Section 5. Terms of Reference

Contents

Project Summary:

Hydrology Project-I, an Integrated Hydrological Information System for Central and participating State agencies comprising the infrastructure and human resources to collect, process, store and disseminate hydro-meteorological quantity and quality variables was implemented in the five regions of CWC in peninsular India. The project started in September, 1995 and closed on December, 2003.

The Hydrology Project-II was a follow up on Hydrology Project-I. The overall project development objective was to extend and promote the sustained and effective use of Hydrological Information System by all potential users concerned with Water Resources Planning and Management thereby contributing to improved productivity and cost effectiveness of water related investments. The project was cleared by the CCEA in October, 2005. The agreement for the project between the Govt. of India and the World Bank was signed on 19th January, 2006 and approved by the GOI in the month of May, 2006. The original completion period of HP-II was June, 2012. The project completion period was extended upto May, 2014 by the World Bank. The major components undertaken during HP-II comprise institutional strengthening and vertical extensions.

Based on the successful outcome of Hydrology Project, Government of India, requested World Bank assistance for a follow on project – National Hydrology Project - Approach towards Integrated Water Resources Management'. There are a total of 47 implementing agencies (IAs) including eight central agencies, 37 state-level agencies and two river basin organizations (RBO).

During the NHP, the Central Water Commission will like to focus on core area activities which will improve the overall efficiency. In future, it is expected that inter-state disputes will crop up more and more and pose a challenge in the field of water management aspect. CWC future plan would be ideally focused on development of good forecasting and real-time management facilities to allow the organisation to develop its ability to manage against catastrophes and to support optimum use of water resources.

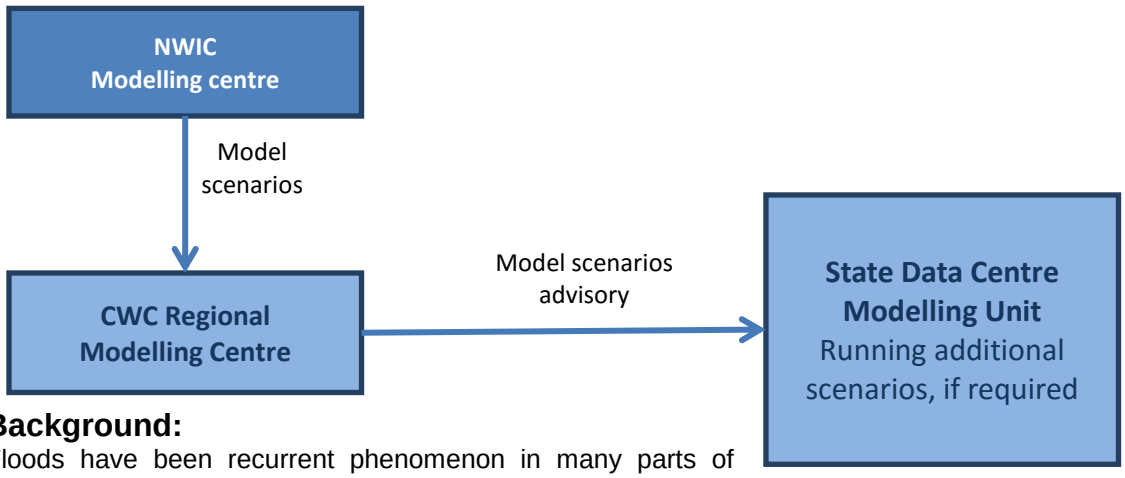
The project seeks to enable improved decisions in water resources planning and operations. It posits that this requires not just improved water information products but also enhanced institutional capacity – both technical capacity and policy & planning capacity. Improved water information products (including water resources assessments, water accounts and audits, scenario analyses and option assessments, forecasts and early warnings) require improved water data and improved tools (analytical and decisions support systems) to transform data into information. The project thus spans the value chain from water resources data through to decision making capacity in water resources planning and operations. Beyond the project, this is expected to lead to improved water resources decisions (operations and planning) generating greater economic, social and environmental benefits from the management of a limited water resource. The PDO of the project is proposed "to strengthen the institutions and water information required for integrated water resources management in India". The key outcome envisaged during the project is as below:

- To establish National Water Information System with multi-disciplinary data from states and central agencies and data exchange amongst agencies in real time basis
- To create National information systems with generic models for improved water resources assessment
- States are able to manage flood and water resources using a river basin approach.
- Reservoirs and irrigation systems are operated more efficiently leading to water savings and improved productivity.

The project will cover all major river basins of India and will require strong collaboration among central and state levels of government. All States and Union Territories will participate in the project given their constitutional mandate for water resources management. Central agencies will be also participate given significant interstate aspects of water management (most large river basins and aquifers cross state boundaries) and the need for a consistent national water information base.

CWC has been envisaged to play a critical role in the implementation of National Hydrology Project (NHP), specially in flood forecasting and inundation modeling, which focuses on developing tools/ models for flood forecasting purposes for entire flood prone area. River basin approach is at the heart of all the activities proposed to be taken up by CWC under NHP. It is also envisaged that when modeling at the basin level is carried out. CWC will also develop platform for scenario analysis and data visualization (user interface for hydrological model and data management)

CWC and CGWB will coordinate this component with assistance from international/national consultants. Consultancies will support an integrated river basin approach including flood forecasting, stream flow prediction and water resources assessment integrating surface water, ground water and water quality.



