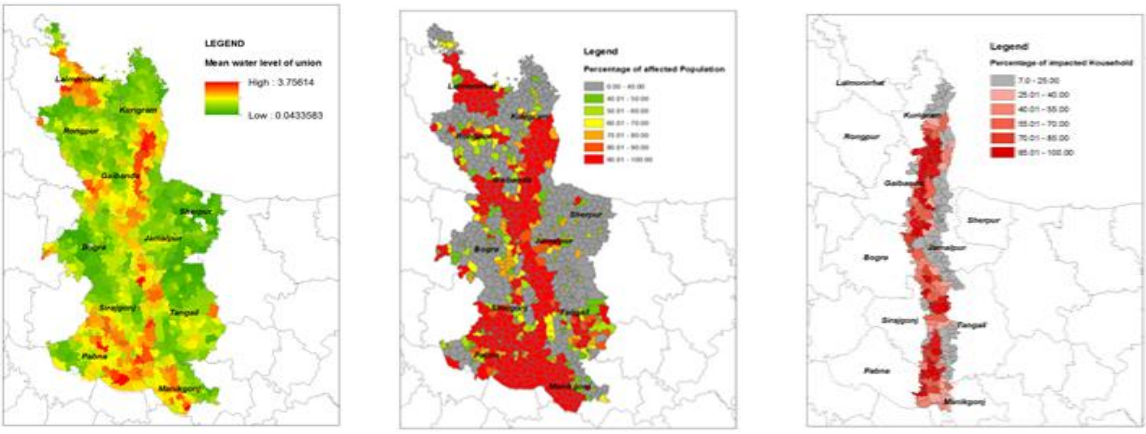



**Figure 5: Methodology to identify 'Where to activate'**

1) Flood Forecast – flood depth map – union wise average water depth
2) Apply affected population based on flood depth (Figure 6)
3) Impacted HH asset based on flood depth (in the unions of the district(s))

Thereafter, the vulnerability index layer will be overlaid to identify and rank the unions with potential largest impacts (Figure 6).




(a) Average forecast flood depth (in meters)

(b) Affected population limit 40%

(c) Impacted HH asset limit 25%

**Figure 6: Forecasted water depth and Impacts on population and HH asset**

# 3 THE 2020 MONSOON SEASON IN BANGLADESH

## 3.1 2020 FORECASTS, TRIGGERS, AND ACTIVATION

To recall, the pre-activation of the pilot occurs when flow at Bahadurabad on Jamuna has 50% or more probability to exceed 1 in 5 years. The flow remains above for three days with 10 days lead time. The flood year 2020 uses the Global Probabilistic Distributed Hydrological model as a source for triggering Anticipatory Action. Also, it checks the 10 days probabilistic forecast by the FFWC model and the experimental RIMS 15 days forecast. The forecast flood depth map (corresponding forecasting return period) will identify the areas/Unions that cross the impact limits (25% HH asset damage).

The pre-activation (or readiness) trigger occurred on 4 July. GLOFAS forecast a 50% chance that the flow will cross the 1 in 5 year return period after 14th July and remain above for more than 3 days and also shows flow likely to cross 1 in 10-year flow level on 15th July (Figure 7). Accordingly, on Saturday (holiday) afternoon at 4 pm activate the pre-action readiness trigger. On 4th July the water level steady and the FFWC forecast shows WL will go down in the next 5day. But then again 10 days probabilistic forecast from FFWC/RIMS (15 days experimental forecast) forecast shows that river flow water likely to reach its trigger limit on 18th July. Although observed data shows the date of the cross the DL +0.85 m at Bahadurabad on 14th July, hence GLOFAS forecast match.

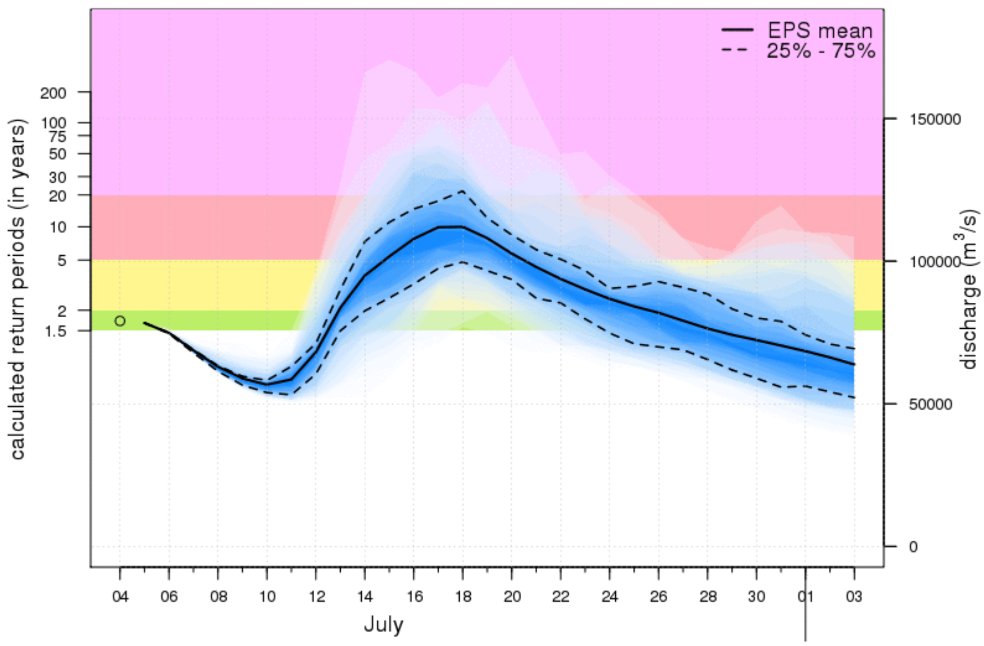



**Figure 7: GLOFAS forecast on 4 July 2020 at Bahadurabad at the moment of triggering**

**The activation trigger occurs** when the water level at Bahadurabad likely to cross DL +0.85 meter and remain above for three days with 5 days lead time. This uses the FFWC 5 days deterministic hydrodynamic model as a source. To check the flow duration that remains above for 3 days or more beyond 5 days in FFWC forecast, the trigger team consulted with other probabilistic models such as FFWC 10 days, GLOFAS 30 days, and RIMS 15 days forecast.

