

## Section 5. Terms of Reference

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**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

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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 (NHP)- 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).

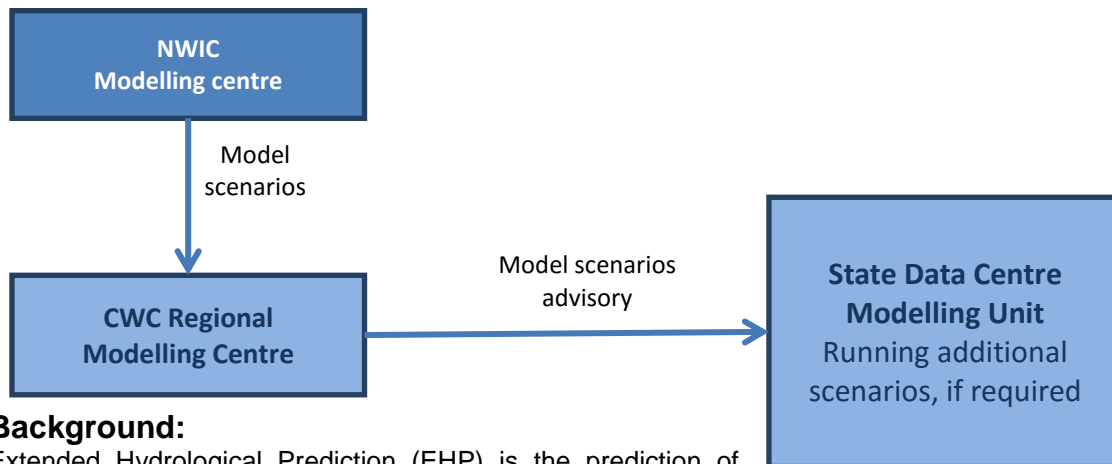
During the NHP, the Central Water Commission will like to focus on core area activities which will improve the overall efficiency. In future, it is expected that inter-state disputes will crop up more and more and pose a challenge in the field of water management aspect. CWC future plan would be ideally 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.

CWC has been envisaged to play a critical role in the implementation of NHP, specially in Water Resources Planning and Operation, which focuses on developing tools/ models for water resources planning as well as for operation purposes. 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 modelling at the basin level is carried out, the water as a resources will be accounted in its totality incorporating the surface, ground and quality aspects. The macro level basin models will be developed in participatory approach along with various stakeholder agencies including CGWB, CPCB and the state government implementing agencies. CWC along with CGWB will develop framework/ model for assessing surface hydrology, water allocation, groundwater assessment and water infrastructures. 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:

Extended Hydrological Prediction (EHP) is the prediction of hydrological variables, most commonly the stream flow, for the period of time that exceeds the short term forecast lead time. At the same time the short term forecast is based on observed hydrological and meteorological variable (precipitation, temperature, discharges, etc.) and optionally on the forecast of these variables, especially the quantitative precipitation forecast for the period of its plausible performance). The lead time of the hydrological forecast differs mostly based on catchment time of concentration. EHP uses the observed values of hydrological and meteorological variables together with other climatologic drivers often dealing with them in a stochastic or statistic manner. The lead time of EHP thus may differ from weeks to months depending on the duration of the effect of the initial condition of the basin and the effect of other drivers used in EHP. The performance of precipitation forecast of Numerical Weather Prediction (NWP) declines with the lead time. The use of the deterministic forecast beyond the time at which the efficiency is worse than the climatology does not make a sense. Therefore the ensemble systems are often used for longer lead time meteorological forecast – it is often named medium range forecast.

At the operational end, water managers need to optimize available water resources and as best as possible devise ways to meet demand pressures from urban, rural and environmental sectors. Water demand across large river basins varies in space and time, and water managers need to make decisions at a range of time scales – days, weeks, months and up to a few years, depending on the broad envelope of wet and dry cycles within different hydro-climatic regions. To address long-term water security, decision-makers need to deal with significant uncertainty about future climate and demand from different economic sectors. Seasonal forecasts of water availability can be made using dynamical, statistical or hybrid modeling approaches. The performance of the current statistical and new dynamic stream flow forecasts varies depending on the location and forecast period. Because the statistical and dynamical modeling approaches are complementary, merging the two forecasts means the merged forecasts are likely to be more accurate and reliable than either of the individual forecasts alone.

