Project Implementation Plan

Satellite Data Based

Operational Geo-spatial Services and Applications

Under

National Hydrology Project

Submitted to

Ministry of Water Resources
Govt. of India

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National Remote Sensing Centre
ISRO, Govt. of India
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1. Introduction

National Hydrology Project (NHP) is being taken up of Ministry of Water Resources, Govt. of India with financial aid from World Bank. The objective of project is to improve the extent and accessibility of water resources information and strengthen institutional capacity to enable improved water resources planning and management across India. The mission is to establish an effective and sound hydrologic database and Hydrological Information System (HIS), together with the development of consistent and scientifically-based tools and design aids to assist in the effective water resources planning and management within each to the implementing agencies based on sound scientific driven framework. HP-III will be implemented across India in all states and union territories.

The project comprises four broad components:

a) *Improving In Situ Monitoring System (IMS)* - To expand and upgrade water resources monitoring systems, bolster database population and maintenance, develop community-based data collection and water management, and conduct site specific surveys to the states in the Indus, Ganges and Brahmaputra Basins and in North-East India

b) *Improving Spatial Information System (SIS)* – To strengthen and make available remote sensing and spatial information data to water managers and stakeholders through providing and processing of spatial data sets, creating tools for tailor-made processing of spatial data, and developing web-based portals for public access to information. Development of centralized spatial data sets will largely be produced by National Remotes Sensing Center (NRSC), Indian Meteorological Department (IMD) and Survey of India (SOI) with the dissemination of the information via a publicly accessible, web-based portal for non-classified data.

c) *Promoting Water Resources Operation and Management Applications (WROMA)* – To ensure the usefulness of the WRMS and WRIS data sets through decision support systems (DSS) for river basin planning, water balance assessments, climate risk assessments, water quality management, scenario analysis for investment planning, and tools for community based water management. It will develop short-term and seasonal flow forecasts, establish multiple flood/flow forecasting systems important for operation of reservoirs and flood management, and introduce on pilot basis operation and water distribution systems for irrigation systems.

Flagship knowledge products will include IWRM systems for selected river basins, a report on the status of India's water resources, including water balance assessments, water quality assessments and support purpose driven studies (PDS) on specific issues for each IA, including climate risk assessments for present and planned water resources infrastructure.

d) *Strengthening Water Resources Institutions and Capacity Building (WRICB)* – To strengthen and build capacity in the participating Implementing Agencies (Water Resources Institutions) through establishing Water Resources Knowledge Centers and providing infrastructure and communication equipment, capacity building and extensive training programs, supporting project management through Technical Assistance and Management Consultancies, and funding of incremental staff. In particular, the project will support the establishment of a National Water Information Center (upgraded version of India-WRIS) and centers of excellence at national and state levels.

In this connection, Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR) consulted NRSC to support NHP through geo-spatial data products, services, customized applications development and capacity building to the stakeholders. NRSC participated various meetings organized by MoWR, RD&GR and World Bank and deliberated on the possible role NRSC/ISRO would play in NHP implementation. Comments and concurrence of draft EFC memo was communicated from the Office of Secretary of Dept. of Space to MoWR, RD&GR. NRSC participated in the Wrap-up Meeting of NHP World Bank Mission held during 14-15 Sep, 2015 at New Delhi and presented the details of possible Role of National Remote Sensing Centre (ISRO) under National Hydrology Project. Further, Joint Secretary, MoWR, RD&GR communicated approval of EFC Memo through D.O. No. 21/97/2015-NHP/3925 Dt. 26th Nov, 2015.

In response to the above, the present proposal is formulated, where in NRSC/ISRO is supporting NHP through geospatial data based services, water resources/hydrology applications development and capacity building under three NHP components – namely: b) SIS, c) WROMA & d) WRICB.

2. Objectives

The overall objective of the proposal is to generate satellite data based geo-spatial products pertaining to water resources sector, water disaster support through development of flood early warning systems, generate in-season inputs on hydrological variables to support water resources management through hydrological modeling and radiation budgeting and to provide capacity building through customized training.

The above broad objectives are proposed to be achieved through various sub-objectives/components as under:

1. Real-time Operational Spatial Flood Early Warning System Development
2. Development of Satellite-based Regional Evaporative Flux Monitoring System for India
3. Glacial Lake Outburst Flood (GLOF) Risk Assessment
4. Development of spatial snowmelt runoff product in the Indian Himalayas
5. Operational National Hydrological Modelling System for the entire Country
6. Satellite data based inputs for Irrigation Scheduling for a selected Irrigation Project command area
7. Operational hydrological drought services using remote sensing data
8. Customized RS & GIS Training and Capacity Building

The objectives of each of the above projects are given below:

2.1 Real-time Operational Spatial Flood Early Warning System Development

- To develop medium-range flood early warning models for the major floodplains of two study river basins using space based inputs through hydrological modelling approach. (Godavari and Tapti Basins are identified for the study)
- To develop spatial flood inundation simulation models using high resolution DEM in the major floodplains of the rivers.
- To develop web-enabled real-time spatial flood early warning system
- To develop workflow for issuing flood advisory to the concerned disaster management authorities during the flood event.
- Generation of flood inundation scenarios in the main flood-plains of the rivers under different flood return periods

2.2 Development of Satellite-based Regional Evaporative Flux Monitoring System for India

- Estimation of daily evaporative fluxes for Indian region at an appropriate spatial framework
- Development of evaporative flux observing and monitoring system at spatial scales of watersheds/river-basins and land use/land cover units and temporal scales of pentads, dekads, fortnights, months and seasons.

- Creation of long term data base of evaporative fluxes and design of structured query and analysis tools

2.3 Glacial Lake Outburst Flood (GLOF) Risk Assessment of Glacial Lakes in the Himalayan Region of Indian River Basins

- Inventory of glacial lakes using high resolution data
- Selection of critical glacial lakes using desk based approach.
- Prioritization of critical lakes
- Generation of high resolution DEM for D/S of prioritized critical lakes (15)
- Investigation of prioritized critical lakes and their surroundings based on high resolution DEM and data.
- GLOF modeling and inundation mapping using high resolution DEM

2.4 Development of spatial snow melt runoff product in the Himalayan Region of Indian River Basins

- To develop a short-term snowmelt runoff forecasting model using satellite derived products and field data
- To generate a spatial daily gridded snowmelt product
- To generate a spatial 3-day snowmelt forecast gridded product
- To provide short term snowmelt runoff forecast at selected basin outlets during snow melt season
- To provide seasonal forecast at selected basin outlets during snow melt season

2.5 Operational Web-based National Hydrological Modelling System for the entire Country

- To establish National level hydrological modeling framework for in season hydrological fluxes estimation at daily/weekly/fortnightly time step
- To establish a comprehensive field experimentation setup for calibration and validation of model computed flux outputs (Soil Moisture, ET)
- To Develop of web-enabled in-season hydrological fluxes information for the entire country on India-WRIS/Bhuvan

2.6 Satellite data based inputs for Irrigation Scheduling for a selected Irrigation Project command area

- To estimate in-season cropping pattern and crop condition using near-real-time satellite data
- To estimate in-season irrigation water demand at weekly/fortnightly time-step
- To quantify the water productivity variations across the command area and evaluate the performance of irrigation system.

- Development of a decision support system for irrigation scheduling

2.7 Customized RS & GIS Training and Capacity Building

- To conduct two training programs (one week) per year on RS & GIS fundamentals and state of art with 25 participants per batch (2017-18 to 2023-24)
- To conduct two customized training programs (two weeks) per year on RS & GIS applications in water resources management with 25 participants per batch (2016-17 to 2023-24)
- Hand holding/Technical support of satellite/GIS data handling to States/UT's

3. Study Area

The study areas are varying with each sub-objective.

Objective 2.1 & 2.6 cover two river basins and one irrigation command area, respectively. Entire country would be covered under Objectives 2.2 & 2.5. Objectives 2.3 & 24 cover Himalayan region of Indian river basins.

4. Satellite and Ancillary Data bases

Objective-wise data requirements and sources in each of the sub-activity are detailed in the corresponding proposals Annexed herewith.

5. Approach Methodology

Methodology adopted in each of the sub-activity is detailed in the corresponding proposal Annexed herewith (Annexure 1 to 8).

6. Deliverables

The details of each of the above are given below:

6.1 Real-time Operational Spatial Flood Early Warning System Development

- Developed flood forecast models (Godavari by Sep 2019; Tapi by Sep 2020)
- Developed Spatial flood early warning models (Godavari by Dec 2020; Tapi basin by Dec 2021)
- Computed flood inundation scenarios (Godavari by Dec 2021; Tapi basin by Sep 2022)

- Developed web-enabled real-time flood forecast system (Godavari by March 2022, Tapi by Dec 2022)

6.2 Development of Satellite-based Regional Evaporative Flux Monitoring System for India

- Satellite data based regional ET estimates for India at spatial scales of watershed/river-basin/land cover units and at temporal scales of daily, fortnightly, monthly and annually
- Long term (from 2004 onwards) ET database
- Validation sites network infrastructure/facility
- Web GIS based regional ET monitoring system

6.3 Glacial Lake Outburst Flood (GLOF) Risk Assessment of Glacial Lakes in the Himalayan Region of Indian River Basins

- Updated inventory of glaciers and glacial lakes
- List and details of potentially dangerous lakes
- High resolution DEM for D/S of prioritized critical lakes
- Possible flood inundation simulation maps in different scenarios for the critical lakes
- Simulated GLOF models in Visualisation system

6.4 Development of spatial snow melt runoff product in the Himalayan Region of Indian River Basins

- Daily Snow cover map at 1km resolution using NPP Suomi or equivalent satellite data
- Forecast models for short term and seasonal snowmelt for Indian Himalayas
- Spatial daily gridded snowmelt product
- Spatial gridded 3-day snowmelt forecast product
- Short term snowmelt runoff forecast at selected basin outlets during snow melt season
- Seasonal forecast at selected basin outlets during snow melt season

6.5 Operational Web-based National Hydrological Modelling System for the entire Country

- Grid-wise periodic Water Fluxes (Evapotranspiration, Soil Moisture, Runoff) daily/weekly/fortnightly time step
- Web based geo-spatial hydrological products and services
- Forecast of inflows into selected reservoirs & corresponding reservoir storage estimation
- Runoff forecast at selected river reaches across the country

6.6 Satellite data based inputs for Irrigation Scheduling for a selected Irrigation Project command area

- Cropping pattern and crop condition at tertiary canal level (in-season) during the rabi seasons 2018-19 to 2023-24
- Weekly /Fortnightly irrigation water requirements at tertiary canal (in-season) during rabi seasons 2019-20 to 2023-24
- Irrigation system performance assessment for the rabi seasons 2019-20 to 2023-24
- Decision support system for irrigation scheduling.