Background:

Floods have been recurrent phenomenon in many parts of India, causing loss of lives and public property and bringing untold misery to the people, especially those in the rural areas. Over the years, several expert Committees have studied the problems caused by floods and suggested various measures for their management to the Government. However, despite the various steps undertaken in the past, the trend of increasing damage and devastation brought by floods has posed a challenge to the government as well as to the people. The Rashtriya Barh Ayog(1980) has reported that out of 40 mha flood prone area, about 15.8 million ha area have been provided with reasonable degree of protection so far.

Flash floods are characterized by sudden rise and recession of flow of small volume and high discharge which causes damages because of suddenness. They generally take place in hilly region where the bed slope is very steep. Flash floods are also experienced in arid and semi-arid regions due to the intense and short duration rainfall in the small catchments of the region.

Floods in Indian river basins are also caused by cyclones. Coastal areas of Andhra Pradesh, Orissa, Tamilnadu, and West Bengal experience heavy floods regularly. During past 110 years (1891-2000), over 1,000 tropical cyclones and depressions, originating in the Bay of Bengal and Arabian Sea moved across India. Passage of such storms over a river basin leads to severe floods.

For minimizing the losses due to floods, various engineering/structural measures and administrative/non-structural measures have been adopted to reduce the flood losses and protect the flood plains. Structural measures comprise multipurpose reservoirs and retarding structures which store flood waters, channel improvements which increase floods carrying capacity of the river, embankments and levees which keep the water away from floods prone areas, detention basins which retard and absorb some flood water, flood-ways which divert flood flows from one channels to another and overall improvement in the drainage system. However, it has been recognized that permanent protection of all flood prone areas for all magnitude of floods by structural means is neither possible nor feasible because of various factors such as financial constraints, cost-benefit criteria or topographic limitations of the region. There should be emphasis on non-structural works such as real time flood forecasting, flood plain zoning for management of the floods with the help of inundation map.

The rivers in India can be broadly divided into the following four regions for a study of flood problems: (a) Brahmaputra River region, (b) Ganga River region, (c) North-West Rivers region, and (d) Central India and Deccan Rivers region

1. Objectives of consultancy:

The broad objective of consultancy is

a) To develop, calibrate and operate comprehensive model/ suite of models for real time flood forecasting (level/ Inflow/inundation maps) using hydro-meteorological data, meteorological forecast and other data; with desired accuracy.

b) To create Inundation map library for various return periods of rainfall events/ flood events including different scenarios of embankment breach at identified vulnerable locations.

c) To integrate all processes for data management, forecast models and dissemination methodology etc., in a single system in GIS environment to run models and generate forecast in fully automatic mode for short term period (3 days or more) with desired accuracy.

d) To develop web based Integrated Flood Warning System with customized GIS tool for real time dissemination of forecast, inundation map, inundation maps library including development of dashboard for query based generation flood warning/flood inundation maps for all stakeholders.

e) Development of interface for real-time display of results of flood warning system on India-WRIS/ e-SWIS site for disseminating the forecast/inundation maps.

f) Training and Capacity building.

2. Scope of the Consultancy:

The following basins/sub basins are to be taken up for the development of hydrodynamic models for Real Time Flood Forecasting coupled with weather forecast including Inundation modeling.

Package	Basin/Sub basin	SN	Basin/Sub basin
1.	Ganga upto downstream of confluence of Ghagra including all tributaries	2.	Tapi and Mahi basin
3.	Ganga from d/s confluence of Ghagra upto Farakka (including all tributaries)	4.	Subarnarekha & Burhabalanga
5.	Brahmaputra upto downstream of confluence of Subansir iincluding all tributaries	6.	Mahanadi (including all tributaries)
7.	Brahmaputra d/s of confluence of Subansiri including all tributaries	8.	Godavari(including all tributaries)

The brief description of these basins is as follows:

Ganga Basin:

The Ganga (Ganges) rises from the Gangotri Glacier in the Garhwal Himalayas at an elevation of some 4100 metres above the sea level under the name of Bhagirathi. This main stream of the river flows through the Himalayas till another two streams – the Mandakini and the Alaknanda – join it at

DevPrayag, the point of confluence. The combined stream is then known as the Ganga. The river after traversing a distance of 2525 kms from its source meets the Bay of Bengal at Ganga Sagar in West Bengal. The Ganga drains a total catchment area of 10.631 lakh sq.km., out of which 8.61 lakh sq.km.lies in India. Thus Ganga basin covers 26 percent of geographical area of the India. The basin extends into 11 states viz. Uttrakhand, Himachal Pradesh, Uttar Pradesh, Haryana, Delhi, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh and West Bengal..Themain tributaries of Ganga are the Yamuna, the Sone, the Ghaghra, the Gandak, the Kosi, theMahananda. The annual rainfall in the Ganga basin varies from 500 mm. to 2500 mm in the mountains and 400 mm to 1250 mm in the plains. Most of rainfall is concentrated during the months of June to September. The rainfall increases from West toEast and from South to North. The flood problem is mostly confined to the areas on the Northern bank of the Ganga River. The damage is caused by the northern tributaries of the Ganga by spilling over their banks and changing their courses. Even though the Ganga is a mighty river carrying huge discharges of57,000 to 85,000 cumecs (2 to 3 million cusecs), the inundation and erosion problems are confined to some specific places only. In general, the flood problem increases from West to East and from South to North. In the North- Western parts of the region, there is the problem of drainage congestion. The drainage problem also exists in the Southern parts of West Bengal. The problem becomes acute when the main river, in which the water is to be drained, already has high water level. The flooding and erosion problem is serious in Uttar Pradesh, Bihar and West Bengal. In Rajasthan and Madhya Pradesh, the problem is not so serious. In Bihar, the floods are largely confined to the rivers of North Bihar and are an annual feature.