Studies undertaken using ensemble weather forecasts have begun to address technological gaps in meeting specific, regional flood vulnerability problems (i.e. data sharing, and forecast lead time) such as for the 8 basins. Consequently, flood prediction partnerships are suggested as a means to bridge the gap between the existing global scale, long lead time weather prediction, and actual implementation and use of the resulting much-enhanced flood prediction capability, since it is clear that better flood discharge prediction will not on its own result in effective outcomes.

### 1. Objectives of consultancy:

The system will be for 10/15 days lead-time forecast (medium and long term) along with DSS creating an enhanced probabilistic river flow forecasting scheme. At weeks to seasonal time scales, some of the points envisaged to be answered in a basin would be:

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- i. Given the current hydrologic condition of a river basin, how much water losses can be anticipated in the water conductor system and what is the likely spatial distribution of the losses?
  - ii. How much is the likely inflow – Next week? Next month? Next season? And next year?
  - iii. What is the range of uncertainty of the likely inflow and how best can this imperfect knowledge be integrated into water allocation and water delivery planning?

The specific objectives of this consultancy are to support the assessment of strategic improvements to basin wise flood forecasting capacity:

**(i) Ensemble discharge forecasts with river discharge estimates to produce optimal river discharge estimates at select locations along the river course.**

The EHP for river flow forecasting system, will be extended and calibrated into 8 designated basins of India namely i) Damodar, ii) Cauvery, iii) Chambal, iv) Narmada/Tapi, v) Krishna, vi) Godavari, vii) Ken Betwa, and viii) Mahi and implemented basin-wise for all the tributaries and corresponding sub-basins of the basins. The forecast modeling will then be improved by optimally-combining additional satellite precipitation estimates (high sampling rate but less accurate National Oceanic and Atmospheric Administration (NOAA) Hydroestimator and Japan Aerospace Exploration Agency (JAXA)/ Earth Observation Research Center (EORC) GSMaP products to be added, in addition to the National Aeronautics and Space Administration (NASA) Tropical Rainfall Measuring Mission (TRMM) and NOAA CMORPH products) and ensemble weather forecasts, and also by utilizing a higher resolution DEM, routing model improvements, and new pre and post-processing statistical tools (“quantile regression based) used in ensemble river flow prediction.

**(ii) Combine ensemble discharge forecasts with remotely-sensed river discharge estimates to produce optimal river discharge estimates at select locations along the river course.** The Skill comparisons between the EHP and DFO-based system will be made, in addition to the benefits in their optimal combination.

**(iii) Validate Radar Altimetry Satellite Data for Operational Flood Forecast.** Synthetic aperture radar (satellite-based microwave sensor) altimetry data will be collected and synthesized over river measurement sites to monitor changes in river water heights. This will be converted into river flow measurements to supplement in-situ discharge data and used to assess river heights at regional scale across all sub-basins. In addition, this approach will also test monitoring of reservoir levels, to remotely-assess water release schedules of management agencies.

## **2. Implementation Approach**

The consultancy builds upon the EHP project, which will produce operational Extended Hydrological Predictions separately for the 8 basins namely **i) Damodar, ii) Cauvery, iii) Chambal, iv) Narmada/Tapi, v) Krishna, vi) Godavari, vii) Ken Betwa, and viii) Mahi**. The consultancy will extend this work by producing forecasts for all sub-basins upstream of the monitoring sites, as well as integrating new adaptable hydrological stream flow multi-model approaches, probabilistic meteorological/climate forecasts, as shown in Figure 1.