6.7 Customized RS & GIS Training and Capacity Building

- Two training programs (one week) per year on RS & GIS fundamentals and state-of-the-art technologies (2017-18 to 2023-24)
- 2. Two customized training programs (two weeks) per year on RS & GIS applications in water resources management (2016-17* to 2023-24)

  (One Training Program only in 2016-17)*

7. Quality Assurance Mechanism

Quality Evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards. Internal and external quality evaluation teams will be constituted to evaluate and certify the quality assurance in the work procedures/processes adopted in the study through quantitative measures. The outputs/deliverables will be denoted with accuracy measures.

8. Magnitude of Work and Manpower

NRSC will execute the project using existing scientific manpower along with Project Scientists/JRFs to be recruited under the project. Also, suitable collaborating partners (Universities, Research Organizations) will be identified and joint research will be carried out for meeting project specific research elements.

9. Project Execution Plan

The project execution plan will be prepared as per the ISO guidelines practiced within NRSC. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

The tentative schedule & milestones of the project are:

Activity	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Flood Early Warning	FF Model Dev.		Validation & Exp. Run		Spatial Simulations model		Web, Real-time, FEW	
ET	Model Framework Dev.		ET validation experiments		Real time runs & web hosting		Validated product dissemination	
GLOF	Inventory & Ranking		Hydrological Investigation		Risk Modelling & Mapping			
Snowmelt	Geo-spatial data		Model dev. & Forecast		Real-time run, validation		Real-time implementation	
Hydrological Fluxes	Model Framework Dev.		Field Experimentation, Validation,		Real-time run, dissemination, Web hosting		Real-time, Value added products, Web hosting	
Irrigation	Geo-spatial data		In-season crop, Field experimentation		Irrigation Demand, Validation, System Performance		Irrigation Demand, In-season inputs, Performance	
Hydrological Drought	Geo-spatial Hydrological data		In-season Hydrological indicators		Validation and Web hosting		In-season Value added products, web hosting	
Capacity Building	1 Batch/ 25 No.	4 Batches per year (100 participants/year from 2017-18 to 2023-24)						

10. Time schedule

The project activity will be from Sep, 2016 to Mar, 2024

11. Project Review and Reporting

Project Management Unit will be constituted for periodic review of project progress and necessary guidance during the project execution. Project Management Committee (PMC) consisting of NRSC and MoWR senior Officials will be constituted for the NRSC-NHP project for periodic review of all study activities, progress monitoring and related issues.

Central Project Management Unit (CPMU) is created under the project and detailed below:

CPMU - NRSC

(To be created shortly)

12. Budget

Item	Sub-Objective								Total
	1. Spatial Flood Early Warning System	2. Regional Evaporative Flux Monitoring System	3. Glacial Lake Outburst Flood (GLOF) Risk Assessment	4. Spatial snow melt runoff estimation	5. Operational Web-based National Hydrological Modelling System	6. Satellite data based inputs for Irrigation Scheduling	7.Operational hydrological drought services	8. Customized RS & GIS Training and Capacity Building	
Geo-spatial base data (Landuse/landcover, Soils, DEM, etc.)	Available databases will be used (NRC, MODIS, NBSS&LUP, FAO, Field data, etc)								0.0
Meteorological data	To be obtained from IMD under NHP								0.0
Satellite data	17.0	19.0	319.8	0.0	21.0	66.0	28.0	0.0	470.8
Field Experimentation & Outsourcing Activities	120.0	705.0	0.0	0.0	355.0	10.0	0.0	0.0	1190.0
NRSC Manpower	62.4	37.0	27.8	19.9	60.1	37.0	37.9	0.0	282.1
Project Scientists @ 0.55 lakh/month/JRF @ 0.35 lakh/month for first 2 years and 0.42 for remaining years	157.1	129.8	119.4	167.2	129.8	119.7	203.3	56.3	1082.5
Data Analaysis	42.0	29.0	33.0	30.0	15.0	8.0	42.0	0.0	199.0
Hardware & Software	126.2	43.8	75.8	49.2	66.4	37.7	500.0	896.3	1795.2
ALTM DEM / High Resolution Satellite DEM Generation	980.0	0.0	720.0	0.0	0.0	0.0	0.0	0.0	1700.0
Travel and Field Works	34.0	34.0	23.0	29.0	10.1	15.0	8.0	0.0	153.1
Training & Workshops	56.0	45.0	24.0	34.0	40.0	23.0	0.0	160.0	382.0
Sub-Total 1	1594.6	1042.6	1342.7	329.3	697.4	316.4	819.1	1112.5	**7254.6**
Project Management @ 5% on Sub-Total 1	79.7	52.1	67.1	16.5	34.9	15.8	41.0	55.6	362.7
Sub-Total 2	1674.4	1094.7	1409.9	345.8	732.3	332.2	860.1	1168.1	**7617.3**
Organizational Overheads @ 5% on Sub-Total 2	83.7	54.7	70.5	17.3	36.6	16.6	43.0	58.4	380.9
Total	**1758.1**	**1149.4**	**1480.4**	**363.0**	**768.9**	**348.8**	**903.1**	**1226.5**	**7998.2**

Total Budget : Rs. 7998.20 Lakhs (Rs. Seventy Nine Hundred Ninety Eight Lakh and Twenty Thousand only)

Annexure 1

Real-time Operational Spatial Flood Early Warning System Development

1.0 Introduction

India, which is traversed by a large number of river systems, experiences seasonal floods. It has been experienced that the floods occur almost every year in one part or the other of the country. The rivers of North and Central India are prone to frequent floods during the south-west monsoon season. In India, an area of more than 40 million ha has been identified as flood prone. For minimizing the losses due to floods, various flood control measures are adopted. The flood control measures -which should more correctly be termed as “Flood Management” can be planned either through structural engineering measures or non-structural measures. Wise application of engineering science has afforded ways of mitigating the ravages due to floods and providing reasonable measure of protection to life and property. Real time flood forecasting and flood plain zoning are some of the important non-structural measures adopted for the management of the flood. Real time flood forecasting systems are formulated for issuing the flood warning in real time in order to prepare the evacuation plan during the flood. Real-time flood forecast models are developed across the globe for flood damage control. The most popular forecast systems are;

The Flood Forecasting System of Three Gorges of the Yangtze River (China): Yangtze River, the largest river in China which traverses the country from west to east, with a total length of more than 6300 km and a basin area of about 1.8 million km2. Flooding through the Yichang Hydrological Station, located at the outlet of the Three Gorges, is usually caused by rainstorms upstream and in the local area (Zhang Ruifang, 1990). The Flood Forecasting System for the Three Gorges consists of three parts: historical hydrological data entry, model calibration, and real-time forecasting. The historical hydrological data entry is controlled by a common program for inputting, error checking, listing, tabulating and duration file accessing. As there is interdependence among the parameters of the conceptual model, it is advisable that a mathematical model of fewer parameters, of clear concept and of simple structure, especially in operational forecasting, be adopted. Therefore, in developing forecasting schemes for such an area, efforts should be concentrated not on model selection but on the solution of concrete problems (Zhang Ruifang, 1990).

Flood Forecasting in Bangladesh: Bangladesh is a predominantly low-lying country comprising the delta at confluence of the Ganges, the Brahmaputra and the Meghna river basins draining the Himalayan mountains through India and other neighbouring countries into the Bay of Bengal (Gregers H J and Jacob H M, 1997). Each year Bangladesh experiences flooding from these rivers with inundation of large areas of the country, and the flooding is aggravated by high local rainfall within Bangladesh. In order to reduce loss of life and property it was planned to develop an effective flood forecasting and warning system that can assist in disaster preparedness. In 1995 the Danish Hydraulic Institute (DHI) initiated a project to enhance the flood forecasting and warning system in Bangladesh. The project is financed by the Danish International Development Aid (DANIDA) and is being carried out in close collaboration with the Bangladesh Water Development Board (BWDB). During a 3-years implementation period the following key elements of the new system are being introduced (Gregers H J and Jacob H M, 1997). A modernized and enhanced telemetry network, real-time forecasting system for all major and secondary rivers in Bangladesh, an improved dissemination system for flood forecasts and warnings are the key points in the system.

European Flood Forecasting System: Various research organizations (researchers from nearly 10 organisations) such as; Institute of Environment and Sustainability, European Centre for Medium Range Weather Forecasting, Swedish Meteorological and Hydrological Institute, Danish Meteorological Institute, etc. have together developed flood forecasting system for real-time flood forecasting in Europe. The European Flood Forecasting System prototype consists of the following components:

1. Global Numerical Weather Prediction models,

2. Optional downscaling of global precipitation from (1) using a regional Numerical Weather Prediction model,

3. A catchment hydrology model comprising a soil water balance model with daily time step and a flood simulation model with hourly time step,

4. A high-resolution flood inundation model.

These are integrated within a generic modelling framework that allows different models to be used interchangeably for each component. The modelling framework is linked to a central database and is mounted on an open, platform-independent architecture that allows encapsulation of various pre-existing simulation codes via appropriate “model wrappers”. Hence, although the hydrology and hydraulic components of the system (3–4 above) have been based around the LISFLOOD suite of raster-based hydrology and hydraulic codes other models can alternatively be used.

Indian Experiences: Several researchers in India have made attempts to develop flood forecast models/methods in various rivers of the country. Sengupth et al. (2007) have explained the efforts made on development of flood forecasting system in Mahanadi Basin. A project has been envisaged under Indo-American collaboration to develop flood forecast system and flood inundation modeling in Mahanahi River Basin. The National Weather Service River Forecast System (NWSRFS) is being implemented and calibrated using hydrologic records for the Mahanadi basin. Data-collection and telemetry are being enhanced through the efforts of Indian agencies. It has been planned to develop flood inundation maps using high resolution DEM.

Andhra Pradesh Government, India in collaboration with Danish Hydraulic Institute has developed flood forecast model for the Godavari and Krishna Basins. Widespread tele-meteorological network has been established to collect the real-time rainfall data over the above basins. Closed contour information along the floodplains has been collected during field surveys and used for possible flood inundation simulation (Ramesh, 2004).

Central Water Commission (CWC) is a pioneer organisation in India that gives flood forecast in many flood-prone rivers. It uses mainly a popular statistical gauge to gauge correlation technique in flood forecasting in many rivers. It is understand that in recent years CWC is in the process of developing hydrological models for some rivers of the country. Application of remote sensing outputs such as landuse/landcover, satellite base rainfall estimates, soil texture etc. in the distributed rainfall runoff models and integration of these databases in GIS environment considerably improves the flood forecasting capabilities.

In view of these, it is proposed to develop real-time spatial flood early warning models for the Godavari, and Brahmani-Baitarani Basins (study basins are yet to be decided by CWC) using space based inputs through hydrological modelling approach. This activity will be executed in collaboration with Central Water Commission and India Meteorological Department.