Brahmaputra Basin:

The river Brahmaputra covers a catchment area of about 5,80,000 Sq.km. right from its origin in Himalayan Lake Manasarover at an elevation of about 5,150 m in Tibet to the outfall in the Bay of Bengal. It flows eastward in Tibet and south, south-west in India and traverses a distance of about 2900 km out of which 1,700km is in Tibet, 900 km is in India and 300 km is in Bangladesh. In the upper reaches, the river is fed by the glaciers and in the lower reaches, it is joined by a number of tributaries which originates at different elevation in the hills encircling the catchment forming watershed. Among the tributaries Subansiri, Manas, Jiabharali, Pagladiya, Puthimari and Sankoshetc are snow fed. The Brahmaputra and its tributaries covers the States of Assam, Arunachal Pradesh, Meghalaya, Mizoram, northern parts of West Bengal, Manipur, Sikkim, Tripura and Nagaland. The catchments of these rivers receive large amount of rainfall ranging from 110 cm to 635 cm a year which occurs mostly during the months of May/June to September. As a result of this, floods in this region take place very often and are severe by nature. The general tectonic wrapping up of North-East region has also significant effect on river Brahmaputra. Almost all Northern tributaries of Brahmaputra are affected by landslides in the upper catchment. Further, the rocks in the hills, where these rivers originate are fragile and susceptible to erosion and thereby cause exceptionally high silt charge in the rivers. In addition, the region is subject to severe and frequent earthquakes causing numerous landslides in the hills, which upset the regime of the rivers. Important problems in this region are flood inundation due to spilling of banks, drainage congestion due to natural as well as man-made structures and change of river flow. In recent years, the erosion along the banks of the Brahmaputra has assumed serious proportions.

Considering the individual states in the region, main problems of flooding in Assam are inundation caused by spilling of the rivers Brahmaputra and Barak as well as their tributaries. In addition, the erosion along the Brahmaputra is a serious problem. In Northern parts of West Bengal, the rivers Teesta, Torsa and Jaldakhaare in floods every year and inundate large areas. During flooding, these rivers carry large amount of silt and have a tendency to change their courses. The rivers in Manipur spill over their banks frequently. The lakes in the territory are filled up during the monsoon and spread to large marginal areas. In Tripura, flood problems are the spilling and erosion by rivers.

Flash floods are characterized by sudden rise and recession of flow of small volume and high discharge which causes damages because of suddenness. They generally take place in hilly region of Ganga and Brahmaputra basins, where the bed slope isvery steep. Flash floods are also experienced in arid and semi-arid regions due to the intense and short duration rainfall in the small catchments of the region.

Tapi & Mahi Basin:
The Tapi is a river of central India. It is one of the major rivers of peninsular India with the length of around 724 km; it runs from east to west. The Tapi River originates in the Betul district from a place called Multai. It is one of only three rivers in peninsular India that run from east to west - the others being the Narmada River and the Mahi River. The Tapi is the second largest westward draining inter-state river basin. It covers a large area in the State of Maharashtra besides areas in the states of Madhya Pradesh and Gujarat.

The Mahi basin extends over states of Madhya Pradesh, Rajasthan and Gujarat having total area of 34,842 Sq.km with a maximum length and width of about 330 km and 250 km. Mahi is one of the major interstate west flowing rivers of India. It originates from the northern slopes of Vindhyas at an altitude of 500 m near village Bhopawar, Sardarpur tehsil in Dhar district of Madhya Pradesh. The total length of Mahi is 583 km. The Som is its principal tributary which joins from right, and the Anas and the Panam joins the river from left. It drains into the Arabian Sea through the Gulf of Khambhat.

These rivers have mostly well-defined stable courses. They have adequate capacity within the natural banks to carry the flood discharge except in their lower reaches and in the delta area, where the average bed slope is very flat.

Subarnarekha & Burhabalanga:
The Subernarekha basin extends over States of Jharkhand, Odisha and comparatively smaller part in West Bengal having a total area of 29,196 Sq.km with a maximum length and width of about 297 km and 119 km. Situated in the north-east corner of the Peninsular India, the basin is bounded by the Chhotanagpur plateau on the north and the west, by the ridges separating it from Baitarani basin on the south, by the Bay of Bengal on the south-east and by the Kasai Valley of Kangsabati River on the east. The Subernarekha and the Burhabalang forms the major river systems in the basin. The Subernarekha River rises near Nagri village in the Ranchi District of Jharkhand at an elevation of 600 m. It flows for a length of 395 km before outfalling into the Bay of Bengal. Its principal tributaries joining from right are the Kanchi, the Karkari and the Kharkai. The Burhabalang rises from south of Similipal village in the Mayurbhanj district of Odisha at an elevation of about 800 m and flows for a length of 164 km and drains into the Bay of Bengal.