- (i)** In particular, the consultancy will make use of the recently available THORPEX Interactive Grand Global Ensemble (TIGGE) multi-center ensemble weather data, with a focus on extreme precipitation in designing a fully-automated scheme for 1-15 day predications of river discharge forecasts of a particular basin within India.
- (ii)** The Dartmouth Flood Observatory (DFO) River Discharge Measurements website provides a model format on which this consultancy can build to provide a prototype portal for model-based discharge prediction and flood warning information. It may provide a sub-scene map view (automated, updated daily) of current river flow severity status of monitored sites, and also a sample time-series of the existing present and historic status output at few sites. The

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consultancy can adapt these displays to incorporate forecast and present-status information and create more appropriate map displays publishable at larger scale for the river basins of interest.

- (iii)** The consultancy will also examine the benefits of data utilization of satellite-derived river discharge estimates on improving forecasting skill. At certain microwave wavelengths, there is very little interference from cloud cover. Using a strategy first developed for wide-area optical sensors, such data can be used to measure river discharge changes. As rivers rise and discharge increases, floodplain water surface area increases. Microwave reflections from river measurement sites, observed from space, can monitor such changes. Earlier work has: (i) examined the capability of using these data to track the downstream propagation of flood waves, and (ii) evaluated their use in producing river flow now-casts, and forecasts of 1-15 day lead times. Through this consultancy, it is proposed to improve and extend the lead time of the near-real time river flow prediction of the hydrologic model using data assimilation of upstream flow information provided by the remote sensing at several upstream and downstream locations.
- (iv)** The large archive will allow production of an innovative flood prediction product. Past inundation extent can be used to match the corresponding remote sensing-derived discharge values (the same approach can be used for any ground station sites for which data output can be made available or is available publicly). Links to the appropriate inundation map can be provided at the individual site displays: when a particular discharge and flood threshold is predicted, the user can call up the inundation that resulted, historically; from the same values. Associating inundation maps to the ensemble of river forecasts produced by the EHP model could then produce a range of possible inundation extent scenarios. The maps should be linked with WRIS for public viewing.