2.0 Objectives

- To develop medium-range flood early warning models for the major floodplains of two study river basins using space based inputs through hydrological modelling approach. (Godavari and Tapti Basins are identified for the study)
- To develop spatial flood inundation simulation models using high resolution DEM in the major floodplains of the rivers.
- To develop web-enabled real-time spatial flood early warning system
- To develop workflow for issuing flood advisory to the concerned disaster management authorities during the flood event.
- Generation of flood inundation scenarios in the main flood-plains of the rivers under different flood return periods.

3.0 Study Basins

It is proposed to develop medium-range spatial flood warning models for the main floodplains of the following basins;

3.1 The Godavari Basin: Godavari Basin extends over an area of 312,812 km^2 and second largest river in India. The basin lies in the states of Maharashtra (48.65 %), Andhra Pradesh (23.40 %), Chattisgarh (12.49 %), Madhya Pradesh (8.63 %), Orissa (5.67 %), and Karnataka (1.41 %). The annual rainfall of the basin varies from 3000 mm to 600 mm. Floods are the regular phenomenon in the basin. Perur to Koida river stretch (which includes Badrachalam, Kunavaram, and Sabari River) and Deltaic portion of the river are the main floodplains of the basin. Sabari, Indravati and Pranahita cause floods in the basin. Upstream of the main Godavari is controlled by many reservoirs. Considering the hydrological description of the River downstream portion of the basin is taken up for flood forecast model development and upstream discharges will act as inflow to the model. Floodplains falling between Perur to Koida river stretch (including Sabari flood plains) will be considered for flood inundation simulations.

3.2 **The Tapi River Basin:** Tapi river is one of the major rivers in India. The total length of the Tapi river is approximately around 724 km. It flows in the central part of India. The river originates from the Betul district of Madhya Pradesh in the Satpura range at an elevation of 752 meter above the sea level. The states through which the Tapi river flows include Maharashtra, Gujrat and Madhya Pradesh. Tapi is one of the main west flowing rivers of the country and joins the Arabian Sea. The Tapi basin extends to the total area of 65, 145 sq km, the main tributaries of the river are Purna, The Girna, The Panjhra, The Vaghur, the Bori and the Aner.

4.0 Methodology

Modelling approaches can be categorised into lumped approach and distributed/semi-distributed approach. In distributed/semi-distributed modelling approach, the spatial variation of the above variables will be considered and the runoff will be computed in spatial domine. GIS platform with the integration of satellite data will give an excellent solution in distributed /semi-distributed modelling approaches. Complete methodology to achieve the said objectives can be broadly categorised into the following stages;

4.1 Development of flood forecast model

- Computing runoff (hydrological modelling)
- Flood Routing (hydrodynamic modelling)
- Calibration of the flood forecast model with historic field discharge data of at least two years
- Flood forecast model validation with historic field discharge data of two years with the accuracy up to ± 20% (discharge) and ± 6 hours (time)

4.2 Development of spatial inundation simulation model

- Extracting topographic parameters like river cross sections, river longitudinal profiles, etc.
- Development of spatial inundation simulation model (using ALTM/LFDC DEM)
- Calibration and validation of the inundation simulations (with satellite data if available) with the accuracy of up to ± 20%

4.3 Development of real-time web-enabled spatial flood early warning system.

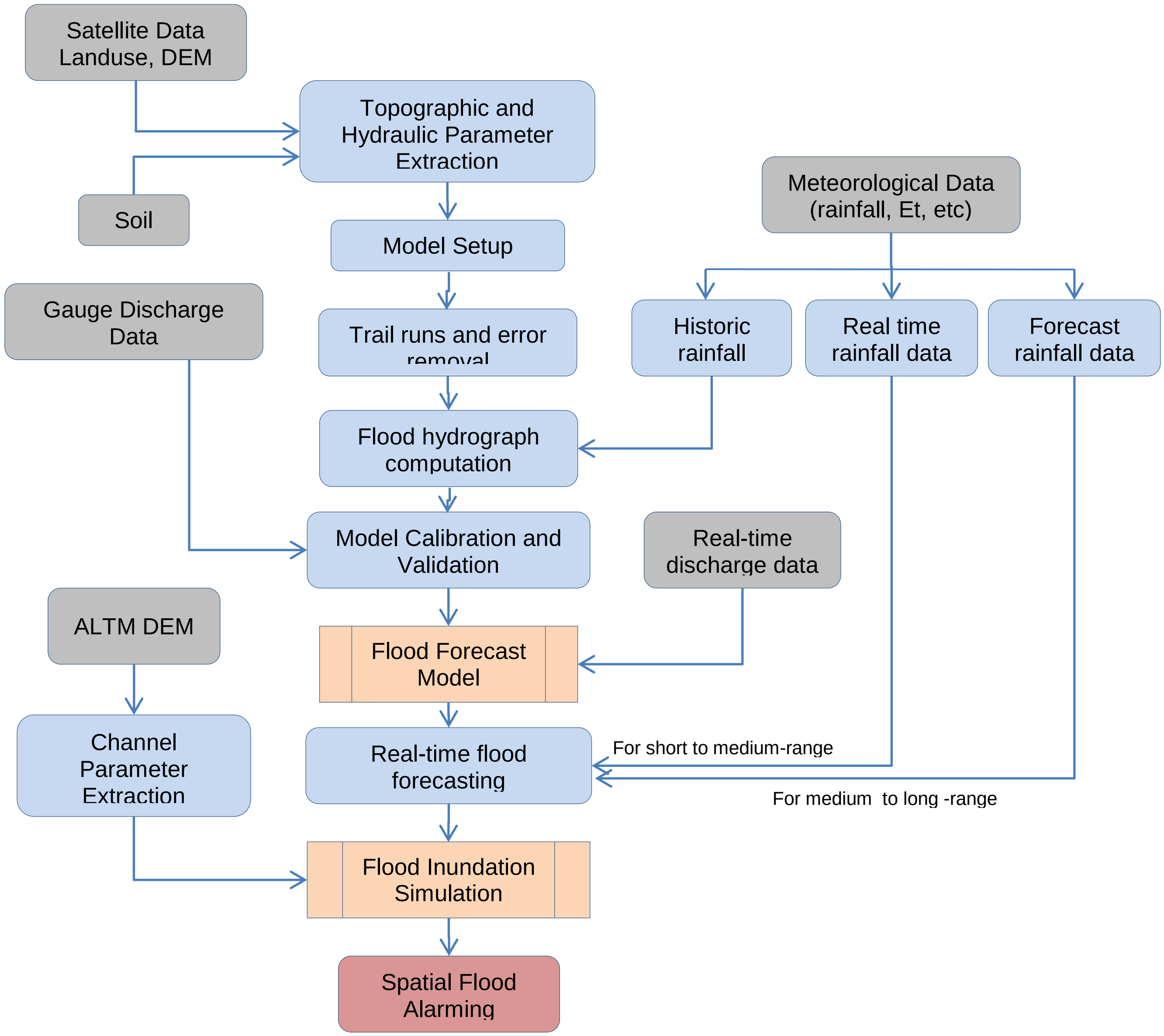
- Real-time simulations using the real-time rainfall data, rainfall forecast grids and tele-meteorological
- Development of web-enabled spatial flood forecast system
- Development of work flow mechanism for issuing flood advisory to the concerned identified authorities.
- Implementation of the real-time flood forecast system.

Various sub-stages involved to achieve the desired objectives are;

- Collection of the field data
- Establishing gauge stations by CWC at prominent locations(if required)
- Creation of spatial and non-spatial database
- Computation of topographic, hydraulic and hydrologic parameters
- Collection and analysis of hydro-meteorological data
- Establishing rain gauge stations by IMD in prominent areas (if required)
- Extraction of river profiles both longitudinally and in horizontally.
- Extraction of topographic parameters for flood inundation simulations.
- Flood area inundation model setup using high resolution DEM
- Development of web-enabled spatial flood early warning system.
- Mechanism to communicate flood advisories to the concerned disaster management authorities.
- Implementation of the activity in real-time

The broad conceptual methodology is discussed in the following schematic diagram.

Existing models developed by NRSC and CWC will be examined thoroughly for its real-time application. If required a new model setup will be developed jointly by CWC and NRSC. NRSC will provide all space based inputs and technical support to CWC in developing hydrological models for flood forecasting of both the basins. Model will be calibrated and validated with the space based inputs and field discharge data. NRSC will develop the flood inundation simulation models using high resolution DEMs. The developed flood forecast models will be integrated with the inundation simulation models at NRSC. CWC will provide all ground data like river cross sections, real-time and historic gauge discharge data, etc. to NRSC. Integration of the models, customisation, dissemination during project period will be done by NRSC in association with the CWC.



Conceptual Methodology

5.0 Topographic and Hydro-meteorological Data

5.1 Topographic Data: Landuse/Landcover (NRC Data), soil textural grid (250K scale), digital elevation model CARTO/ASTER/SRTM. High Resolution DEM of floodplains (msl or near msl corrected DEM). Details on flood retention structures such as; embankments, culverts, bridges, river cross section profiles/bathymetry data, etc. should be provided by CWC.

Floodplains of the Godavari from Perur to Koida including Sabari is approximately 3000 Sq.Km. and from Koida to delta area is approximately 6000 Sq.Km. Considering the data availability, data volume, software and hardware capabilities it is proposed to do flood inundation simulations in main Godavari floodplains between Perur and Koida in the first phase and the deltaic portion will be attempted in the subsequent phase after the acquisition of the high resolution DEM. For other floodplain areas of the basin, CARTO 10 m DEM will be used wherever it is suitable and required.

In Tapi River, floodplains are yet to be identified by the CWC. Floodplains in the downstream of Ukai Dam will be considered for flood inundation simulations in the first phase of the work. Subsequently it will be extended further to other floodplains if any. Initially CARTO 10m DEM will be used for flood inundation simulations and it will be replaced by high resolution DEMs subsequently wherever it is required.

5.2 Hydro-meteorological Data: CWC/MoWR should facilitate in providing the following meteorological and hydrological data of all stations from IMD/State Departments/CWC/INCOIS/ and any other departments. High density meteorological data is required for operational flood forecast hence data from all type of stations and sources has to be pooled up and provide to NRSC in real-time.

Sub-daily real-time rainfall data through tele-meteorological network, other meteorological data for ET computation, real-time 3 hour gauge-discharge data at various locations, rating curves, real-time 3 hour reservoir releases, reservoirs operation tables, etc. classified discharge data (if andy) and rainfall forecast data at 3 hour frequency.