From 4 July onwards, the BDRCS-led forecast monitoring team continuously monitored the FFWC 5 days forecast. On 11 July, FFWC 5 days deterministic forecast shows highly likely it will cross the DL +0.85m on 15 July and forecasting impact likely to cross limit in many Unions (figure 8). On 11 July, the water level at Bahadurabad and upstream gauges have crossed the Danger Level (figure 8). However, observed data shows the flood level at Bahadruabd crossed the threshold on 14 July already, almost 1 day before the forecasted date. The FFWC flood 2020 forecast found within 15 cm agreement up to 3 days lead time but 4- and 5-days lead time is erroneous in terms of time and magnitude.

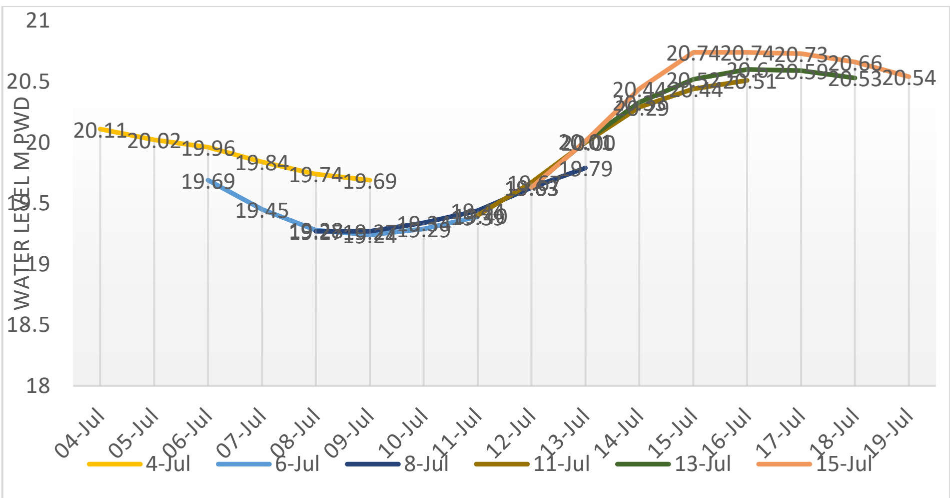



**Figure 8: FFWC 5-day deterministic model forecast from 4 to 11 July 2020 at Bahadurabad**

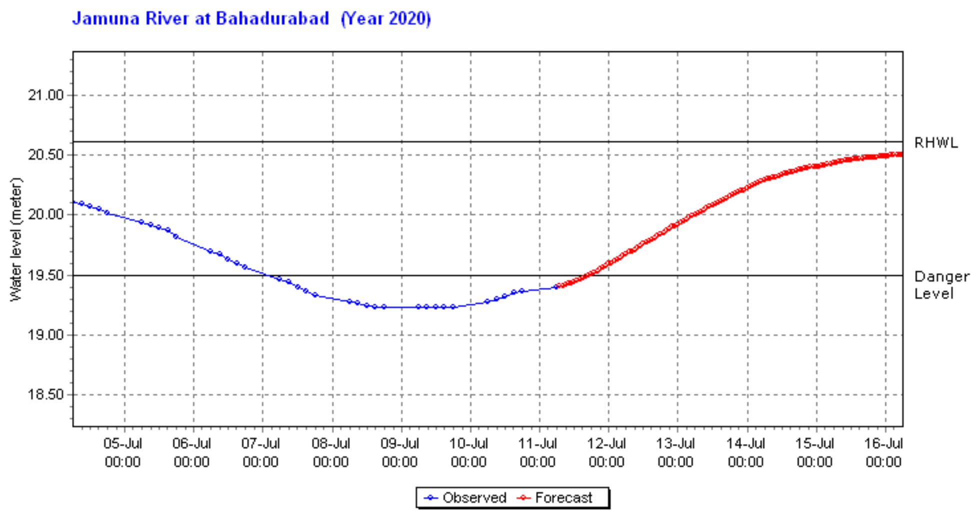
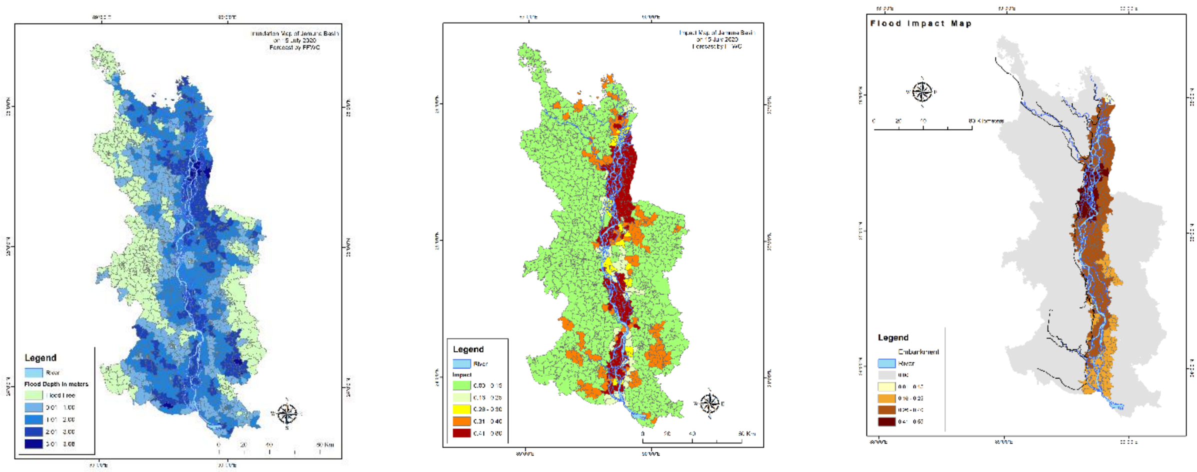



**Figure 9: FFWC 5-day deterministic model forecast on 11 July 2020 at Bahadurabad**

## 3.2 FLOOD DEPTH, DURATION, AND IMPACT

Figure 10 shows the flood impact based on the FFWC flood depth map on 15 July 2020 and compares against the flood tool generated forecast on 11 July for the 15 July impact. It shows there are variations tabulated in table 5.