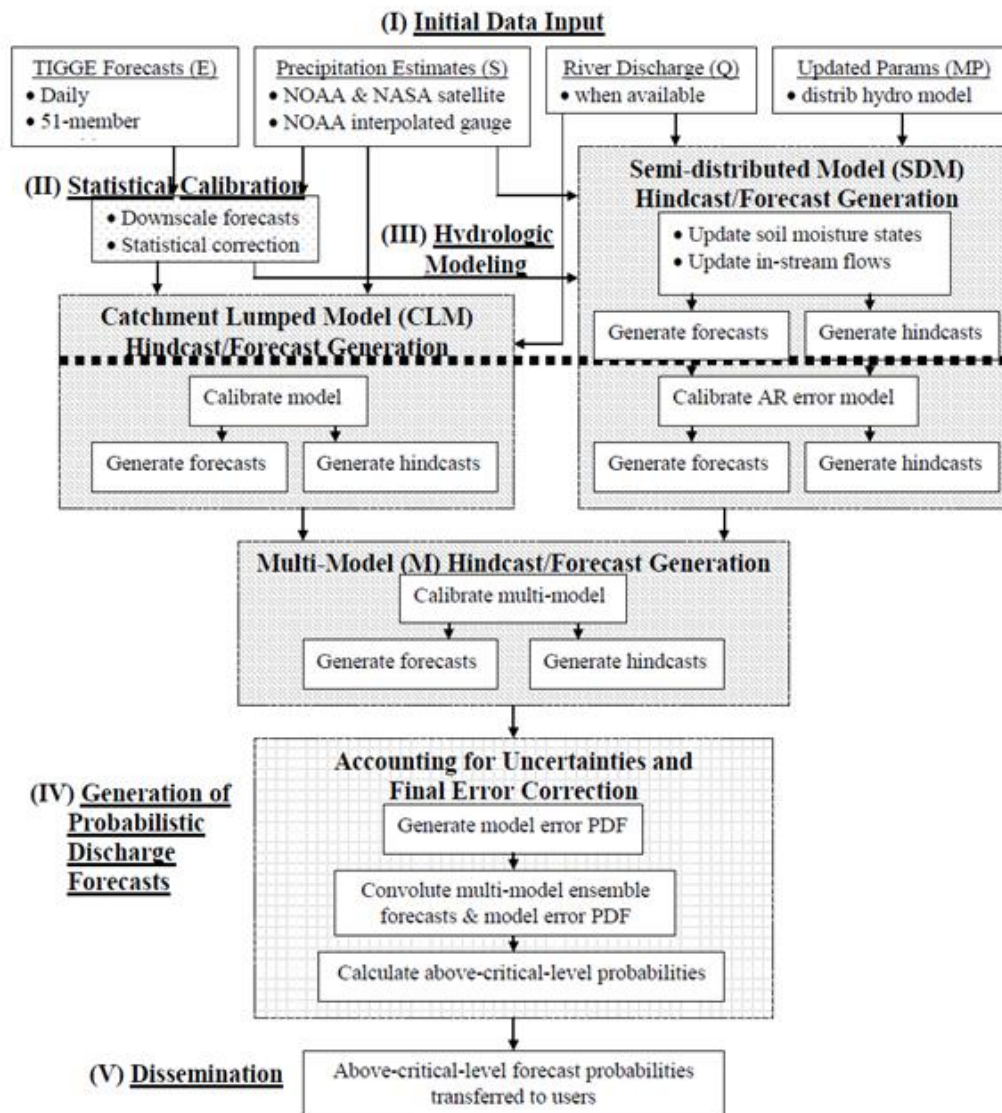


Figure 1. Flow chart of the automated medium-range forecasting scheme.

### 3. Key steps for getting the work done

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

**Phase I-** Development of the comprehensive model/ suite of models for EHP, creation of scenarios 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.

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

### 3.1. The key tasks in Phase I

Flow chart for working methodology has been depicted in Figure 2. With reference to the key **steps** to be undertaken include:

#### 3.1.1. 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.

#### 3.1.2. Task 2: Identification and Procurement of suitable software and hardware

- Identification of required license free/public domain modeling software/suites of models, compatible hardware, system for EHP, 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.
- 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.
- Procurement of all hardware and software, if required, in consultation with the client by the consultant during project period and to be handed over to the client after completion of the consultancy. (cost shall be reimbursed)

#### 3.1.3. 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	Sol/NRSC (Sol/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.
6.	Utilization data/releases	From respective state governments

#### 3.1.4. Task4: Basin auto delineation

- Delineate sub-basins and river networks using SRTM/GDEM (30m horizontal DEM resolution) data. Calculate grid-weighting per sub-basin for gridded rainfall observation, estimates, and forecast products. This process will generate (fractional) weights that will efficiently combine precipitation values from neighboring grids to produce sub-basin average rainfall, based on the grid-box spatial overlap with the basin.

#### 3.1.5. Task 5: Rain Gage and Stream Gage Data Collection and Processing

- Collect archived data – for use in model calibration and analogue-technique selection
- Derive rating curves from observations – available river discharge and stage measurements will be used to generate rating curves at select sites.
- Automate real-time download of available rain and river stage gage sites.

#### 3.1.6. Task6: Satellite Precipitation Estimates

- Collect archived data from NOAA, NASA and JAXA/EORC for calibration purposes
- Automate real-time download of these products and combine for operational hydrologic model and in-stream flow initialization
- Optimal combination of products, based on available rain gage values

#### 3.1.7. Task 7: Creating Ensembles and Hydrologic Modelling and Multi-modelling

- Collect archived data – It will require downloading from ECMWF data and automate real-time download
- Pre-process and optimal combination of products, based on available rain gauge values, utilizing a quantile-regression (estimating either the conditional *median* or other *quantiles* of the response variable) and analog based approach, generating calibrated probability distribution function inputs into hydrologic model.
- semi-distributed 2-layer models for each sub-basin, River routing, Optimal combination of model outputs, combine models for each lead time and post-process and combine using quantile-regression and analogue based-approach generating calibrated final probability distribution function

#### 3.1.8. Task 8: Transforming forecasts into informative visualizations and Dissemination

- Couple the flood discharge estimates, on a selected site and reach basis, to produce online libraries of measured or predicted discharge and matching floodplain inundation maps.
- Create graphical displays providing: (i) public access to both predicted and present river discharge status of a relatively dense network of measurement points, and (ii) to estimated and forecasted inundation maps.
- Develop **EHP System** with Graphical User Interface (GUI) for real time dissemination of Model output in form of scenario 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.