- Meteorological data from IMD and state departments (AWS, ARG, and other sources)
- Gauge Discharge and other hydrological data from CWC/state departments
- Storm surge data of Delta area if applicable from INCOIS

Required Data formats (action on other groups)

1. Sub-daily real-time rainfall data and sub-daily rainfall forecast data from IMD in grid format (*.grid)
2. Daily/monthly ET data in grid format (*.grid)

Note: CWC and IMD should establish gauge sites at prominent and important locations if required. Tele-hydro-meteorological data of all stations should be transferred in NRSC in real-time directly from all gauge sites.

6.0 Role of Ministry of Water Resources/Central Water Commission:

Ministry has to facilitate in providing the mentioned historic and real-time meteorological data from IMD, historic and real-time gauge discharge data, river cross sections, other field data, and classified data (if any) from CWC & state governments/agencies, and storm surge data from INCOIS to NRSC. The details of hydro-meteorological data requirements are spelled out in the section 5.2. This activity will be executed by the NRSC with the association of CWC. Role of NRSC and CWC in developing the customised spatial flood early warning models are spelled out in the methodology. CWC has to provide calibrated and validated hydrological model for flood forecasting to NRSC. NRSC will provide necessary space based inputs and technical support to CWC in this task.

7.0 Collaboration

- Central Water Commission
- India Meteorological Department
- INCOIS, Hyderabad
- State Disaster Support Centres and other State Centres
- International institutes like DHI/HEC software Group for customization/training, etc..

Proper MoU should exist between NRSC, CWC, IMD, and INCOIS for real-time transmission of hydro-meteorological data directly through tele-network stations to NRSC

8.0 Software: HEC-Software or MIKE software package will be used for hydrological and hydrodynamic modelling based on the modelling capabilities and ease in customisation procedures.

9.0 Deliverables:

- Developed flood forecast models (Godavari by Sep 2019; Tapi by Sep 2020)
- Developed Spatial flood early warning models (Godavari by Dec 2020; Tapi basin by Dec 2021)
- Computed flood inundation scenarios (Godavari by Dec 2021; Tapi basin by Sep 2022)
- Developed web-enabled real-time flood forecast system (Godavari by March 2022, Tapi by Dec 2022)
- Developed spatial and non-spatial database (first quarter of 2024)
- Project Reports for both the basins (first quarter of 2024)

These outputs will be handed over to the identified nodal officer of the Ministry of Water Resources, India

Note: it is proposed to demonstrate the overall methodology and mechanism at the earliest possible with the existing databases. The models will be keep on updating time to time as and when the better data will be available during the project period. The above mentioned schedules are for completing the final tasks.

10.0 Limitations of the Study:

- In real-time operations quality check cannot be done on hydro-met data hence, the accuracy of flood forecast models vary based on topographic and hydro-meteorological data used.

- Based on the basin size, shape flood forecast lead time will vary from 1 day (upstream sites) to 2 days (downstream sites) for bigger catchment. For smaller catchment the lead time will be reduced further.

- Rainfall forecast data will be used in the models to improve the lead time and satellite based near real-time rainfall products will be used in absence of field rain gauge data in any pockets of the catchment hence, model accuracy will be subjected to accuracy of these products.

- Reservoir rating curves (rule curve of elevation-capacity-outflow) wherever reservoir outflow gauges are not available hence the accuracy of the model will be subjected to the accuracy of operations of reservoirs based on rule curves.

- Flood inundation simulations will be done using high resolution DEM where ever it is available. CARTO DEM of 10 m resolution will be sued in absence of high resolution DEMs hence, the accuracy of simulations will vary accordingly.

- Delay in supplying data by any second party will have impact in project time lines.

- Flood inundation simulation model accuracy depends upon the input flood forecast results also.

11.0 Manpower:

Scientist/Engineer: 03 No (1 SG, 1 SD, 1 SC)

Research Scientists: 02 No.

JRF/SRF: 02 No.

One programmer on sharing basis (research scientist).

12.0 Time Scale: Eight Years (2016 to 2024)

The project will be executed in 4 stages, 1. Flood forecast model development, 2. Flood inundation simulation model development, 3. Development of web-enabled flood forecast system, and 4. Real-time operations (trail runs) and transfer of technology. (Detailed work schedule is given in the section 11)

13.0 Quality Assurance Mechanism:

Both Internal and external quality checks will be done in the project. Flood forecast accuracy, inundation simulation accuracy, accuracy of spatial and non-spatial database preparation will be thoroughly checked by the project team internally. Subsequently, it will be checked by the external quality assurance team of WRG/RSA/NRSA.

14.0 Role of NRSC in model development of other river basins: NRSC will provide necessary technical support to CWC/MoWR in developing models for other basins where ever require as applicable.

13.0 Budget (figures are in Rs. Lakhs): Total 1758.1 lakh rupees (Spatial Flood Early Warning System)

S. No.	Item Description	Sub-Objective	Financial Year-wise Budget (Lakh Rs.)								Total
			2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	
1	Geo-spatial base data	(Landuse/landcover, Soils, DEM, etc.)	Available databases will be used (NRC, MODIS, NBSS&LUP, FAO, Field data, etc)								
2	Meteorological data		To be obtained from IMD under NHP								
3	Satellite data		0.0	3.0	4.0	4.0	2.0	2.0	1.0	1.0	17.0
4	Field Experimentation & Outsourcing Activities		0.0	10.0	45.0	45.0	5.0	5.0	5.0	5.0	120.0
5	NRSC Manpower		3.3	8.4	8.4	8.4	8.4	8.4	8.4	8.4	62.4
6	Project Scientists @ 0.55 lakh/month; JRF @ 0.325/month and DEO @0.1/month	2 PrS, 2 JRF, and 1 DEO	0.0	22.4	22.4	22.4	22.4	22.4	22.4	22.4	157.1
7	Data Analysis		0.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	42.0
8	Hardware & Software + maintenance	*(2 WS + 2 Desktop +1 Laptop+1 ArcGIS + 1 Img+ ydrological modelling software)*	13.0	76.0	1.0	7.2	7.2	7.2	7.2	7.2	126.2
9	ALTM / High Resolution DEM Generation	1	0.0	560.0	420.0	0.0	0.0	0.0	0.0	0.0	980.0
10	Travel and Field Works	1	1.0	6.0	6.0	6.0	6.0	3.0	3.0	3.0	34.0
11	Training & Workshops	1	0.0	10.0	25.0	10.0	5.0	2.0	2.0	2.0	56.0
Sub-Total 1			17.3	701.9	537.9	109.1	62.1	56.1	55.1	55.1	1594.6
Project Management @ 5% on Sub-Total 1			0.9	35.1	26.9	5.5	3.1	2.8	2.8	2.8	79.7
Sub-Total 2			18.2	737.0	564.8	114.6	65.2	58.9	57.9	57.9	1674.4
Organizational Overheads @ 5% on Sub-Total 2			0.9	36.8	28.2	5.7	3.3	2.9	2.9	2.9	83.7
Grand Total			**19.1**	**773.8**	**593.0**	**120.3**	**68.5**	**61.9**	**60.8**	**60.8**	**1758.1**

Note: ALTM data is estimated for 14000 Sq.Km. @ Rs.7000/- per Sq.Km. Actual area of ALTM data and its cost may vary. Man power cost for programmer (research scientist) is a common for all projects. Outsourcing cost is approximate and it may vary.

14.0 Work Schedule

S.N	Activity	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
1	Collection of field data and establishing gauge sites by CWC/IMD (if required)								
2	Preparation of spatial and non-spatial database								
3	Flood forecast model development								
4	FF Model calibration and validation								
5	Development of spatial Inundation simulation models								
6	Inundation simulation models calibration and validation								
7	Inundation simulations for different flood return periods								
8	Development of web-enabled flood forecast system								
9	Establishing linkages with user organisations								
10	Implementation of the activity in real-time at NRSC								
11	Transfer of technology and models to CWC								
12	Compilation & report preparation								

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Annexure 2

Proposal

Development of Satellite-based Regional Evaporative Flux Monitoring System for India

Under

National Hydrology Project

Submitted to

Ministry of Water Resources
Govt. of India

August, 2016
National Remote Sensing Centre
ISRO, Govt. of India
Hyderabad-37

1. Introduction

Evapotranspiration (ET) is a term used to describe the loss of water from the Earth's surface to the atmosphere by the combined processes of evaporation from the open water bodies, bare soil and plant surfaces, etc. and transpiration from vegetation or any other moisture containing living surface. It is a vital component of the hydrological cycle along with precipitation, runoff, seepage and sub-surface hydrology. It governs the water and energy exchange between hydrosphere, biosphere and atmosphere and plays a major role in hydrology, meteorology and agriculture. Obtaining regional estimates of actual evapotranspiration in water-limited regions/river basins located at climatic transition zones is critical. Meteorological factors such as solar radiation, wind speed, precipitation, vapor pressure deficit, air temperature etc. have been observed to have significant impact on actual ET. Globally, the mean evapotranspiration from the land surface accounts for 60% of the total precipitation (Courault et al 2005). Conventional techniques of estimating ET involve weighing lysimeters, eddy correlation, bowen ratio, scintillometer etc. However, they are largely restricted to site measurements and are not suitable for obtaining regional estimates of evapotranspiration. Remote sensing technology is now recognized as the only viable means of obtaining globally consistent estimates of evapotranspiration at varying spatial and temporal scales. It is proposed to employ a suitable satellite remote sensing based procedure for estimating daily evaporative flux at 0.05 degree fixed grid spacing and development of evaporative flux monitoring system for Indian region.

2. Objectives

The objectives that are proposed to be achieved through the study are as under:

a) Estimation of daily evaporative fluxes for Indian region at an appropriate spatial framework
b) Development of evaporative flux observing and monitoring system at spatial scales of watersheds/river-basins and land use/land cover units and temporal scales of pentads, dekads, fortnights, months and seasons.
c) Creation of long term data base of evaporative fluxes and design of structured query and analysis tools.

3. Study Area

Entire India region is taken up as study area.