The Burhabalang is one of the east flowing medium river situated in the northern part of Orissa State. It drains parts of the areas on Mayurbhanj and Balasore districts of Orissa with a total catchment of 4800 sq.km. and this is a flashy river having a source at an elevation of 800m (Similipal range of hills) and drops into the sea after traversing a total distance of 198.75 km. The prominent tributaries of the Burhabalanga are Palapala, Sunei, Kalo, Sanjo, Deo, Gangahari and Katra.

The basin is generally influenced by the South-West monsoon, which onsets in the month of June and extends upto October. The average annual rainfall for the basin is around 1800 mm. The climate in the sub-basin is tropical with hot summer and mild winters.

Mahanadi Basin:
The Mahanadi River system is the third largest in the peninsula of India and the largest river of Orissa state. The basin (80º30'–86º50' E and 19º20'–23º35' N) extends over an area approximately 1415,89 km2, has a total length of 851 km. The basin is characterized by a tropical climate with average annual rainfall of 142 cm (NWDA, 1981) with 90% occurring during the SW-monsoon. The river begins in the Baster hills of Madhya Pradesh flows over different geological formations of Eastern Ghats and adjacent areas and joins the Bay of Bengal after divided into different branches in the deltaic area. The main branches of River Mahanadi meet Bay of Bengal at Paradip and Nuagarh (Devi estuary). The tidal estuarine part of the river covers a length of 40 km and has a basin area of 9 km2. Based on physical characteristics, the estuary has been characterized as a partially mixed coastal plain estuary.The Delta area of the Mahanadi on the east coast periodicallyface flood and drainage problems, in the wake of cyclonic storms.

Godavari Basin:
The river with second longest course within India, Godavari is often referred to as the Vriddh (Old) Ganga or the Dakshin (South) Ganga. The name may be apt in more ways than one, as the river follows the course of Ganga's tragedy. The river is about 1,465 km (900 miles) long. It rises at Trimbakeshwar, near Nasik and Mumbai (formerly Bombay) in Maharashtra around 380 km distance from the Arabian Sea, but flows southeast across south-central India through the states of Madhya Pradesh, Karnataka, Orissa and Andhra Pradesh, and empties into the Bay of Bengal. At Rajahmundry, 80 km from the coast, the river splits into two streams thus forming a very fertile delta. Some of its tributaries include Indravati River, Manjira, Bindusara and Sabari. Some important urban centers on its banks include Nasik, Bhadrachalam, Rajahmundry and Narsapur. The Asia's largest rail-cum-road bridge on the river Godavari linking Kovvur and Rajahmundry is considered to be an engineering feat.

The Delta areas of the Godavari on the east coast periodically face flood and drainage problems, in the wake of cyclonic storms.

The Scope of the Consultancy is broadly divided in three phases as follows:

Phase I- Development of the comprehensive model/ suite of models for, creation of online inundation map library, real time flood forecasting (level/ Inflow/inundation maps) including integration of models with input data, creation of dissemination web based GIS portal and dissemination of model output in defined platform.

Phase II- Maintenance, updating and Running of the model in real time during operational support period of 5 years.

The activities of training and capacity building are to be conducted in all phases.

2.1. The key tasks in Phase I

2.1.1. Task 1: Review of Data availability

- Identification of required data (hydro-meteorological, topographical, and other data required for modeling) for setting up of model, calibration, and validation.
- Review of available data and information with respect to minimum and optimum requirement for model development.
- Requirement of additional data, if any may also be recommended by the consultant for better performance of the model. This may be incorporated in new hydro-met design to be undertaken by CWC under NHP.

2.1.2. Task 2: Identification and Procurement of suitable software and hardware

- The main frame of the modeling and flood forecasting system should be based on HEC suite of software, which includes HEC RAS, RES HMS, HEC RTS etc. The consultant should identify other required software like GIS, remote sensing, database management, web hosting and data dissemination, data visualization. These ancillary software should be compatible with HEC system, and should preferably be license free / public domain software.
- The consultant should identify compatible hardware for real time flood forecasting, generation of inundation map, System for data assimilation (automated coupling of input data (HO, MET (station and gridded data in form of QPF and other various state of the art satellite/radar/ any other new technology products) and topography)and output dissemination (Including all necessary, software, hardware and web system) in real time.