### 3.1.9. Task9: Capacity Building/ Training and Reporting

A key objective of this consultancy is to ensure that the experience gained through this consultancy can be used to develop EHP for other basin of India. The knowledge and experience gained must be transfer to the officers of CWC/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.

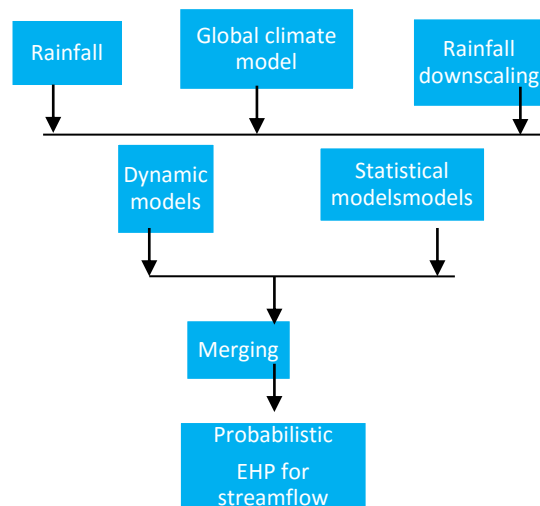
This will require substantive training from the Consultants. This may include:

#### 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.



**Figure 2:** Flow chart for working methodology

### 3.1.10. Task 10: Deliverables and Schedule

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) Detailed Methodology for model development
    - iv) Data used
      - ◆ Geospatial data
      - ◆ Hydrological data
      - ◆ Hydraulic data
      - ◆ Geopolitical data
      - ◆ DEM with vertical accuracy and horizontal resolution
      - ◆ Ancillary data, if any
    - v) Approach for model development
      - ◆ For 1D modeling
      - ◆ For 2D modeling, if required
    - vi) Output of the model in the form of
      - ◆ Maps in the form of shape files,
      - ◆ Graphical outputs, tables etc.
      - ◆ Hydrographs
      - ◆ Lateral spills including both extent and volume
      - ◆ Water retained in depressions
      - ◆ Development of mutually agreed suitable Dashboard 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, raster files and any other soft format as needed. The consultant is required to submit file geo-databases including all feature/layer/raster/other formats. 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.

- **User Manual:** 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.

The expected deliverables and their schedule are provided as below:

<b>System name:</b>	<i>BASIN EHP name</i>
<b>Operational status of the system:</b>	<i>Research project, experimental, pre-operational / operational</i>
<b>Start of operation:</b>	<i>201*</i>
<b>Lead time of the forecast:</b>	<i>10 days/15 days</i>

Deliverables	Description	Timing (months after signing)
1. 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.	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. Satellite ensembles, NWP estimate and Multi-model compilation report	Basic knowledge base and initial results from setting up of hydrological model and calibration; outline of assumptions and challenges faced (Step 6-7). Technical document describing features, model calibration, sensitivity analysis and compilation of multi-model results.	T+6th month

<b>3. Draft Final Report (completion of flood forecasting for the main basin at sub-basin levels – validations and flood forecast scenarios using lead time ensembles result)</b>	Overall report on flood forecast development and sub-basins level flood forecast results as described in overall tasks. Delivery of technologies, trainings imparting knowledge and process followed in developing the model.	T+7th month
<b>4. Training Plan</b>	Details about training	T+8 months
<b>5. Final Report and training</b>	Final report with outputs of all tasks. Summary Power Point. Transfer of data, tools and developed models, Operational training of the full system and dissemination workshop.	T+11th month
<b>5. finalization of 1<sup>st</sup> draft of peer-review paper</b>	First draft of peer-reviewed journal article on research findings completed.	T+11 th month
<b>6. Current and planned developments</b>	Scientific basis Dissemination of outputs User training and documentation Others	T+12 th month
<b>7. Comments</b>	<i>Any additional comment or notes you wish to share</i>	