(a) FFWC 15th July Flood depth map (source FFWC raster file)

(b) Flood impacts based on FFWC 15th July flood depth map

(c) Forecasted Impact map on 11th June for 15th July (Flood alert tool FbF)

**Figure 10: Flood depth and impact map (15th July 2020) for the Jamuna river floodplain**

Table 5 shows according to the FFWD flood depth map impact unions 129 but from the FbF flood tool the forecasted unions 133 which likely to cross the impact limit (25% of the household asset). There is not much variation at the Union level but large variation at the District level.

**Table 5: Variation of Impact forecast unions between FFWC and FbF flood tool, July 15, 2020 flood**

| ***District*** | ***Trigger Unions 11 July*** | ***Population*** | ***Unions FFWC FM July 15*** |
|---|---|---|---|
| Bogra | 13 | 196,869 | 8 |
| Gaibandha | 15 | 329,697 | 11 |
| Jamalpur | 55 | 881,167 | 39 |
| Kurigram | 24 | 619,429 | 41 |
| Sirajganj | 26 | 640,165 | 30 |
| Total | 133 | 2,667,327 | 129 |

Also, compare the average depth of flood between two sources shown in Figure 13. Very good and Good agreements are 13% and 52% respectively. FFWC flood depth shows overestimated (0.5 meters) compare to the FbF alert tool. Without a field survey difficult to assess which represents the actual impacts.

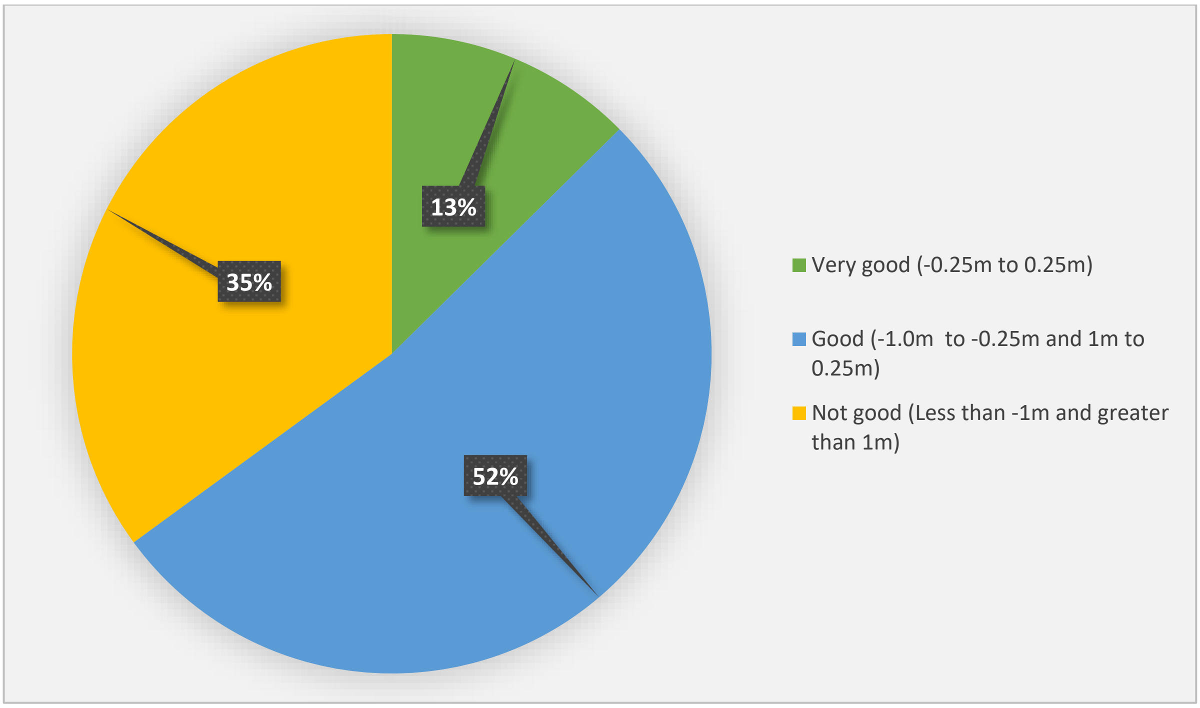



**Figure 11: Flood depth variation between FFWC and FbF flood alert tool (For 15th July 2020)**

The impact forecast yielded good results from the perspective of beneficiaries. From the 2020 Beneficiary Assessment, we see that around 81% of the people reported having been "severely affected" by the floods. Another 18% reports having been slightly affected. The rest said they weren't affected. The survey data from 9100 interviews after the flood in 2020 shows about 60% of the houses were flooded above the floor, and 5% did not flood as shown inf Figure 7.

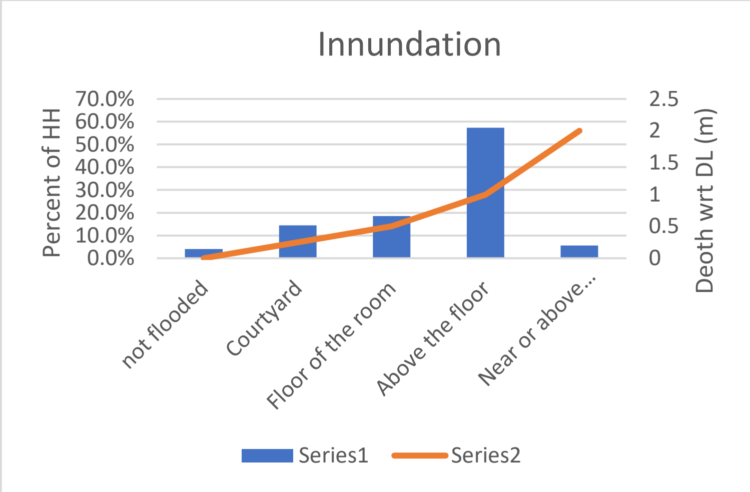



**Figure 12: House inundation of 2020 flood in the Jamuna floodplain**

## 3.3 AFFECTED POPULATION

According to the National Disaster Response Coordination Center (NDRCC), one (1) million households were waterlogged. The disruption of services hindered meeting basic needs and, people suffered from hunger, illness, thirst, and filthiness. The NDRCC report informs that at the peak on 4 August 2020, 5.5 million people were directly affected and, that 1,059,295 households were inundated. Among them, 211,859 families were displaced, and 94,414 people were evacuated in 1,525 shelters. The Department of Public Health and Engineering (DPHE) informs that 928,60 tube-wells and 100,223 latrines were damaged. The Ministry of Agriculture (MoA) informed that around 83,000 hectares of paddy fields were affected. According to the Ministry of Health and Family Welfare (MoHFW), 257 people lost their lives due to floods.