- Procurement of all required hardware and software in consultation with client, if required, by the consultant during project period and to be handed over to the client after completion of the consultancy. (cost shall be reimbursed)

2.1.3. Task 3: Data Collection and Validation

- Collection of required data from various agencies as the prevailing data dissemination policy of respective agencies.
- In case the data is required to be procured from an agency, prior permission of same shall be obtained by the consultant from the client. The actual cost of the procurement shall be reimbursed to the consultant.
- Correction of digital elevation model using surveyed controls points to attain desired accuracy. Vertical datum should be mean sea level (MSL) incorporating data of embankments, road network and all other relevant layers.
- Collection of extra-topographical data including cross-section at suitable interval in river (if required) along with section details near structures in river (Bridges, Headwork or any type of structures). Survey of cross-sections should be taken from embankment to embankment or Highest Flood level (HFL).
- Collection of details of structures across the river reaches.
- Validation of input data for consistency.
- Correction and gap filling of data based on consistency check.
- The probable sources of data is as follows:

S. No.	Type of Data	Source
1.	DEM	SoI/NRSC (SoI/NRSC shares the DEM on chargeable basis), SRTM, ASTER GDEM.
2.	Satellite Imageries/LULC/Soil data	NRSC,NBSS-LUP/India-WRIS/state agencies
3.	Historical flood damage data	State Government
2.	HO and Met data	CWC/State Government/IMD
3.	Gridded Rainfall/QPF/other Satellite based precipitation estimates	IMD/TRMM/ NOAA /GPM/JAXA/other agencies
4.	Cross-section, Bridges, Hydraulic Structures, Reservoir operation rules	CWC, State Government/Additional data to be surveyed by the consultant/Morphological study
5.	Tidal data	Survey of India/Port Authorities/INCOIT,NIOT, other agencies collecting costal data.

2.1.4. Task 4: Development of Hydrologic/Hydrodynamic/2-D models

- Delineation of sub-basins, river networks and extraction of basin/catchment parameters.
- Develop Hydrologic/Hydrodynamic/ reservoir/control structures model/2-D models(selected reaches)
- Model is to be calibration for minimum 4 recent years including all major peaks to the accuracy of present CWC norms. Inundation model is to be calibrated using the high resolution satellite data and validation of inundation depth is to be done through ground survey.
- Model calibration up to desired accuracy (Level forecast +/- 0.15m, Inflow forecast +/- 10% and inundation maps+/- 5% of observed inundation extent)

- Generate real time forecast for identified Reservoirs and forecast locations for 3 days or more where QPF is available for longer duration.
- Generate real time flood inundation maps for reaches/locations identified by CWC to predict inundation extent, depth, arrival time and duration in any location in the basin. Inundation extent with depths should be validated with high resolution satellite later and periodic updation of model is to be done.
- Prepare Flood inundation map library corresponding to different return period of rainfall (2, 5, 10, 25, 50, 75, 100, 150 Year).
- Perform bias correction on Satellite Near real time Rainfall data, Forecasted rainfall using long term historical rainfall data and real-time rainfall data of recent years. For this purpose, consultant should obtain point rainfall data from ground measurements and satellite rainfall / forecast of same period and perform bias correction for at least 4 recent years.
- Run the models for each sub-basin using precipitation estimates generated, observed input data and update the model at every 3 hour.
- Model should be capable of updating the state parameters using observed data (using appropriate filtering scheme) and capable of generating short term / medium term ensemble forecast (using forecast products from different agencies) and Probabilistic forecast for longer lead times.

2.1.5. Task 5: Input data assimilation and processing precipitation /releases estimates

- Consultant will develop work flow for each process to automate collection, validation and management of observed input data (H.O data, releases from control structures, Rainfall (satellite/radar/ rain gage values (including AWS/ARG) /any other new products [in optimum combination]) flow to model.
- Automate real-time acquisition of QPF from IMD/FMO to be updated at 6 hour interval (or at specified interval).
- The whole process of acquiring input data (from various sources like websites, ftp folders etc); processing the data in required format, gap filling and quality check, providing the data as inputs to models, generation of outputs in form of GIS layers, rasters, maps and tables, updating of outputs on website and databases etc. should be automated and should not require any human intervention at any of the mentioned stages.

2.1.6. Task 6: Development of Integrated Flood Warning System

- Develop **Integrated Flood Warning System** with Graphical User Interface (GUI) for real time dissemination of Model output in form of levels, discharge, inundation extent, depth, arrival time and duration etc.
- System should be capable of graphical displays, sound alert, for providing:
    - Access to both predicted and present water level/discharge at monitoring station and CWC notified location.
    - Access to forecasted inundation maps with Inundation extent and inundation depth.
    - System should have capability for generating results (quarry based) for level, discharge, inundation extent, inundation depth, population/area affected upto village level due to flooding.
    - System should have capability of generating flood forecast report, flood bulletins, text messages, animations, flood summary report, report of user defined queries etc.
- Development of interface for real-time display of results of flood warning system on India-WRIS/e-SWIS site.

- Development of Dashboard for query based generation of flood warning/flood inundation maps for all stakeholders and display of same on India-WRIS e-SWIS/site for dissemination.
- Apart from website, the input data used and outputs generated should also be made available in the form of web service / web query; enabling stakeholders to develop own mobile apps regarding flood forecast.

2.1.7. Task 7: Capacity Building and Training

A key objective of this consultancy is to ensure that the experience gained through this consultancy can be used to develop full-fledged Real Time Flood Inundation Modeling (RTFIM) and Flood Inundation Maps (FIM) library for flood affected reaches of all major rivers of India. The knowledge and experience gained must be transferred to the officers of CWC and states for their capacity building. The capacity building will be achieved through various modes including formal, on the job and e-learning. The e-learning will be designed to approach all the interested stakeholders including state departments and will be possible opened to the public.