4. Satellite and Ancillary Data bases

The following data sources will be used for estimation of evaporative flux:

1. Insolation & LST products of Kalpana 1 & INSAT 3D (MOSDAC portal)
2. NDVI/LAI & Albedo products (MODIS / NPOESS / JPSS/OCM 2/AWiFS)
3. LULC (NRC-250k)
4. DEM (SRTM/ Aster/ Cartosat-1)
5. IMD Surface Meteorological data - hourly/daily (historic, current, forecast)
6. ISRO AWS - hourly/daily (historic, current)
7. Insitu data / Literature / Experimentation

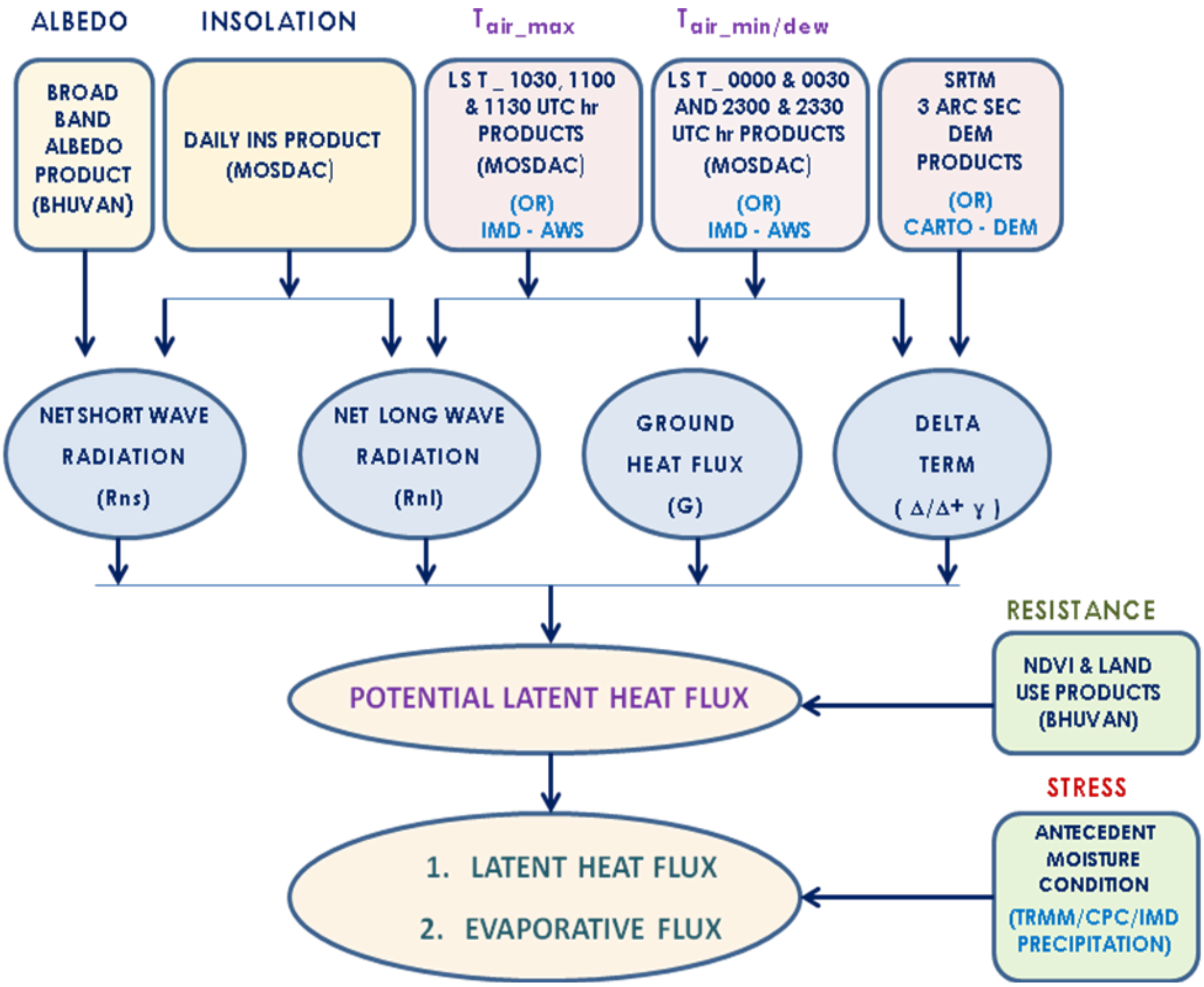
5. Approach Methodology

The Priestley-Taylor (PT) equation has been shown to work well over many vegetation types with only small modifications. The formula calculates evaporation as a function of the available energy – net radiation (Rn) minus ground heat flux (G) – and a dimensionless coefficient (α) that parameterises the resistance to evaporation. Considering values of α for optimal environmental conditions (no evaporative stress), the model can be applied to describe the potential latent heat
flux, λEp (MJm−2), as:

$$\lambda E_p = \propto \frac{\Delta}{\Delta + \gamma}(R_n - G)$$

where Δ is the slope of the temperature/saturated vapour pressure curve (kPaK−1) and is the psychrometric constant (kPaK−1). λ Ep can be divided by the latent heat of vaporization, λ(MJ kg−1) to derive potential evaporation (Ep) in mm.

The satellite data based ET estimation procedure is shown in the following schematic diagram:



In the Priestley Taylor's radiation based approach, the available energy at surface is partitioned into latent heat flux based on the evaporative demand of the atmosphere, which is determined by actual vapor pressure, air temperature and atmospheric pressure. The daily net radiation has been computed by summing up net shortwave and net longwave radiations derived using Kalpana-1/INSAT 3D daily insolation product and OCM2 surface albedo product. The daily maximum and minimum air temperature data are derived from Kalpana-1/ INSAT 3D diurnal land surface temperature products. Alternately, the near surface air temperature data are obtained from IMD AWS records. The AWiFS NDVI and Land Use products are processed to obtain the evaporative resistance values required for estimating the potential latent heat flux. The evaporation stress factors are arrived at based on the antecedent moisture conditions determined by three days antecedent precipitation and/or current day soil moisture.

The VI-Ts Triangle Feature Space

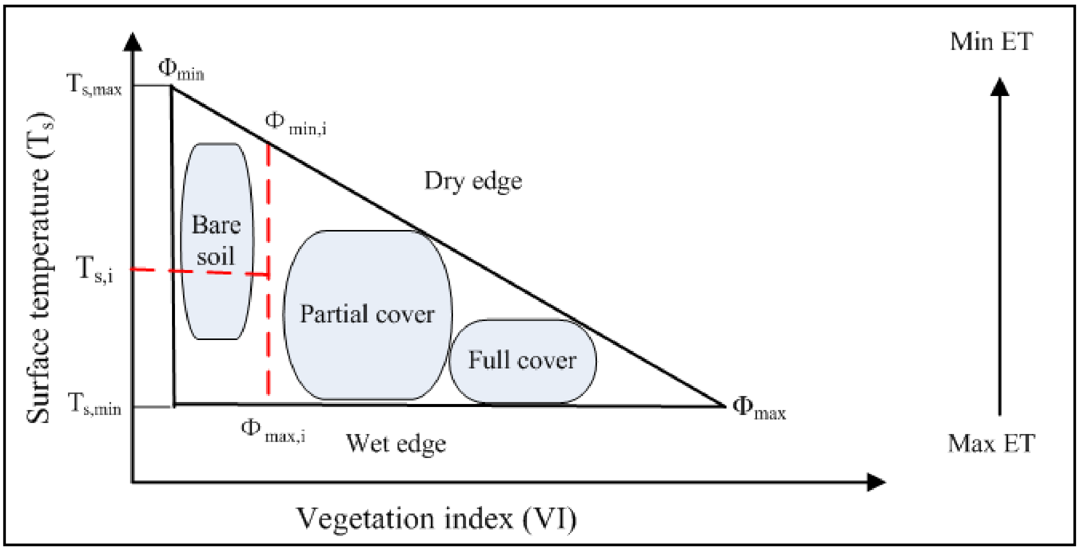
The simplicity of a Priestley-Taylor formulation with fully remotely sensed data proposed by Jiang and Islam representatively based on the interpretations of the remotely sensed Ts-

NDVI triangle feature space, has been employed to estimate regional evaporative fraction (EF) and ET, which can be expressed as:

$$\lambda E_p = \varphi \frac{\Delta}{\Delta + \gamma}(R_n - G)$$

where φ is the combined parameter representing both the moisture stress and resistance factor and it ranges from 0 to 1.26.

Solution of parameter φ generally involves a certain degree of simplicity and some assumptions, including: 1) a complete range of soil moisture and vegetation coverage at satellite pixel scale should be ensured; 2) contaminations of clouds and atmospheric effects have to be removed; 3) two-step linear interpolation scheme is used to get the value of φ based on the Ts-NDVI triangle feature space as displayed in the figure given below.



The simplified VI-Ts triangular space (after Lambin & Ehrlich)

This two-step linear interpolation is realized in the following manner: 1) a global minimum and maximum φ are respectively set to φmin = 0 on the driest bare soil pixel and φmax = 1.26 on the pixel with largest NDVI and lowest Ts, and φmin,i for each NDVI interval (i) is linearly interpolated with NDVI between φmin and φmax, and φmax,i for each NDVI (i) is calculated using the lowest surface temperature within that NDVI interval (generally, one assumes that φmax,i = φ max = 1.26); 2) φi within each NDVI interval is linearly increased with the decrease of Ts between φmin,i and φmax,i.

6 Satellite Data based Geophysical Products

Daily insolation products

The insolation products posted at MOSDAC portal are generated using VIS, TIR and WV channels of Kalpana-1 VHRR at rectangular grid spacing of about 0.069 X 0.075 deg. A spectrally integrated, clear sky and three layer cloudy sky model is implemented to estimate direct, diffuse and global instantaneous surface insolation. Daily total insolation is computed through trapezoidal integration from half an hourly insolation. It has been reported that results of validation of the product indicated an RMSE of 1.85 MJm-2 which corresponded to 10% of the measured mean. Also it has been specified that accuracy in cloudy sky is less than in clear sky.

Surface albedo products

The 15 days time composited broadband albedo version 1.0 products that are validated and available from BHUVAN portal at a spatial resolution of 1km (1080m to be precise) are derived from the data acquired by Ocean Color Monitor (OCM2) sensor onboard Oceansat-2. For validation purpose, these products (at 360 m) were resampled to 500m and compared with MCD43A3 16 day composite products of MODIS. The correlation plot for four months data between the OCM2 and MCD43 broadband products showed good overall correlation with r^2 ~ 0.90.

Land Surface Temperature (LST):

A Single Channel (SC) algorithm was developed for retrieving LST from the thermal channel (10.5-12.5 mm) of Kalpana-1 VHRR sensor over India using an atmospheric RT model – MODTRAN (Pandya et al., 2010). The SC algorithm relies on the concept of Atmospheric Functions that are dependent on atmospheric transmissivity and upwelling and downwelling atmospheric radiances computed with known land surface emissivity and atmospheric water vapour. The specifications of LST product are given below:

Kalpana-1 VHRR LST Product Specifications

Product Name	Format of file	Geographical extent	Repetivity	Spatial Resolution
LST	HDF5	Long: 50-130° E; Lat: 0-50° N	Every half an hour	0.1 degree

The LST product was compared to the MODIS LST product for day and night dataset. It showed a good match for night time data (with an absolute difference of up to 3K), and a systematic overestimation for the daytime retrievals (with an absolute difference of up to 9K). A validation campaign for the comparison of Kalpana-1 derived LST with the ground-based observations in a homogeneous region of the Rajasthan desert located in the western India showed a fairly good agreement between satellite estimates and ground observations (R2 of 0.98 and RMSE of 1.57K).