Thirteen districts in Bangladesh were severely affected, where water levels crossed the Danger Level + 0.85-meter mark and remained above for more than 5 days. Six districts are in the Jamuna flood plain area based on the FFWC forecast on 18th July 2020. The historical data on the affected population is illustrated in Figure 13. Over this period, the affected population has reduced substantially due to an effective early warning system in place and mitigation measures by the DRR program in the country.

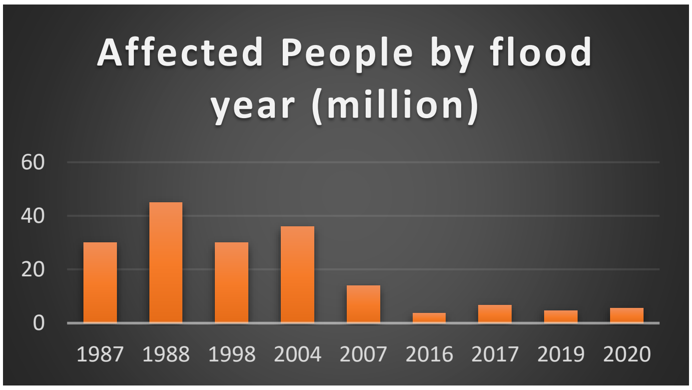



**Figure 13: Affected population from 1987 to 2020 (source CEGIS, DDM, and NDRCC)**

## 3.4 OBSERVED FLOOD PEAKS

Three were four flood peaks in 2020 for the Jamuna river as measured in Bahadurabad. The first peak was on 30 June which just barely reached the trigger water level (20.35m PWD). The second peak was 20.79 m PWD on 16 July, the third was 20.6 m PWD on 27 July and finally, the fourth peak was 20.07 m PWD on 3 August (shown in figure 14).

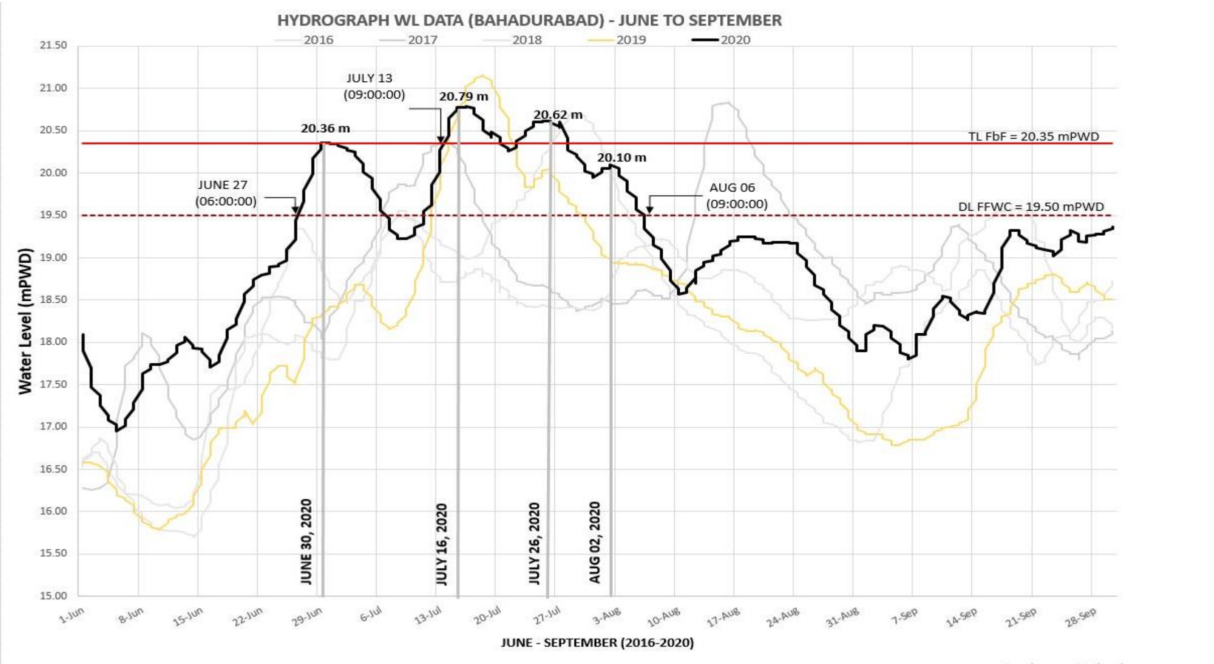



**Figure 14: Hydrographs showing peaks in 2020 flood at Bahadurabad compared to other flood years**

Of note, the first flood wave crossed the threshold (20.35 m) on 29 June for 39 hours but did not meet the criteria of activation for a predicted duration of 72 hours. While the second flood wave crossed the threshold on 14th and remained above for 6 days and 12 hours. The framework was triggered based on predictions for this second peak.

The above analysis focuses on peak levels at Bahadurabad gauging station. The timing, magnitude, and duration of peak flood levels varied across time and space along the Jamuna river basin (see figure 15).