### **3.2. The key tasks in Phase II include**

#### **3.2.1. 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.

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- 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 upon the data situation and accuracy of result.
  - Updating of forecast with 10/15 days lead-time forecast (medium and long term) along with DSS creating an enhanced probabilistic river flow forecasting scheme and dissemination.
  - Run the models for each sub-basin using precipitation estimates generated, observed input data and update the model at every day.
  - Conducting workshops/conferences addressing the issues faced during real time forecasting and dissemination.

### 3.2.2. 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.
- **Generation of EHP reports:** Consultant shall generate EHP report on real time basis on fortnightly basis every year in mutually agreed format, to put it on web.
- **Comparison of results:** At the end of each season, 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 vs point observation of data.
- **Records and Metadata**
  - a. The consultant shall consolidate all data used in updating of mathematical model.
  - b. The updated metadata records.

### 3.2.3. Capacity building and training

- CWC official should be trained annually 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.

## Relation to Prior Research

The consultancy will leverage technologies developed under previous similar work, some of which include: US National Science Foundation base funding for NCAR, USAID, US Army, and most recently, NASA-funded research feasibility project designed to define the pathway for sustainable implementation of a flood mapping processor, a merger between an automated, near real time ), MODIS sensor-based flood map product and a complementary, radar frequency, Envisat ASAR based global flood mapping processor.

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

The following amenities will be provided by the Client:

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

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## **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 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, and 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 contract, 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 basin models may be considered 'restricted' as per Ministry of Defence 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. International Consultant Study Team**

### **Lead Organization Criteria**

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.

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- Demonstrated experience in Extended Hydrological modelling, flood forecasting at basin scale, and environmental flow assessments in large complex river basins.
  - 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 including India.
  - Ability to quickly deploy a team (professionals with relevant experience and qualifications) either from the lead organization or through sub-contracting arrangements.

The table below provides an indication of the size of team for this project, the range of skills and team composition. It is anticipated that one project coordinator would need to be based in New Delhi. At various times during the project extended missions would be required to ensure adequate engagement and consultation.



## 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	<ol style="list-style-type: none"> <li>1. Relevant advanced academic degree in Hydrology, Hydraulic and / or Water Resources engineering.</li> <li>2. At least 15 years working experience in water resources.</li> <li>3. Preferably he has knowledge of hydrological and hydrodynamic modeling tools used in flood forecasting.</li> <li>4. He has handled at least two projects as a Team Leader/Dy Team leader in international project in water resources.</li> <li>5. Should have been with bidding firm for past 3 years</li> </ol>	<ul style="list-style-type: none"> <li>• Project Management</li> <li>• Reports</li> <li>• Deliverables</li> <li>• Organization of Trainings</li> <li>• Coordinate the modeling efforts</li> <li>• Focal person for interaction with client</li> <li>• Lead in presentations</li> </ul>	12	0
Hydrologist / Deputy Team Leader	1	<ol style="list-style-type: none"> <li>1. Relevant advanced academic degree in Hydrology, Hydraulic and / or Water Resources engineering.</li> <li>2. At least 5 years working experience in meteorological forecast/meteorological product (field observation, Doppler radar, Satellite products / combined products) etc</li> <li>3. Extensive knowledge of hydrological and hydrodynamic modeling tools</li> <li>4. Desirable: experience in application Software Development / design in Water resources sector.</li> </ol>	<ul style="list-style-type: none"> <li>• Analysis of meteorological forecast</li> <li>• Bias Correction on satellite / forecast products</li> <li>• Review of Data</li> <li>• Data quality check and gap filling for modeling</li> <li>• Assist in Setup, calibrate and validate the models for Hydrology, river hydraulics and flood inundation</li> <li>• Assist in Ongoing improvement in models with recalibration and incorporation of new data</li> </ul>	12	5
Senior	3	<ol style="list-style-type: none"> <li>1. Relevant academic degree in Hydrology,</li> </ol>	<ul style="list-style-type: none"> <li>• Review of Data</li> </ul>	30	15

