# Terms of Reference
## for
## Consultancy to develop, implement and operationalize aFlood Forecast and Inundation Model using public  domain and license-free softwarein Bagmati-Adhwara Basin

## 1. BACKGROUND

Bihar is India's most flood-prone State, with 76 per cent of the population in the north living under the recurring threat of flood devastation. Recurrent floods are devastating to Bihar's economy and undermine poverty alleviation efforts. There is a need to develop a long-term flood management strategy for Bihar based on analysis and stakeholder inputs that builds upon the wisdom of the substantial documentation that currently exists on the problem. The Flood Management Information System (FMIS) Centre developed under two previous DfID-financed grants, aims to generate and disseminate timely and customized information to move from disaster response to improved disaster preparedness and to effectively support flood control and management in the flood-prone areas of the State.

The FMIS Centre.under a previous consultancy, has developed a flood forecasting model (using the proprietary NAM/MIKE11 software) and inundation mapping tools from Dheng bridge to Hayaghat for the B-A basin. It is now proposed to improve  and consolidate this model with appropriate meteorological inputs. It is also proposed to develop,in parallel, a model with public domain and licensefree software to compare and enable scalingup to other basins in the State.

## 2. OBJECTIVES

The objective is to develop, implement and operationalize a comprehensive model/ suite of models for flood forecasting bundled with  inundation mapping tools,using public domain and license free software,along the main river in the Bagmati-Adhwara river basin.

1)  to forecast water level and discharge at any section

2)  to predict extent, time of arrival, duration and depth of likely inundation at the community level.

## 3. SCOPE

The flood forecast modeling and inundation mapping approach needs to take note of hydrologic and hydraulicdata availabilityin Bagmati-Adhwara basin and propose appropriate data management strategies. The model shall evaluate and use satellite based ensemble rainfall estimate to supplement ground observations, and ensemble weather forecasts to improve (in reliability and lead-time) probabilistic flood forecast.The forecasting and inundation mapping would be along the main stem of Bagmati-Adhwara river system. The software application shall provide necessary simpletools to import grid

or sub-basin-wise rainfall estimates and forecasts from the customized meteorological framework application (under development in a separate consultancy) andthe FMISC database including spatial data in Arc GIS environment, and for generating model inputsand to visualize model outputs. The model results shall also be exported for publicationin the FMIS website. The system should be able to convert the inundation mapping outputs to SMS alerts to send to designated recipients. Suggestions for additional functionalities to improve ease-of-use are encouraged from the consultant.Capacity building in WRD through structured and hands-on training is essential to operationalize the model and to sustain operations through model upgrading. The consultant is expected to closely interact with the WRD engineers during development. Consultant shall also suggest how flood model operations can be sustained in WRD through strengthening capacity in staff and skill sets, equipment, mainstreaming in WRD, and integrating in Standard Operating Plans of the department.

## 4.Tasks and Deliverables

### Task 1(by month 1)

Review current status of data availability and quality, basin hydrology and hydraulics and select the Public Domain / License free Softwarethat can best meet consultancy objectives.

Task 1.1

Selection of public domain / license free software appropriatefor the complex basin hydrology and hydraulics of the B-A basin, data availability and objectives.

### Task 2 (by month 2)

To evaluate satellite based ensemble rainfall estimates and short to medium range ensemble weather forecasts available from the customized meteorological framework, for supplementing existing ground measurements and current IMD forecast for integration in the flood forecast model.

Task 2.1
Accessensemble rainfall estimates and weather forecast customized for B-Abasin from the customized meteorological framework being developed under a separate consultancy and evaluate for supplementing ground rainfall measurements and to improve weather forecast for use in making   deterministic flood forecasts with short lead time (1-3 days) and  probabilistic flood forecasts with medium (up to 10 days) lead time.

*Output*

Report on proposed approach for integrating ensemble rainfall estimates and weather forecasts in the flood forecast model.

### Task 3 (by month 5)

Design, Develop, calibrateand validate selected public domain /license-free software based model to provideflood forecasts (stage and discharge) at any location along the main stem with longer lead-time (short range at one to three days and medium rangeupto ten days).Accuracy will be reported as the range in stage and dischargeatspecified confidence level for different lead-times as agreed with WRD, based on performance of similar models elsewhere.

Task 3.1
Package input data set for the model, including ensemble rainfall estimates and ensemble weather forecasts.

Task 3.2

Develop, calibrateand validate selected public domain /license-free software based model to providedeterministic and probabilistic flood forecast in short and medium range.

Task 3.3

Develop and integrate customized front-end tool to package user-selectable model parameters such as rainfall measurements, estimates and forecasts from global and national sources, and thematic data from the spatial data system, and other parameters for plugging into the model.

Task 3.4
Develop and integrate customized tool for generating spatial and non-spatial outputs including hydrologic status and flood warning reportsin appropriateformats. This application should include tools for generating hydrograph and travel time of flood from different hydrological observation site to another in Bihar Region, and travel time of flood and flood hydrograph at Dheng Bridge due to rainfall occurring in Nepal region.