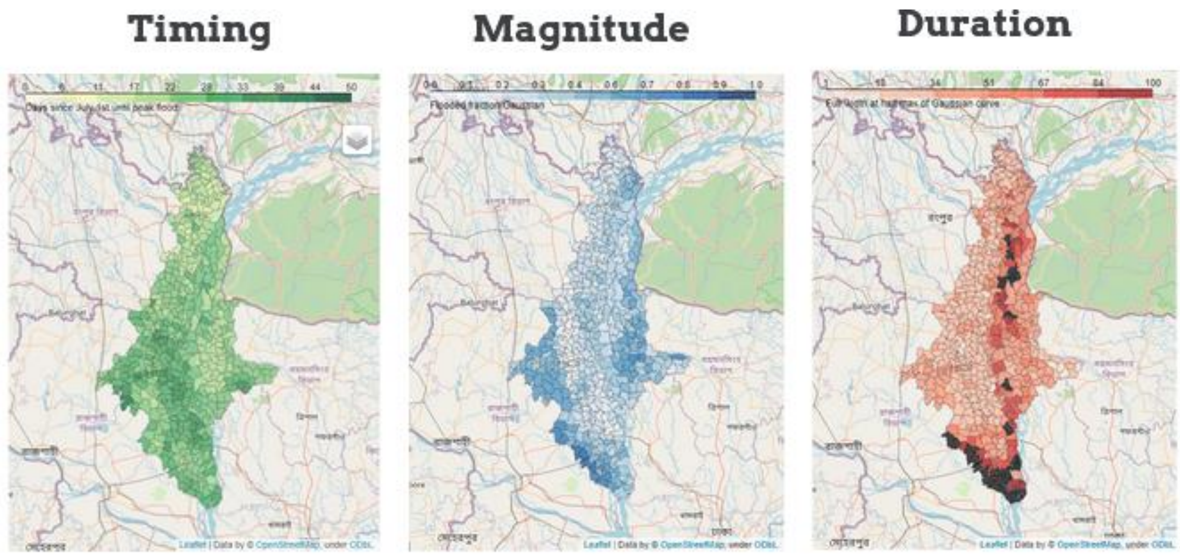



**Figure 15: Timing, Magnitude, and Duration of 2020 floods along Jamuna river (source: Center for Humanitarian Data)**

## 3.1 HYDROLOGY AND HYDRAULICS

Bangladesh Water Development Board (BWDB) under the Ministry of Water Resources regularly observes the water level at sixty (60) hydrological stations. Bahadurabad stations are one of the long records at the upstream inlet on the Brahmaputra-Jamuna river. The maximum recorded water level at Bahadurabad is 5cm and 37cm higher for the year 2017 and 2019 respectively with respect to flood in 2020.

BWDB water level data at Bahadurabad from 1964 to 2020 was collected and the annual maximum water level at Bahadurabad is shown in Figure 5. In the last 55 years, the record shows that after the 1988 flood there were eight (8) instances when it crossed DL+0.85m. In the last 5 years (2016 to 2020), four floods crossed DL+0.85 m. The reason perhaps due to any river hydro-morphological changes or climate change.

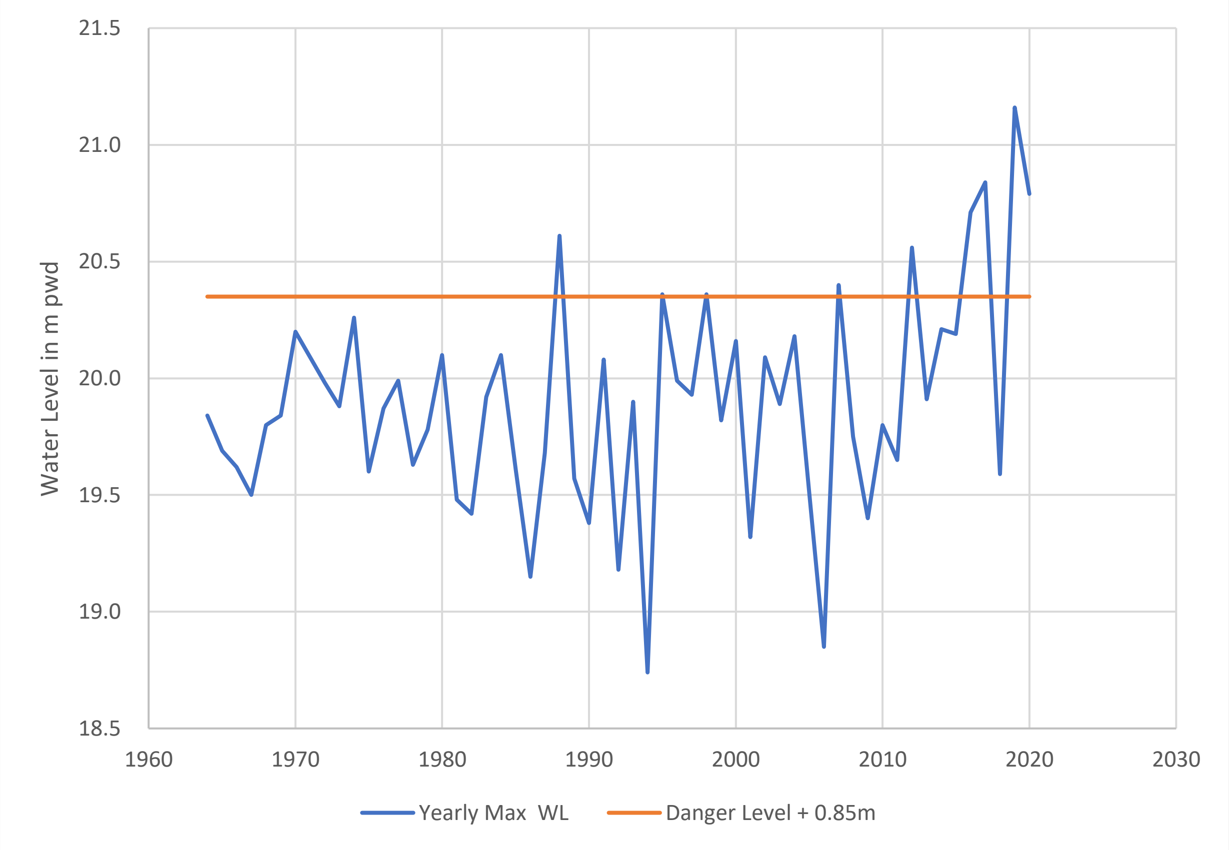



**Figure 16: Annual Max Water Level at Bahadurabad (BWDB, 1964-2020)**

To understand the recent behavior of floods in the Jamuna river, the frequency analysis using Gumbel distribution for the station records at Bahadurabad with yearly peak. The analysis shows yearly maximum water level at Bahadurabad represents a return period of 1 in 10-year using Gumbel distribution is 20.5 m PWD (DL +1.0) with 55 years of data from 1964 to 2020. However, WL of 20.7 m corresponds to a 1 in 10-year return period for the time series between 1991 and 2020, which is 20 cm higher (Figure 16). This perhaps is a combination due to climate change and reduction in the channel capacity due to siltation or other factors in recent years.