Hydrologic Modeler		<p>Hydraulic and / or Water Resources engineering.</p> <ol style="list-style-type: none"> <li>At least 10 years working experience in flood modeling and early warning system / GIS use for modeling.</li> <li>Extensive knowledge of hydrological and hydrodynamic modeling tools with very good experience of rainfall- run-off modeling.</li> <li>Proven experience in setting up models for forecasting in large river basin.</li> <li>Should have been with bidding firm for past 3 years</li> </ol>	<ul style="list-style-type: none"> <li>Data quality check and gap filling for modeling</li> <li>Setup, calibrate and validate the models for Hydrology, river hydraulics and flood inundation <ul style="list-style-type: none"> <li>Ongoing improvement in models with recalibration and incorporation of new data</li> </ul> </li> </ul>		
Junior Hydrologic Modeler	8	<ol style="list-style-type: none"> <li>Relevant academic degree in Hydrology, Hydraulic and / or Water Resources engineering.</li> <li>At least 5 years working experience in flood modeling and early warning system / GIS use for modeling.</li> <li>Extensive knowledge of hydrological and hydrodynamic modeling tools with very good experience of rainfall- run-off modeling.</li> <li>Proven experience in setting up models for forecasting in large river basin.</li> </ol>	<ul style="list-style-type: none"> <li>Assist the senior hydrologist in data quality check and gap filling</li> <li>Assist in model development and calibration</li> <li>Interlinking and data exchange between various models</li> <li>Ongoing improvement in models with recalibration and incorporation of new data</li> </ul>	96	180
GIS/RS specialist		<ol style="list-style-type: none"> <li>M.Sc. Geography/Geo Science with specialization in GIS/RS.</li> <li>5 year experience in RS/GIS applications for resource mapping, preparation and integration of GIS datasets, experience in integrating global satellite derived data; experience in hydrologic application, 3D analysis and customization and experience in flood inundation mapping for GIS/RS specialist.</li> </ol>	<ul style="list-style-type: none"> <li>Assist the modelers for spatial dataset generation</li> <li>Help in procuring / processing Spatial data on DEM, Snow cover, forecast products</li> </ul>	12	5
Database specialist / web		<ol style="list-style-type: none"> <li>Graduate in Engineering in Computer Science/IT</li> </ol>	<ul style="list-style-type: none"> <li>Automation of forecasting system from data</li> </ul>	30	60

management specialist / Programmer		<p>2. 5 year experience in data base applications for Database, web management etc ;</p> <p>3. Extensive experience in scripting using Python or related tools</p>	<p>collection to forecast dissemination</p> <ul style="list-style-type: none"> <li>• Write scripts for exchange of data between various formats and models</li> <li>• Develop and maintain real-time flood forecast website</li> <li>• Assist in procuring hardware / software for the forecasting system</li> </ul>		
Technical Support Staff	2	Graduate. He should have basic knowledge of computer.		30	0
Other Supporting Staff	3	Matriculate and above		45	60

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## **Administration**

For the purposes of this assignment, the Consultant will report to River Data Directorate of CWC. The Consultant will work closely with the CWC offices as a Client throughout this assignment – especially to discuss interim results and on methodology.

### **8. Duration of Consultancy**

**6 years**

### **9. Payment Schedule**

#### **Phase-I**

- 10 percent on signing of contract as advance against a bank guarantee
- 5percent after acceptance of Inception Report.
- 5 percent after submission and approval data compilation report.
- 10 percent after submission and approval of Satellite ensembles, NWP estimate and Multi-model compilation report.
- 10 percent after approval of Draft Final Report (completion of flood forecasting for the Main Basin at sub-basin levels – validations and flood forecast scenarios using lead time ensembles result) and training plan
- 10 percent after completion of training and workshop and submission and approval of Final Report.

#### **Phase II**

- 5 % Payment will be made on half yearly basis after providing the satisfactory services during that period (5 % per half Yearly \* 5 years = 50%).