The availability of two thermal channels in the Imager sensor onboard INSAT-3D would enhance the derivation of LST through the split-window algorithm.

Normalised Difference Vegetation Index (NDVI):

The Normalised Difference Vegetation Index (NDVI) is a measure of land surface vegetation cover condition at a given point of time. It is derived from satellite data using reflected red (R) and near infrared (NIR) radiances. The BHUVAN portal of NRSC posts OCM2 sensor derived 15 day composited NDVI images periodically. The Normalized Difference Vegetation Index (NDVI) computed with NIR (OCM2-B8) and Red (OCM2-B6) bands Top of Atmosphere reflectance data is given by:

$$NDVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R} = \frac{\rho_{B8} - \rho_{B6}}{\rho_{B8} + \rho_{B6}} \qquad (29)$$

In the NDVI product, all pixels with values less than or equal to zero were brought to zero to enhance the variation in vegetation more predominantly. The 15-day NDVI composite products version02_01 were generated using all the seven/eight scenes (OCM revisit period is two days), preserving all maximum NDVI values for the entire period.

Compositing is a strategy for removing cloud contamination, atmospheric effects, and view & illumination geometry problems from a series of images over a discrete period of time. The semi-monthly NDVI composites are generated from cloud screened images using Maximum Value Compositing (MVC) technique. This MVC technique is developed based on Holben method widely employed for this purpose.

The spatial resolution of these 15 day time composited NDVI v02_01 products is 1080 m (0.01017 deg) and the geometric accuracy is better than 500 m.

Though elaborate comparison was not made so far with ground measured vegetation indices, a comparison is made with reference to NDVI products from MODIS sensor data by visually identifying common regions of the images. Mean values of these regions are considered for analysis. A 97.8% correlation was observed with MODIS NDVI composite.

Land use/Land cover (LULC):

The land use/land cover (LULC) maps of the entire country at a scale of 1:250000 are prepared on annual basis under National level LULC mapping project taken up by NRSC as a part of NNRMS-DOS programme using Resourcesat - AWiFS data. The project had so far completed nine (9) cycles of assessment starting from 2004-05 to 2012-13 bringing out the temporally explicit spatial distribution of the feature classes at national level. All the nine cycles' data have been organized under Bhuvan geoportal and are provided access through FTP services. The recent ninth cycle LULC maps are generated using multi-temporal satellite data of Resourcesat 2 - AWiFS sensor for year 2012-13. About 21 AWiFS full scenes covering the entire country were used. Besides, RISAT-1 CRS data were also used in the area with persistent cloud cover, especially during Kharif 2012 season. A hybrid classification approach was followed to get information on 19 LULC categories.

The accuracy was assessed at state level (India administrative unit). Stratified random points generated were used to assess the accuracy of classification. The number of sample points for each strata for selected based on the proportion of the area and a minimum of 20 sample points were considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa coefficients. The overall classification accuracy is found to be 90.07 % with a range of 86 to 95 % in different states.

For areas covered in the plain terrains second order polynomial method was used for registering multi temporal datasets and registration accuracy of one pixel was achieved. For hilly terrains, TIN based model was used and an accuracy of 2-3 pixels was achieved. The LULC products are provided in raster format in geographic coordinates over WGS-84 datum.

7 Validation Requirements of ET Estimates

Comparisons between turbulent heat fluxes derived from remote sensing ET models and in-situ measured data are required to evaluate the reliability and accuracy of the applied ET models. Although it may be feasible and reasonable to validate pixel-averaged fluxes derived from remote sensing ET models with traditional measurements mainly conducted at the "point" scale over uniform areas, problems will be encountered when validation is performed over complicated land surface areas (Li et al., 2009).

Nowadays, several conventional techniques such as Bowen ratio, eddy correlation system and weighing lysimeters have been commonly applied to measure the ET at ground level. Lysimeters provide the only direct measure of water flux from a vegetated surface. Its measurements can therefore be used as a standard for evaluating the performance of other physically based ET models. However, data measured by Lysimeters are essentially point data and thus cannot be used for validating the regional ET estimates [Kairu, 1991]. Study has shown that measurements from Bowen ratio and large weighing lysimeters for irrigated alfalfa during advective conditions can differ by up to 29% [Todd et al., 2000]. Eddy correlation technique, based on the principle that atmospheric eddies transport the entities of water vapor, CO2, and heat with equal facility, is particularly useful for rough surfaces with high coefficients of turbulent exchange. It has overtaken Bowen ratio as being the most preferred micrometeorological technique for ET measurements in the past few decades [Farahani et al., 2007]. The source area of an eddy correlation system generally represents an upwind distance of about 100 times the sensor height above the surface, which is appropriate to validate the ET at pixel sizes of an order of hundred meters. In the past decades, most studies used measurements conducted by the Bowen Ratio Energy Balance (BREB) and the eddy correlation system to validate ET at local and regional scales. Angus and Watts [1984] showed that LE measured by Bowen ratio was dependent on the range of Bowen ratio values. For ET at the potential rate, relative errors of up to 30% in Bowen ratio can produce relative errors of 5% in LE. However, as soil water becomes less available, the precision in LE will decrease [Kalma et al., 1990]. Energy balance non-closure in eddy correlation, typically higher over strongly evaporating surfaces such as irrigated crops [Farahani et al., 2007], can reach up to 20%, even for non-advective conditions [Gowda et al., 2007]. Measurements from eddy correlation system at night under low wind-speed stable conditions can yield large errors and the instrument errors and atmospheric stability contribute to the sources of errors [Shuttleworth, 2007].

Validation of remote sensing ET derived from satellite data at high spatial resolution, such as TM and ASTER data, was generally performed using the measurements made by the BREB and eddy correlation system. However, difficulties still remains in validation of ET estimated from low spatial resolution satellite data such as MODIS, GOES whose pixel size in thermal bands is a magnitude of an order of kilometers.

The newly developed (Extra-) Large Aperture Scintillometers (XLAS, LAS) provide a promising approach to validate the remote sensing ET at much larger scales [Hemakumara et al., 2003]. Scintillometers are regarded as the unique possibility of measuring the sensible heat flux averaged over horizontal distances comparable to the grid size of numerical models and satellite images and thus can be employed to validate to a certain degree the regional turbulent heat fluxes derived from remote sensing models. One limitation of using Scintillometers is the saturation of scintillation, which can be overcome by using either large, incoherent transmitter and/or receiver apertures or a longer wavelength.

Currently, validation of estimated ET is one of the most troublesome problems, mainly because of both the scaling effects, i.e., comparisons between remote sensing ET and ground-based ET measurements, and the advection effects. Several validation techniques have to be developed. These may include comparisons of remote sensing ET with ground-based ET measurements conducted over validation test sites, inter-comparisons with ET estimated from satellite data at different spatial resolution or estimated using combined various data sources and land surface process models, intercomparison of trends derived from independently obtained reference data and remotely sensed data, and analysis of process model results which are driven or constrained by remotely sensed data and ET.

However, due to the surface heterogeneity and scaling effects, it may be questionable to validate the turbulent heat fluxes at satellite pixel scale with the “point” scale measurements obtained from the Bowen ratio, lysimeter and eddy correlation system over non-uniform and heterogeneous surfaces. The newly developed LAS (XLAS) can provide a promising approach to validate the remote sensing ET at much larger scales.

8. Deliverables

a) Satellite data based regional ET estimates for India at spatial scales of watershed/river-basin/land cover units and at temporal scales of daily, fortnightly, monthly and annually
b) Long term (from 2004 onwards) ET database
c) Validation sites network infrastructure/facility
d) Web GIS based regional ET monitoring system
e) Monograph document

9. Quality Assurance Mechanism

Quality Evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards.

10. Magnitude of Work and Manpower

NRSC will execute the project using existing scientific manpower along with Project Scientists to be recruited under the project.

11. Project Execution Plan

The project execution plan will be prepared as per the ISO guidelines practiced within NRSC. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

The tentative schedule & milestones of the project are:

Work Schedule

Major Activity	2016-17		2017-18		2018-19		2019-20		2020-24	
	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2
Creation of spatial framework for estimation of ET	■	■	■							
Collection & organisation of spatial and non-spatial historical data sets		■	■	■						
Development of ET estimator (soft tool)				■	■	■				
Establishment of field (ET&SM) observation network			■	■	■	■				
ET validation experiments & analysis						■	■			
Long term database generation and trend analysis								■	■	■
Development & positioning of web-enabled ET monitoring system							■	■		
Trial runs at near real time							■	■		
Monograph preparation								■		
Operational runs & system hand-over/release for public use									■	■

HY1: Apr-Sep; HY2: Oct-Mar

10. Time schedule

The project activity will be from Apr, 2016 to Mar, 2024

11. Project Review and Reporting

Project Management Committee (PMC) consisting of NRSC and MoWR senior Officials will be constituted for periodic review of study activities, progress monitoring and related issues.

12. Budget

The total budget estimate is Rs.1149.4 lakhs. Details are given in the following pages:

Details of Budget

Item	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	Total
Satellite data	0.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	19.0
Field Experimentation	0.0	5.0	250.0	250.0	50.0	50.0	50.0	50.0	705.0
NRSC Manpower	1.6	5.1	5.1	5.1	5.1	5.1	5.1	5.1	37.0
Project Scientists @ 0.55 lakh/month	0.0	18.5	18.5	18.5	18.5	18.5	18.5	18.5	129.8
Data Analysis	2.0	5.0	5.0	5.0	3.0	3.0	3.0	3.0	29.0
Hardware & Software	12.0	16.0	1.0	3.0	3.0	3.0	3.0	3.0	43.8
Travel and Field Works	1.0	6.0	6.0	6.0	6.0	3.0	3.0	3.0	34.0
Training & Workshops	0.0	5.0	12.0	12.0	10.0	2.0	2.0	2.0	45.0
Sub-Total 1	16.6	63.6	300.6	302.6	98.6	87.6	86.6	86.6	1042.6
Project Management @ 5% on Sub-Total 1	0.8	3.2	15.0	15.1	4.9	4.4	4.3	4.3	52.1
Sub-Total 2	17.4	66.8	315.6	317.7	103.5	92.0	90.9	90.9	1094.7
Organizational Overheads @ 5% on Sub-Total 2	0.9	3.3	15.8	15.9	5.2	4.6	4.5	4.5	54.7
Grand Total	**18.3**	**70.1**	**331.4**	**333.6**	**108.7**	**96.6**	**95.5**	**95.5**	**1149.4**

Annexure 3

Glacial Lake Outburst Flood (GLOF) Risk Assessment of Glacial Lakes in the Himalayan Region of Indian River Basins Under National Hydrology Project

Submitted to

Ministry of Water Resources, River Development & Ganga Rejuvenation
Govt. of India

July, 2016

Water Resources Group

National Remote Sensing Centre

ISRO, Govt. of India

Hyderabad-37

1. Introduction

Glaciers and Glacial lakes are mostly located in highly elevated rugged terrain which makes the accessibility difficult. These glaciers as well as glacial lakes are the sources of the headwaters of many great rivers in the region. Most of these lakes are located in the down valleys close to the glaciers. They are formed by the accumulation of vast amounts of water from the melting of snow and ice cover and by blockage of end moraines. A Glacial Lake Outburst Flood (GLOF) is a type of outburst flood that occurs when the dam containing a glacial lake fails. The dam can consist of glacier ice or a terminal moraine. Failure can happen due to erosion, a build-up of water pressure, an avalanche of rock or heavy snow, an earthquake or cryoseism, volcanic eruptions under the ice, or if a large enough portion of a glacier breaks off and massively displaces the waters in a glacial lake at its base. Glaciers and glacial lakes are generally located in remote areas, where access is through tough and difficult terrain. Creating inventories and monitoring of the glacial lakes can be done quickly and correctly using satellite images and aerial photographs. Visual and digital image analysis techniques integrated with Geographic Information Systems (GIS) are very useful for the study of glacier, glacial lakes. Satellite remote sensing offers several unique advantages quick data collection, reliability, more accurate, repetitive collection, geometric integrity and digital storage, which makes it an ideal tool for mapping, inventorying and monitoring the natural resources.