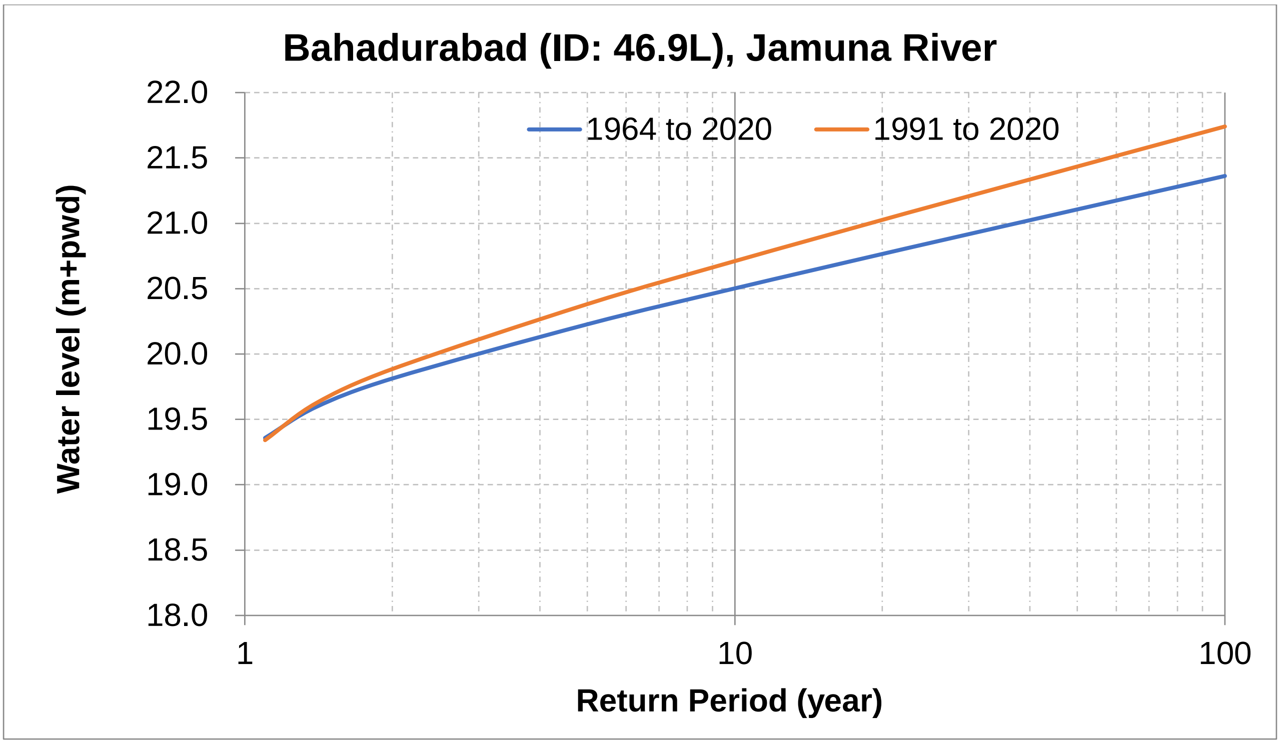



**Figure 17: Gumbel distribution for yearly maximum water level at Bahadurabad on river Jamuna**

### *3.1.1 Flood wave traveling time*

The floodwater enters in Brahmaputra-Jamuna river floodplain in Bangladesh from the rivers Bhamaputra at Noonkhawa, Dharla, Dudkumar, and Teesta. The first flood wave (29 June) traveling time from the measurement station at Noonkhawa to Shirajganj is about 48 hours covering about 185 km. While 2nd wave (15 July) takes 57 hours from Nonnkhawa to Shirajganj and reaches Aricha 72 hrs. (57+15). Nookhawa is used as a boundary station, but Chilmari is the forecasting station of FFWC, and the travel time between these two is 0-3 hours. We can gain 48 hours as the lead time for the intervention in Serajganj compares to early action in Kurigram.