This will require substantive training from the Consultants. This may include:
Formal Training

- Conduct Training program after each milestone.
- Conduct workshops on current technologies and future developments and operational management of full system.
- Training program including Training of Trainer (TOT) shall be organized on modeling software, model development, GIS processing and flood warning system. A minimum of 30 officials shall be trained during the development of model.
- A workshop comprising 50 officials from Central/State Govt. officials on complete system including modeling and dissemination.
- Develop E-learning module for end to end flood forecasting system

Informal Training

- Provide on the job training, where client may appoint officers from CWC / States to work with consultant during development phase of models / interfaces for better transfer of technology.

2.1.8. Task8: Key Deliverables and Reporting

The consultant shall also provide following deliverables for this work:

- **Inception report:** consultant shall provide an “inception report” clearly indicating how consultant has planned to achieve the assigned objectives of this consultancy. The inception report shall include detailed work plan along with time schedule, selection of database, and finalization of models, data requirement, review of available data and data gaps, if any. The inception report shall indicate the time schedule represented by weekly Gantt chart showing major milestones, task deliverables, completion dates and any interdependencies.

- **Monthly progress report:** Consultant shall provide monthly progress report of the work carried out by them in the month positively by 5th of the next month clearly indicating achievements, works proposed to be taken up, and bottlenecks in carrying out the work.

- **Model development report:** The consultant will submit the complete model development report within the stipulated time to the client. The report should include following chapters-
  i) Objective
  ii) Study area

iii) Methodology for model development
iv) Data used
- Geospatial data
- Hydrological data
- Hydraulic data
- Geopolitical data
- DEM with vertical accuracy and horizontal resolution.

v) Approach for model development
- For 1D modeling
- For 2D modeling.

vi) Output of the model in the form of
- maps in the form of shape files
- hydrographs
- lateral spills including both extent and volume
- Water retained in depressions etc.

vii) Confidence limit in result prediction
viii) Sensitivity Analysis
ix) Uncertainty in model development
x) Shortcomings in the models

- Discussion, Conclusion & Future Recommendation.
- **Final report and prepare peer-reviewed papers for a joint publication.** Consultant shall submit the final report to the client in hard (10 set) and soft copy. Consultant will prepare a paper based on results of the modeling in consultation with CWC for joint publication in a national/international journal.

- **Records and Metadata**

a. The consultant shall consolidate all data used in development of mathematical model and data formats as decided in consultation with Engineer-in-Charge.
b. The metadata records shall be delivered free of errors in both content and format.
c. The consultant shall deliver all data and data products, metadata records which detail datum, re-projections, re-sampling algorithms, processing steps, field records, and any other pertinent information etc.
d. **Geospatial data**- in the form of shape files. The consultant is required to submit a file geo database or shape files listing all the below mentioned geospatial files, with their respective attributes. All the geo-spatial and time series data should be properly catalogued, including basin, sub-basin and other station IDs as provided by the client; and should be consistent with nomenclature used by client.
e. **Cross section** - it shall include the hydraulic model cross-sections used to develop the inundation mapping. This will allow the modeling to be archived for future applications and updates to the inundation mapping.

- Development of technical, operational, user manuals, online help, workbooks/tutorials, training presentations and other training material. Provide 5 copies of user manuals (software design, operation and troubleshooting tips) in hard copy and electronic form.

2.2. The key tasks in Phase II include

2.2.1. Maintenance, updating and Running of the model in real time during operational support period of 5 years:

- Maintenance of the model including updating of software used for the models

- Develop scripts for automatic alert (via email and sms) to developers / modelers / programmers in case the system malfunctions due to inability to download data, unavailability of servers, error in data etc. The consultant should develop an automated system for alert so that appropriate actions could be taken with minimum delay.
- Maintenance of the auxiliary systems for coupling real time HO and Met data with the model and data dissemination portal.
- Review of model and updating of parameters based on the model performance and improving model results.
- Incorporation changes in model in case data from new station/sources accepted by the implementation committee and further calibration. The recalibration may be required for at least 2 times a year, depending on the data situation and accuracy of results.
- Updating inundation map libraries and improvising the technology for real time inundation forecast and dissemination.
- Generate real time forecast for identified Reservoirs and forecast locations for 3 days or more, depending on availability of forecasted rainfall data.
- Generate real time flood inundation maps for reaches/locations identified by CWC to predict inundation extent, depth, arrival time and duration in any location in the basin. Inundation extent with depths should be validated with high resolution satellite later and periodic updating of model is to be done.
- Run the models for each sub-basin using precipitation estimates generated, observed input data and update the model at every 3 hour.
- Conducting workshops/conferences addressing the issues faced during real time forecasting and dissemination.