The inventory of glacial lakes & water bodies in the Himalayan region of Indian River basins using AWiFS data of 2009 was carried out by National Remote Sensing Centre (NRSC) and a comprehensive report was submitted to Climate Change and IAD Directorate, Central Water Commission, Ministry of Water Resources, New Delhi in June 2011. Subsequently, monitoring of these glacial lakes & water bodies was carried out using satellite data for the months of June to October during the years 2011 to 2015.

Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR) consulted NRSC to support National Hydrology Project (NHP) through geo-spatial data products, services, customized applications development and capacity building to the stakeholders. NRSC participated various meetings organized by MoWR, RD&GR and World Bank and deliberated on the possible role NRSC/ISRO would play in NHP implementation. Comments and concurrence of draft EFC memo was communicated from the Office of Secretary of Dept. of Space to MoWR, RD&GR. NRSC participated in the Wrap-up Meeting of NHP World Bank Mission held during 14-15 Sep, 2015 at New Delhi and presented the details of possible Role of National Remote Sensing Centre (ISRO) under National Hydrology Project. Further, Joint Secretary, MoWR, RD&GR communicated approval of EFC Memo through D.O. No. 21/97/2015-NHP/3925 Dt. 26th Nov, 2015.

In response to the above, the present proposal is formulated, where in NRSC/ISRO is supporting NHP through GLOF risk assessment of glacial lakes in the Indian Himalayas, which includes inventory using high resolution satellite data, identification of critical lakes, GLOF modeling and potential socio-economic impacts.

2.0 Objectives

The main objective of this study is to carry out risk assessment of critical glacial lakes in the Indian Himalayas for glacial lake outburst flood (GLOF). The detailed objectives are:

- Inventory of glacial lakes using high resolution data.
- Selection of critical glacial lakes using desk based approach.
- Prioritization of critical lakes
- Generation of high resolution DEM for D/S of prioritized critical lakes (15)
- Investigation of prioritized critical lakes and their surroundings based on high resolution DEM and data.
- GLOF modeling and inundation mapping using high resolution DEM

3.0 Study Area

The present study is carried out for the area covering Himalayas under the major river basins of Indus, Ganga and Brahmaputra. The study area extends across different countries namely India, Nepal, Bhutan and China. The index map showing study area is given in Figure 1.

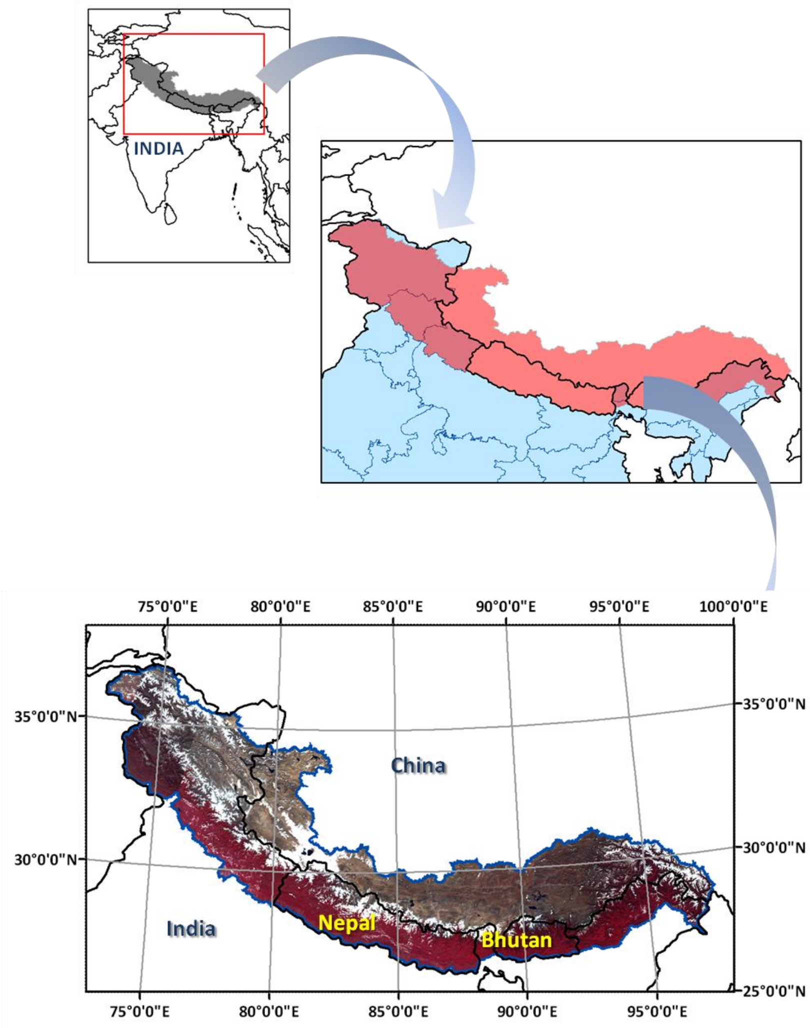


Figure 1 Study Area

4.0 Data used

Satellite data: For identification and selection of critical glacial lakes and glaciers, multi temporal satellite data will be used. The project plans to use LISS III (23.5 m resolution), LISSIV (5.8 m resolution), Landsat 8 data (28.5 m resolution) and Kompsat data (4 m resolution) for inventory of glaciers and glacial lakes. Latest satellite data will be used for settlement and infrastructure mapping. It is proposed to acquire data for the months of August–November when cloud cover and snow cover is likely to be minimum. In the years of late snow fall, images with minimum snow cover during December can also be used.

It is proposed to use Cartosat 2.5 m stereo data for generating of hydrologically corrected Digital Terrain Model (DTM) for downstream of selected critical glacial lakes by taking breaklines and mass points. The expected accuracy of DTM will be 4m (relative). To improve the absolute accuracy, available IceSAT GLASS data will be used to remove bias in the data. Very high resolution DEM from suitable foreign satellite will be used for detailed mapping of glacier lakes and surroundings.

Ancillary data: The following ancillary information will be used in the project:

- Glacier atlas from SAC, Ahmedabad
- Geology map of the study area
- Topographic map, Base map (road/rail, drainage and settlement) and Administrative boundary, basin boundary map (with co-ordinates) project site location map.
- Locations and details of villages, details of bridges, any other field information.
- Hydrographic details of the lake (if available) will be an added advantage in estimating the lake volume more accurately.
- Landslide information
- Any other relevant information

5.0 Approach Methodology

Approach methodology includes inventory of glaicers/glacial lakes, development of criteria for selection of critical lakes, ranking of critical lakes and detailed investigation of critical lakes and GLOF modeling.

5.1 Inventory of glacial lakes/glaciers: The glacial lakes are delineated based on the visual interpretation of satellite images through panchromatic mode and/or different colour combinations of the multi-spectral bands namely green, red, near infrared and shortwave infrared. To identify the glacial lakes, different image enhancement techniques are used to improve the visual interpretation. This method is complimented with the knowledge and experience of the Himalayan terrain conditions for inventorying glacial lakes. The water spread area of the lakes in false colour composite images ranges in appearance from light blue to blue to black. The frozen lakes appear white in colour. Sizes of water bodies are generally small, having circular, semi-circular, or irregular shapes with very fine texture. They are generally associated with glaciers. The boundary of glacial lakes are digitized using on-screen digitisation techniques as polygon feature. The polygons are geoprocessed and the water spread area of each glacial lake is computed digitally. The lakes are identified and digitized as on the date of satellite data. There is a possibility that some lakes that are frozen or overlaid with snow might be omitted in this inventory. Subsequently the glacial lakes are classified as cirque lake, debris dammed lake, supraglacial lake, other lake fed by glacial melt, end moraine dammed lake, lateral moraine dammed lake and water body depending on their characteristics as seen from the satellite data.

Automated glacier mapping from satellite multispectral image data is hampered by debris cover on glacier surfaces. Supraglacial debris exhibits the same spectral properties as lateral and terminal moraines, fluvioglacial deposits, and bedrock outside the glacier margin, and is thus not detectable by means of multispectral classification alone. Based on the observation of low slope angles for debris-covered glacier tongues, Paul et al (2004) have developed a multisource method for mapping supraglacial debris. This method combines the advantages of automated multispectral classification for clean glacier ice and vegetation with slope information derived from a digital elevation model (DEM). Neighbourhood analysis and change detection is applied for further improvement of the resulting glacier/debris map. A significant percentage of the processing will be attempted automatically. It is proposed to use this method for inventory of glaciers in the study area using medium resolution datasets.

5.2 Selection of critical glacial lakes: Primary selection of critical lakes will be done based on area criteria and any lake with area above 0.1 sq km and associated with a glacier will be considered large enough to cause damage downstream if they burst out.

Second level of selection will be based on the characteristics of lake, its dam, associated glaciers and other topographic features. Ranking also needs information on associated glaciers, condition of moraine dam, occurrence of landslide or earthquake, etc. which will be generated using satellite data or collected from other ancillary sources. A suitable desk based criteria will be evolved based on the available data and literature for selection of 15 critical lakes requiring further investigations.

5.3 Ranking of potentially dangerous glacial lakes: Various investigation surveys will be carried out for the identified potentially dangerous 15 glacial lakes. This includes hydrological survey, bathymetric survey and geophysical & glaciological survey of lakes, dams and surrounding areas. High resolution satellite data will be used for this purpose. Where ever feasible, field survey will be carried out in association with local government departments/agencies and CWC. Cartosat stereo images will be used for generating hydrologically corrected digital elevation model (DEM) for D/S of selected critical glacial lakes. High resolution DEM will be used for glacier lake and its dam characteristics.