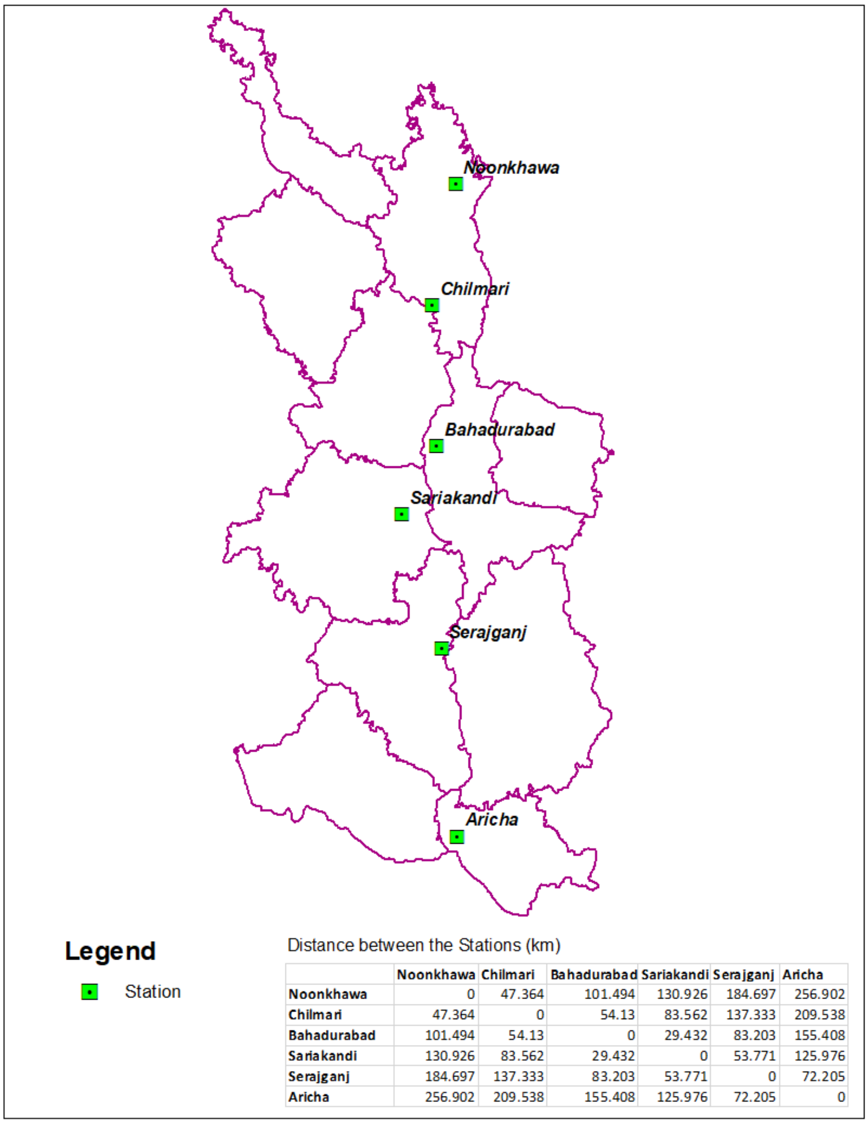
The Distance between Noonkhawa to Aricha is about 256 km and the flood wave traveling distance between the six stations is shown in Figure 8. The distance from Bahadurabad to Shirajganj is about 85 km and the traveling time for the 2nd flood peek is about 30 hours. The flood wave velocity between Noonkhawa to Shirajganj 3.2 km/hr. but faster wave velocity (3.5 km/hr.) between Sirajgan and Aricha. Although, it should be another way around, maybe due to the backwater effects of the Jamuna bridge at Shirajganj.

### *3.1.2 Duration of exceeding the thresholds*

FFWC/BWDB's six stations along the Brahmaputra-Jamuna river were analyzed to compute inundation duration for different thresholds as shown in Table 6. According to observation data, the flood level does not cross DL+1.0m at Noonkhaw, Serajganj, and Aricha. The recent flood duration above DL +1 meter in 2017, 2019, and 2020 are 4, 7, and 8 days respectively at Bahadurabad station.

**Table 6: Duration of flow crossing threshold at BWDB stations, Jamuna, 2020 flood.**

| SL | Station Name | DL | DL +0.5m | DL +1m |
|---|---|---|---|---|
| 1 | Noonkhawa | 30 | 14 | |
| 2 | Chilmari | 36 | 17 | 1 |
| 3 | Bahadurabad | 39 | 28 | 8 |
| 4 | Sariakandi | 55 | 28 | 9 |
| 5 | Serajganj | 34 | 16 | |
| 6 | Aricha | 31 | 16 | |




| | Noonkhawa | Chilmari | Bahadurabad | Sariakandi | Serajganj | Aricha |
|---|---|---|---|---|---|---|
| Noonkhawa | 0 | 47.364 | 101.494 | 130.926 | 184.697 | 256.902 |
| Chilmari | 47.364 | 0 | 54.13 | 83.562 | 137.333 | 209.538 |
| Bahadurabad | 101.494 | 54.13 | 0 | 29.432 | 83.203 | 155.408 |
| Sariakandi | 130.926 | 83.562 | 29.432 | 0 | 53.771 | 125.976 |
| Serajganj | 184.697 | 137.333 | 83.203 | 53.771 | 0 | 72.205 |
| Aricha | 256.902 | 209.538 | 155.408 | 125.976 | 72.205 | 0 |

**Figure 18: Location of Measuring stations of BWDB along the river Jamuna and its traveling time with distance.**

# 4 LEARNING

From the above observation and analysis of the trigger model following is the learning summary:

a) The affected population by flood 2020 is less than 2019 flood but the impact is higher could be the duration and unexpected new area were flooded. The maximum recorded water level at Bahadurabad is 5cm and 37cm higher for the year 2017 and 2019 respectively with respect to flood in 2020. The recent flood duration above DL +1 meter in 2017, 2019, and 2020 are 4, 7, and 8 days respectively at Bahadurabad station.
b) Fixing a threshold (say 1 in 10-year return period to define extreme event) found difficult possibly due to climate change impacts on hydrology and dynamics of large river morphology. In the last 5 years (2016 to 2020), four floods crossed DL+0.85m. Besides, frequency analysis shows that water level 20 cm higher represents 1 in 10-year return period with respect to recent data (1991 to 2020) compare to long recodes (1964 to 2020).
c) Challenge to define the impact limits. In 2015-16 survey data and consultation with the community to find the condition to evacuate with respect to courtyard level and found 0.5 m (DL +1.0) cause 25% impact of HH asset. The Vanderbari (Bogra District) land survey data shows about 40% of people will be affected if the water level reaches DL + 1.0. Although the survey data from 9100 interviews (no GPS) after the flood in 2020 shows about 60% of the houses were flooded above the floor of the house. There may be differences in the assumption of plinth/floor level of houses used previous activations with respect to the recent OCHA survey 0.5m and may need further investigation.
d) Lead time for the activation can be added as the flood wave traveling time between Chilmari to Sarangi about 2 days. To take the advance, anticipatory action can be started from upstream to the downstream unions.
e) Pre-activation lead time using GLOFAS match, but flood wave come 1-2 days early according to the forecast of RIMS model. GLOFAS forecast is available in the afternoon which loss a day.
f) FFWC forecast on 11th June at Bahadurabad, water level likely to cross DL +0.85 meter on 15th July but observation data shows that the WL cross on 14th July. This means activation time reduce by one day.
g) Difficult to access flood depth map from FFWC because of lack of resources (manpower, hardware, upgrade software). FbF alert tool to estimate the flood depth and impacts for the Unions in the Jamuna river floodplain found good agreements with FFWC flood depth map but need improvement.