Task 3.5

Develop and integrate tool for sharing model outputs to update flood levels and discharge in the Embankment Asset Management System (EAMS) developed under a different consultancy. Also tools to exchange data with  Hydrologic Information System ( HIS),  to import current data on rainfall and river stage and discharge, and to export forecasted water level and discharge.

Task 3.6

Install Beta version of model in FMISC for evaluation  by a joint team of FMISC engineers and consultant staff

*Output*

Report on design, development, calibration,  validation  of the flood forecast model.

Beta version of model

**Tasks 4 (by month 7)**

Develop Inundation mapping tools to predict extent, time of arrival, duration and depth of inundation at the community level along the main stem of Bagmati-Adhwara  river system, and validate.The accuracy for inundation maps (extent, depth and duration) would be dependent on data available for validation, DEM used, and mapping tools developed, and would be mutually agreed between the client and consultanttaking note of accuracy achieved elsewhere.

The mapping tool would need to take note of the multiple causes of flooding in any location. Inundation could be from embankment breaches and cuts along the jacketed portions of the rivers, over-bank flow in the un-jacketed portions, tributary flooding backing up behind the embankments, local heavy rainfall and impeded drainage in other areas. The model should have the ability to test these various scenarios.  Validationcould be based on historical inundation maps available FMISC and reported flooding area.

Task 4.1

Develop appropriate inundation mapping tools to predict inundation extent, depth, arrival time and duration and validate.

Task 4.2

a) Develop Graphical User Interface (GUI) to generate standard and customized inundation products such as flood extent map and tabular data showing administrative units affected. Develop application to generate likely flood forecast and Inundation products for publishing to the FMIS website and integration to EAMS

b) Develop a library of possible inundation scenario for vulnerable breach locations and flow conditions for integration to EAMS.

Task 4.3

Develop and integrate a tool to generate community targeted inundation forecasts and/or alert messages (via SMS) and to publish at the FMIS website to display likely affected area maps and to generate products based on user-selected geographical area and time period.

Task 4.4

Install Beta version of forecasting model with inundation mapping tools for evaluation by joint team of FMISC engineers and consultant.

*Outputs*

Flood inundation mapping tool to map inundation extent, at any location along the main stem. The tool would also compute/predict depth, arrival time and duration. The tool should include customized application software for generating inundation maps and tabular data for potential breach locations and specified flow condition.

Library of possible inundation scenario for vulnerable breach locations and flow conditions
Beta version of forecasting model with inundation mapping tools


**Task 5 (by month 9)**

Implement and operationalize the flood forecast model and inundation mapping tool in WRD

Task 5.1

Implement the flood forecast model and inundation mapping tool in multi user platform. The software should be installed at a central server and should allow concurrent users not more than ten to access the model from intranet or internet.

Task 5.2

 Provide training to model team of WRD.

Two training sessions will be provided to a minimum of 10 engineers of WRD. The first training will be on model selection, modeling concepts, model setup including data selection, quality control and packaging, calibration, and validation,and a case study based on the selected open source model. This will be just after Task 1and will be of five days duration The second training will be on flood forecast model and inundation mapping tool developed in this project. The training should be on actual model setup, calibration, validation and model upgrading with new and better data ( such as network strengthening, new cross section survey, change in model setup if any) for 15 working days. This should includehands on trainingfor minimum of 10 working days.  The consultant would provide just the trainer and training material whereas other logistics like venue, arrangements, food etc would be taken care of by the employer.

Task 5.3

Prepare Manuals thatinclude
a) Installation manual, including trouble shooting and interfacing the model with other information system

b) User manual covering model setup, calibration, validation operational use and upgrading for new/ updated input data in future.

c) Comprehensive training manual containing training material and supplementary information related to flood modeling

Task 5.4

Recommendations for sustainable model operation by WRD, that includes staffing, skill upgrading, and equipment upgrading (hardware, software and communication & networking). Provide framework for scaling up the model to other basins in Bihar state.

Outputs

Training Reports and Manuals
Report on sustaining model operation in WRD
Plan for post-installation maintenance support
Flood forecasting and inundation mapping system
Report on suggested framework for scaling-up to other basins
Final Report on implementation and operationlization in WRD including upscaling to other river basins in the State
Operational Flood forecasting model with inundation mapping tools

## 5. Reporting and Review

All reports should be submitted in hardcopy (10 copies) and soft copy (5) of each report in word format in DVD/ CD media.

The following reports will be reviewed and approved within 2 weeks after submission, by a Standing Review Committee constituted by WRD.