2.2.2. Key Deliverables

- **Monthly progress report:** Consultant shall provide monthly progress report of the work carried out by them in the month positively by 5th of the next month clearly indicating achievements, works proposed to be taken up, and bottlenecks in carrying out the work.
- **Flood forecasting report:** Consultant shall generate flood forecasting report on real time basis during the monsoon period i.e. June to October every year, giving details of FF sites, observed water levels, forecasted water levels, spatial forecast of inundation area etc. in mutually agreed format, to put it on web.
- **Flood Summary Report:** A flood summary report is to be generated after the end of each monsoon season. The summary report will have all the details i.e. methodology, deviation in forecast and actual observed parameters, bottlenecks/limitations, sensitivity detail of model results, all graphical details, performance of real time data transmission system, quality of received data vis-à-vis objectives etc. The consultant will make presentation in the CWC organized Flood Appraisal workshop to deliberate these experiences and outputs in this workshop.
- **Comparison of results:** At the end of each monsoon period, the consultant should prepare a detailed comparison report for observed and predicted flow/ levels; and analyze the reasons for discrepancy (if any) and incorporate the changes in the model for improving accuracy during next season. The comparison should also be made for forecasted rainfall vs point observation of rainfall data, and bias correction be updated every year before and after monsoon season.
- **Records and Metadata**

a. The consultant shall consolidate all data used in updating of mathematical model.
b. The updated metadata records.

2.2.3. Capacity building and training

- CWC official should be trained on updating of the model.
- Conduct training program before onset of monsoon every year.
- An Annual workshop comprising 50 officials from Central/State Govt. officials on complete system including updating of the models.

3. Schedule for completion of tasks:

A. Phase I:

Deliverables	Description	Period
1. Inception Report	Analysis of data availability and data quality, Review of International experience, Identification of possible models suitable to each river basin, Conceptual design of flood Monitoring system, Methodology for the development of model, Identification of data inputs for the model, Outputs expected, Methodology for the calibration and validation of model, and fortnightly schedule of implementation work plan.	T+3 months
2. Data collection Report	Collection of Required data (hydro-meteorological, topographical, GIS layers including DEM and other data required for modeling)-parallel activity along with inception report.	T+4 months
3. Model Development Report	Detailed report of flood modeling, Inundation Modeling including inputs and outputs, Internal and external interfaces, Data flow schedules for dynamic updating of model, and Input-output data formats	T+10 months
4. Training Plan	Details about training	T+10 months
5. Development of Integrated Flood Warning System	i) Detail report on Development of GIS based flood warning system including real time dissemination of Model output in form of levels, discharge, inundation extents and inundation depths etc. ii) Development of interface for real-time display of results of flood warning system on CWC India-WRIS e-SWIS/site for disseminating the forecast/inundation maps iii) Development of Dashboard for query based generation flood warning/flood inundation maps for all stakeholders and display of same on India-WRIS e-SWIS/site for dissemination. iv) Demonstration of complete system	T+12 months
6. Draft Final Report	Draft Final report with outputs of all tasks.	T+13 months
7. Final Report	Objective confirming to all Task described in the ToR Operational training of the full system and dissemination workshop.	T+15 months

B. Phase II

Activities of Phase II will start after acceptance of final report and successful completion of operational training of the full system. Time period of phase II will be 5 years.

4. Data Services & Facilities to be Provided by the client:

The following amenities will be provided by the Client:

- Suitable Office space,
- Consultant has to collect available historic and current data on hydrometeorology, hydrology and hydraulics; available thematic data; rainfall and flood forecast of CWC; as per prevailing policy/guidelines. The client will facilitate the process in the form of permissions, letters etc.

5. Responsibilities of 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. The consultants will have to acquire real time data which is not available with CWC from different agencies/networks if required for the Modeling work. Consultant has to bear all expenses on data collection.
- Conduct field visits as required for data collection or to verify model results.
- Undertake digitization / data conversion of source data as needed for modeling.
- Consultant team will have to work in CWC premises during project period.
- Presence of key staffs in CWC premises during warranty and maintenance should be ensured.
- Consultant should use appropriate modeling software for satisfactory results. Requirement of all input data for the model, consistency of data, primary or secondary validation should be analyzed well in advance. At later stages, any gap in input data shall not be taken as a reason for poor performance of the model.
- Consultant has to provide all software, hardware, data, source code of all applications after the completion of the consultancy to the client.

6. Handling Restricted Data

The Consultants, their sub-consultants, and the personnel of either of them shall not, either during the term or even after the expiration of this contract, disclose any proprietary or confidential information related to the Project, the services, this contact, or the Client's business or operations without the prior written consent of the Client. Certain data (such as topographic maps in 1:50,000 scale with heights and contour information, hydro-meteorological data for river system and DEM with 50 cm contour interval) which may be used in development and operation of flood models may be considered „restricted" as per Ministry of Defense and Ministry of Water Resources guidelines. Keeping in view security guidelines for data secrecy and to provide optimum functionality and to enable sharing data with the consultants, a secure data handling environment has been proposed. The unit will be equipped with necessary hardware and software and peripheral units, but will not be connected with outside LAN network. CD/DVD Writer & Floppy/ Pen Drive facilities will only be available on the main server. Entry to the confidential unit shall be appropriately screened for authorization. Proper record of date and time of entry and exit in the confidential unit along with the details of work done shall

be recorded in logbooks. Entry to office will be strictly prohibited before and after office hours. For emergent circumstances approval of competent authority will be required. Permanent passes for the consultant staff deputed for working in CWC shall be issued by the competent authority. Confidentiality and non-disclosure Agreements are to be signed by the Consultant firm, as well as the individual Consultants deputed for working in CWC. Technical data brought by the Consultant may be allowed to be loaded on the server. No original data kept on server will be modified or changed. Change/ modification required if any will be done only after copying the data.