# 5 RECOMMENDATIONS

## 5.1 BANGLADESH

1. Scale up the existing Jamuna river flood plain trigger model to cover all the river flood risk areas in the country. Existing FFWC (1-5days) forecast 47 locations along the river and cover 2/3rd of river flood risk area. But tidal floods are not covered and flash flood areas in the northeastern part of Bangladesh with limited lead time. Develop an alert tool using FFWC 1-5days forecast mainly in the Northwest, central region (Padma river), and part of Ganges river flood plain. Hence, IbF steps can be followed to develop the trigger for the national level Anticipatory Action. But need pre-processing to apply the IbF methodology at the national level. The pre-preprocessing includes:

2. Understanding of flood risk to prioritize the districts to consider in phases.
3. Defining influence area of FFWC stations using remote sensing (flood extend) data and historical water level records. Also consider the connectivity from the river to the flood plain using DEM, river network, and flood flow berries such as roads and embankments for delineating flood cells.
4. Define community-based danger level (impact level) for each flood cell and link with the government defines DL of the respective station.
5. Increase the lead time by use flood wave traveling time between the gauges. Divide the area or attribute the flood cells with forecast skill categories against the lead time.
6. Improve Readiness for Anticipatory Actions: Seasonal or sub-seasonal forecast can be used to get ready with resources including the financial arrangement of respective department/agencies of the government or development partners. As part of readiness, no regrade options can be considered. Also, use mid-range forecast at Harding Bridge on the Ganges, Bahadurabad on Jamuna, and Bhairab Bridge on Meghna to inform and alert the concerned district disaster committees. Develop an alert tool for DDM and other key stakeholders.
7. Develop Sector-based Multiple trigger framework for the Government: The sector such as agriculture, health, infrastructure, and humanitarian sectors are at risk from floods for different thresholds and conditions of timing and duration. Say as an example for agriculture sector (with consultation) – define the Timing of flood in late August, duration 7 days plus and threshold DL to DL 0.5 m and the map showing the location.
8. Build capacity and awareness on Anticipatory Actin for a flood: FFWC, BMD, and DDM (government organizations) buy in the criteria and threshold used in the trigger model. Build FFWC capacity from hazard forecast to impact-based forecast and institutionalize the trigger model in close coordination with ARRCC program of UKMet office. Provide support to FFWC with resources to update the hardware and software for the flood depth map.
9. Update the trigger model for Jamuna river basin from learning 2020 flood.

## Specific recommendation for improvement of the forecast

FFWC flood model uses boundary data from 24 hours Indian forecast, rainfall forecast using WRF model / BMD data. Besides it uses global model foredate such as GLOFAS. However, in the end it uses judgment and expert opinion and manual inputs the boundary data in the FFWC deterministic flood foredate model. It has been observed that beyond 3 days, the forecast skill is not up to par. Forecasts are undershooting about 30-40 cm with a lead time of 4 -5 days and reach the flood wave earlier.

Challenge is how forecast skill can be improved with increased lead time and suggestions are as follows:

*a) FFWC model should use boundary flow data from GLOFAS or any hydrological model but no manual inputs. GLOFAS need to calibrate with recent flood discharge measurements at least at Hardinge Bridge on Ganges and Bahadurabad on the Jamuna river are the main source of flooding in Bangladesh.*

*b) Calibrated and validate the combined model (MIKE 11+GLOFAS) for the recent flood years. With Bias correction (undershoot) and lag correction of the forecast, the skill of the forecast will be substantially improved with 5-7 days lead time. More preparedness time and skill for the anticipatory actions.*

c) *The flood depth map needs to improve with recent topography, infrastructure (barrier), and satellite data. The challenge is to build the topography of dynamic islands within the breaded belt of the river. The study can be taken to build a digital elevation model with satellite radar altimetry and field information on the age of char and land use.*

d) *There is no alternative to improve flood depth forecast, without improving discharge measurements and cross-sections of the river system and continue water level measurement with quality.*

e) *Besides, the need adjustment of the GLOFAS discharge values for the return periods match with the observed discharge data used by FFWC.*

**Upgrade and update the trigger threshold and criteria for Anticipatory Action.**

a) *Pre-activation trigger: Lead time is 10 days but, it is actually 8-9 days. After 2020 flood activation, both BDRCS and WFP felt necessary to increase the lead time for the pre-activation trigger to 15 days to get ready for activation of humanitarian assistance. There also needs to harmonize the threshold as an extreme event, BDRCS follow 1 in 10 years but AA Pilot use 1 in 5-year return period but both use GLOFAS 50% probability. Also need to find is the chances to reach activation trigger with a lead time of 15 days.*

b) *Activation trigger – Now 5 days but with combo model of MIKE 11 + GLOFAS may increase the lead time to 7 days. Before the model is ready continue with 5 days.*

## 5.2 REGIONAL

In the region, the extreme rainfall in the summer led to massive **flooding** in In Indonesia, Nepal, Pakistan, Mongolia, Bangladesh, and India, and millions of vulnerable populations loss of life and livelihoods.

The Red Cross Red Crescent Movement currently implements Anticipatory Action (FbF, FbA, etc) for humanitarian assistance in 12 counties in the Asia Pacific region. Since 2015, BDRCS/GRC and WFP develop the EAP and implementing FbF in Bangladesh with technical assistance from Climate Center (RCCC). In 2017, Vietnam and the Philippines start FbA for a flood. RCCC carry out a FbA feasibility study for Indonesia and Nepal and start piloting.

Hence, OCHA can extend the support to the region from learning in AA pilot in Bangladesh are:

- Conduct regional workshop on AA concept, implementation challenges, and shear lesson learning from AA flood pilot in Bangladesh. The participants from DM authorities and Hyro-met departs in Nepal, Pakistan, India, Indonesia, and Myanmar.
- Develop a road map on OCHA assistance with technology and finance to the FbA feasible countries in the region.