1. Inception Report

2. Report on design, development, calibration, validation of the flood forecast model.

3. Report on design, development, calibration, validation of the flood forecast model and inundation mapping tools and installation of Beta version

4. Final Report on implementation and operationlization in WRD including the Report on suggested framework for scaling up for other basins in Bihar

Reporting Schedule

- Inception Report will be submitted within 1 month after effective contract
- Report on proposed approach for integrating ensemble rainfall estimates and weather forecasts in the flood forecast modelwithin 2 months

- Report on design, development, calibration, validation of the flood forecast model within 5 months
- Report on design, development, calibration, validation of the flood forecast model and inundation mapping tools,and installation of Beta version, within 7 months
- Final Report on implementation and operationlization in WRD including the Report on suggested framework for scaling up for other basins in Bihar within 9 months

Review Committee

| SL No. | Designation | Position in Review Committee |
|---|---|---|
| 1 | Chief Engineer, Planning & Monitoring Patna, | Chairman |
| 2 | Chief Engineer Muzaffarpur / Samastipur | Member |
| 3 | Superintending Engineer, Monitoring Circle -1, Patna | Member |
| 4 | Superintending Engineer, Flood Monitoring Circle | Member |
| 5 | Joint Director, FMISC, WRD, Patna, | Member |
| 6 | Deputy Director-1, FMISC, WRD, Patna, | Member Secretary |
| 7 | Executive Engineer, Flood Control & Monitoring Division-1, Patna | Member |
| 8 | Mr. S. K. Sinha, E-in-C (Retd.), WRD, GOB, Flood Management Specialist –cum- Project Advisor, FMIS-II Project, | Member |
| 9 | Mr. S. N. Tiwary, Director, GFCC (Retd.), Embakment Specialist, FMIS-II Project, | Member |
| 10 | Mr. B. K. Gupta, Chief Engineer (Retd.), WRD, GOB | Member |

## 6. POST-IMPLEMENTATION MAINTENANCE SUPPORT SERVICES

The consultant would provide maintenance support for two years after successful implementation. This would include trouble-shooting on-site or through remote assistance.

## 7. DATA, SERVICES AND FACILITIES TO BE PROVIDED BY THE CLIENT

- Office space, and computer hardware and Oracle and GIS software to access confidential data (topo sheets, LIDAR data, CWC stage/discharge data, etc) in secure data handling environment in FMISC.

- Available historic and current data on hydrometeorology, hydrology and hydraulics; available thematic data; rainfall and flood forecast from IMD/CWC; topographic data; embankment breach details
- Facilitate access to other State and central agencies for data collection
- Access to other consultants working on meteorological framework and forecast model development using proprietary software.
- Access to information systems and databases available.
- Facilitate implementing improved flood forecast and inundation mapping tool in WRD

## 8. RESPONSIBILITIES OF THE CONSULTANT

- Conduct and complete the consultancy as per the agreed ToR and scope of the consultancy
- Collect data as needed for modeling from concerned agencies.
- Conduct field visits as required for data collection or to verify model results
- Undertake data conversion of source data as needed for modeling
- The key members of the modeling team are expected to interact with FMISC at key stages as agreed to support collaboration.

## 9. KEY STAFF

The key staff to be provided by the consultant are shown below. However, the consultants are free to propose their own team composition suitable for the project duration of the consultancy for development of flood model.

| Discipline of the Consultant | Qualification and Experience | Suggested Man-Months |
| --- | --- | --- |
| Project Team Leader / Flood modeler | -Advanced academic degree in Hydrology, Hydraulic and / or Water Resources (or allied field) engineering. <br> -10 years working experience in flood / water resources modeling / GIS use for modeling. <br> -Extensive knowledge of hydrological and hydrodynamic modeling tools used in flood forecasting | 9 |
| Database/GIS Specialist | -Graduate in Engineering in Computer Science/IT Database <br> -2 years' experience in GIS and data base applications | 2 |
| Software programmer | -Bachelor degree in computer science/master degree in | 2 |

| | computer applications<br>-Five years' experience in programming for interfacing multiple information systems, web-enabling model outputs, SMS generation, etc. | |
|---|---|---|

## 10. FINANCIAL PROPOSAL

The Consultant has to quote the cost separately for
a) main consultancy,
b) post implementation maintenance support.
The financial evaluation will be based on sum of both costs ie.a+b. The contract amount will cover (a) and payment for (b) will be prorataafter model implementation based on agreement with WRD, Bihar

## 11. PAYMENT SCHEDULE

<u>Payment schedule for (a)</u>

15percent after acceptance of Inception Report.

40percent after acceptance of Report on design, development, calibration, validation of the flood forecasting model with inundation mapping tools, and implementation of Beta version.

45 percentafter implementation of final version of model and tools, and acceptance of Final Report on implementation andoperationlization in WRD including the Report on suggested framework for scaling up for other basins in Bihar

<u>Payment schedule for (b)</u>

Twenty five percent (25 %) of the price agreed for annual technical support services (not exceeding 5% of consultancy cost i.e. (a)) would be paid on quarterly basis on completion of each quarter based on satisfactory review of 'Quarterly Service Delivered Report' describing the services rendered and deliverables produced during this period and satisfactory performance.

## 12. Duration of consultancy

Nine months after effective date of contract which will be signing of contract.

## 13. Estimated cost
To be completed