7. Consultant and their key team qualification:

The lead organization for the project will meet the following criteria

- Minimum ten years of experience in providing international consultancy services in the water sector, with particular emphasis and a track record of successfully delivering major analytical projects that directly interface with water resources policy or management.
- Demonstrated experience in Extended Hydrological modeling, flood forecasting at basin scale,
- Strong capability in convening effective multi-stakeholder consultation processes, especially in developing country contexts.
- Track record of managing major multi-organizations technical partnerships on complex water problems including in the last five years.
- Experienced in technical assignments in developing countries; preferably India.
- Ability to quickly deploy a team (professionals with relevant experience and qualifications) either from the lead organization or through sub-contracting arrangements.

Consultant Team

Discipline of the Consultant	No of Persons	Qualifications and Experience	Role and responsibility	Suggested Man-Months During Phase I	Suggested Man-Months during Phase II
Team Leader	1	1. Relevant advanced academic degree in Hydrology, Hydraulic and / or Water Resources engineering. 2. At least 15 years working experience in water resources. 3. Preferably he has knowledge of hydrological and hydrodynamic modeling tools used in flood forecasting. 4. He has handled at least two projects as a Team Leader/Dy Team leader in international project in water resources. 5. Should have been with bidding firm for past 3 years.	• Project Management • Reports • Deliverables • Organization of Trainings • Coordinate the modeling efforts • Focal person for interaction with client • Lead in presentations and workshops	15	0
Deputy Team Leader / Meteorologist / forecaster	1	1. Relevant advanced academic degree in Meteorology or Hydro-meteorology and / or Atmospheric Physics. 2. At least 10 years working experience in meteorological forecast/meteorological product (field observation, Doppler radar, Satellite products / combined products) etc. Relevant advanced academic degree in Hydrology, Hydraulic and / or Water Resources engineering. 3. Preferably he has knowledge of hydrological and hydrodynamic modeling tools used in flood forecasting. 4. He has handled at least two projects as a	• Assist the team leader in man power management • Analysis of meteorological forecast • Bias Correction on satellite / forecast products	15	5

		Team Leader/Dy Team leader in water resources sector.			
Senior Hydrologic Modeler	3	1. Relevant academic degree in Hydrology, Hydraulic and / or Water Resources engineering. 2. At least 10 years working experience in flood modeling and early warning system / GIS use for modeling. 3. Extensive knowledge of hydrological and hydrodynamic modeling tools used in flood forecasting; should have a very good experience with rainfall- run-off modeling. 4. Proven experience in setting up models for flood forecasting in large river basin. 5. Experience in integrating flood forecast with early warning system/ inundation models with others information system/ databases. 6. 50% of the team should be from the firm for at least last three years.	• Review of Data • Data quality check and gap filling for modeling • Setup, calibrate and validate the models for Hydrology, river hydraulics and flood inundation • Ongoing improvement in models with recalibration and incorporation of new data	36	15
Junior Hydrologic Modeller	8	1. Relevant advanced academic degree in Hydrology, Hydraulic and / or Water Resources engineering. 2. At least 5 years working experience in flood modeling and early warning system / GIS use for modeling. 3. Extensive knowledge of hydrological and hydrodynamic modeling tools used in flood forecasting; should have a very good experience with rainfall- run-off modeling. 4. Desirable: experience in application Software Development / design in Water resources sector.	• Assist the senior hydrologist in data quality check and gap filling • Assist in model development and calibration • Interlinking and data exchange between various models • Ongoing improvement in models with recalibration and incorporation of new data	120	180
GIS/RS specialist	1	1. M.Sc. Geography/Geo Science with specialization in GIS/RS. 2. 5 year experience in RS/GIS applications for resource mapping, preparation and integration of GIS datasets, experience in	• Assist the modelers for spatial dataset generation • Help in procuring / processing Spatial data on DEM, Snow cover, forecast products	12	5

		integrating global satellite derived data; experience in hydrologic application, 3D analysis and customization and experience in flood inundation mapping for GIS/RS specialist. 3. RS in snowmelt, inudnantation mapping.			
Database specialist / web management specialist / Programmer	2	1. Graduate in Engineering in Computer Science/IT 2. 5 year experience in data base applications for Database, web management etc ; 3. Extensive experience in scripting using Python or related tools	• Automation of forecasting system from data collection to forecast dissemination • Write scripts for exchange of data between various formats and models • Develop and maintain real-time flood forecast website • Assist in procuring hardware / software for the forecasting system	30	60
Technical Support Staff	2	Graduate. He should have basic knowledge of computer.		30	0
Other Supporting Staff	3	Matriculate and above		45	60

8. Payment Schedule

Phase I

- 10 percent on signing of contract as advance against a bank guarantee.
- 5 percent after acceptance of Inception Report.
- 10 percent after submission and approval of Modeling Report.
- 10 percent after approval of forecast model & early warning system and inundation mapping tool subject to real time testing of model at least in one monsoon season.
- 5 percent after submission and approval of draft final report and training plan.
- 10 percent after completion of training and workshop, submission and approval final report.

Phase II

5 % Payment will be made on half yearly basis after providing the satisfactory services during that period. (Total for 5 years = 50% of contract value)

9. Duration of Consultancy

15 months for model development + 5years (Operational Support, refinement, recalibration)