Based on parameters like area of the lake, distance to glacier, moraine characteristics, lake surroundings, field investigations and socio-economic factors, etc., suitable weightages for each parameter will be added to give ranking. Some of the parameters will be area of glacial lake at the year of inventory, increase in water spread area of glacial lake, glacier characteristics (Distance between glacial lake and associated glacier, Condition of associated glacier(Retreating or advancing condition), rapid glacier retreat, presence of crevasses, hanging glacier and ponds on glacier surface), dam condition (Slope of the outer moraine wall, Ratio of freeboard to Height of moraine), past landslide location, past earthquake location, socioeconomic factors (Hydropower plants, Bridges, Settlements) etc.

5.4 GLOF modeling and inundation mapping: Glacial lake parameters are estimated either from field survey or other sources. Appropriate dam breach models will be used to simulate different scenarios and possible flood hydrograph will be generated for critical lakes. Subsequently, vulnerability of downstream areas of the critical lakes will be assessed. For each scenario, the possible inundation area will be simulated. Simulated models will be made available in user friendly visualization system.

5 Deliverables

Following are the expected deliverables.

- Updated inventory of glaciers and glacial lakes
- List and details of potentially dangerous lakes
- High resolution DEM for D/S of prioritized critical lakes
- Possible flood inundation simulation maps in different scenarios for the critical lakes
- Simulated GLOF models in Visualisation system.

6 Quality Assurance Mechanism

Quality Evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards. Project team will first ensure the quality of the product which will be checked / validated by the internal quality team of WRG.

7 Magnitude of Work and Manpower

The study involves analysis of satellite data, preparation of geospatial database and generation of desired outputs including analysis of the outputs for fulfilling the objectives of the study. NRSC will execute the project using existing scientific manpower along with Project Scientists to be recruited under the project.

8 Project Execution Plan

The project will be executed by NRSC as per the project execution plan that will be prepared as per the ISO guidelines. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

9 Time schedule

The project activity will be from July, 2016 to March, 2024 and the tentative schedule & milestones of the project are shown in Table 1.

10 Project Review and Reporting

Project Management Committee (PMC) consisting of NRSC and MoWR senior Officials will be constituted for periodic review of study activities, progress monitoring and related issues.

11 Budget

The total budget for this project is Rs 1480.77 Lakhs. The year-wise budget details are provided in Table.2.

13. Project limitations

- The inventory of glacial lakes depends on the cloud and snow free satellite data. The lakes covered under permanent snow cover and mountain shadows will not be mapped and cannot be covered under the inventory.
- It has to be noted that the glacial lake inventory is based on the available satellite data pertaining to the latest period. If any detectable lakes formed after this period will not be covered under this activity.
- The glacial lake growth map depends on the available old data sets which are comparable to inventory data sets. Changes deciphered will be subjected to the resolution of data compared.
- Flood inundation simulation depends upon the accuracy in estimation of volume of water in the lake, for which field hydrographic data is required. In absence of this data, depth will be estimated approximately based on the surrounding topographic conditions.
- Lake failure analysis will be carried out assuming the case similar to the earthen dam failure theory.
- Inundation simulations will be carried out for steady state conditions and its accuracy depends upon the DEM accuracy.

14. Work sharing

Responsibility of NRSC

- NRSC is responsible for overall execution of the project including satellite data procurement, processing, analysis, outputs, report generation, etc.
- NRSC will provide the outputs as outlined in the deliverables section of the project proposal within the period mentioned thereof.
- NRSC will take up the study on receipt of advance payment from CWC.

Responsibility of MoWR, RD & GR

- MoWR, RD & GR shall share the information available with them on glacial lakes, glaciers in the study area and other related maps available with them that will be useful for the study.
- MoWR, RD & GR is required to pay advance payment of the project cost to NRSC.
- All kind of local logistic support during the course of fieldwork needs to be provided.

Table 1: Time schedule for the project

S. No.	Activity	2016		2017				2018				2019				2020				2021				2022			
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Inventory of glacial lakes			■	■	■	■	■	■	■	■																
2	Inventory of glaciers			■	■	■	■	■	■	■	■																
3	Ranking of critical lakes					■	■	■	■	■	■	■	■	■													
4	Field investigations											■	■	■	■	■	■	■	■	■							
5	Generation of hydrologically corrected DTM										■	■	■	■	■	■											
6	GLOF modeling											■	■	■	■	■	■	■	■	■	■	■	■	■			
7	Inundation mapping											■	■	■	■	■	■	■	■	■	■	■	■	■			
8	Visualisation system																					■	■	■			

Q1: Jan-Mar; Q2: Apr-Jun; Q3: Jul-Sep; Q4: Oct-Dec

Table 2: Project budget

S.No.	Item Description	Cost (Rs in Lakhs)						
		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Total
3	Satellite Data	19.8	150	150	0	0	0	319.8
5	NRSC Manpower	2.5	5.1	5.1	5.1	5.1	5.1	28
6	Project Scientist	0	23.9	23.9	23.9	23.9	23.9	119.5
7	Geo-spatial data processing and analysis	3	6	6	6	6	6	33
8	Hardware & Software	17	37	11	3.6	3.6	3.6	75.8
9	ALTM DEM / High Resolution Satellite DEM Generation	0	0	360	360	0	0	720
10	Ground truth, Travel, Outputs	1	4	4	4	5	5	23
11	Training & conferences (Domestic & Overseas)	0	4	8	8	2	2	24
	Sub-Total1	43.3	230	568	410.6	45.6	45.6	1343.1
	Project Management @ 5% on Sub-Total 1	2.165	11.5	28.4	20.53	2.28	2.28	67.155
	Sub-Total 2	45.465	241.5	596.4	431.13	47.88	47.88	1410.26
	Organizational Overheads @ 5% on Sub-Total 2	2.27325	12.075	29.82	21.5565	2.394	2.394	70.5128
	Total	47.738	253.58	626.22	452.69	50.274	50.274	1480.77

Annexure 4

<u>Proposal</u>

Development of Spatial Snowmelt Runoff product in the Indian Himalayas

<u>Submitted to</u>

Ministry of Water Resources, River Development & Ganga Rejuvenation
Govt. of India

July, 2016
Water Resources Group
National Remote Sensing Centre
ISRO, Govt. of India
Hyderabad-37

1. Introduction

The snowmelt water from Himalayan region during summer months becomes crucial for millions of people residing in this region for their multiple needs such as drinking water supply, irrigation, hydro-power generation, etc. Himalayas being inaccessible terrain, the remote sensing technology provides a viable tool to collect information on the status and extent of the snow cover in this region. Satellite derived snow cover information is useful in estimating snowmelt runoff.

Snow melt runoff is an important component of hydrological cycle where significant proportion of precipitation is expected to fall in a snow form. Many models have long been introduced to enable the simulation of snowmelt processes in the river basins. Snowmelt runoff models can be broadly categorised into temperature index and physically based methods. Air temperatures or degree day methods have been widely used in hydrologic modelling to approximate snowpack energy exchange in lieu of the more data intensive energy budget approach. Energy balance approach is data intensive and uses shortwave and long net radiation, sensible heat flux, latent heat flux, conducting from the ground as well as the energy contained in rainfall for estimating snowmelt runoff (Debele et al 2009, Wang and melesse2005, Li and Williams, 2008).

NRSC has been involved in estimation of snowmelt runoff modeling and forecasting for few Himalayan river basins. Seasonal (3 months) and short-term (16-days) snowmelt runoff forecasts were provided during April to June months. NRSC has been providing a seasonal forecast of snowmelt during Apr-May-Jun months every year to CWC for Chenab, Beas, Sutlej, Yamuna and Ganga basins using remote sensing inputs. In addition a short term forecast on 16-day basis was also provided to CWC for the above 5 basins.

Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR) consulted NRSC to support National Hydrology Project (NHP) through geo-spatial data products, services, customized applications development and capacity building to the stakeholders. NRSC participated various meetings organized by MoWR, RD&GR and World Bank and deliberated on the possible role NRSC/ISRO would play in NHP implementation. Comments and concurrence of draft EFC memo was communicated from the Office of Secretary of Dept. of Space to MoWR, RD&GR. NRSC participated in the Wrap-up Meeting of NHP World Bank Mission held during 14-15 Sep, 2015 at New Delhi and presented the details of possible Role of National Remote Sensing Centre (ISRO) under National Hydrology Project. Further, Joint Secretary, MoWR, RD&GR communicated approval of EFC Memo through D.O. No. 21/97/2015-NHP/3925 Dt. 26th Nov, 2015.

In response to the above, the present proposal is formulated, where in NRSC/ISRO is supporting NHP through development of spatial snowmelt runoff product at higher temporal resolution for entire Indian Himalayas.

2. Objectives

The overall objective of the proposal is to generate satellite data based snowmelt runoff products for Indian Himalayas during snow melt season of April-June. The objectives of the study are proposed as under:

1. To develop a short-term snowmelt runoff forecasting model using satellite derived products and field data.
2. To generate a spatial daily gridded snowmelt product.
3. To generate a spatial 3-day snowmelt forecast gridded product.
4. To provide short term snowmelt runoff forecast at selected basin outlets during snow melt season.
5. To provide seasonal forecast at selected basin outlets during snow melt season.

3. Study Area

The present study is aimed to carry out in Indian Himalayas, which are part of Hindu Kush Himalayas (HKH). Its boundary is obtained by joining the catchments of rivers providing water to India. It stretches from Jammu & Kashmir in the West to Arunachal Pradesh in the East (21057' – 3705' & 72040' – 97025') and occupies 0.9 M sq. km. in Nepal, Bhutan, Tibet and India. Indian Himalayas are divided in four zones, viz., Upper, Western, Central and Eastern. Figure 1 shows the Index map of the study area.

4. Satellite and Ancillary Data bases

The project proposes to use following dataset in the initial years. The project will be migrated to different satellite data available from time to time based on the need and requirement.

- Daily snow cover, Land Surface temperature (LST) and Albedo from Suomi-NPP/MODIS.
- 8-day/3-day time composites of snow cover, Land Surface temperature (LST), and Albedo from Suomi-NPP/MODIS.
- Historic data of snow cover, Land Surface temperature (LST), and Albedo from MODIS for seasonal forecast.
- Digital Elevation Model (DEM) at 90/30m resolution from SRTM/ASTER.

- Rainfall forecast and temperature forecast (8day / 3 days) available from sources such as IMD / MOSDAC / GEFS / etc.
- The hydrometeorological and discharge data from CWC/field organisations is a must to validate the methodology and products.

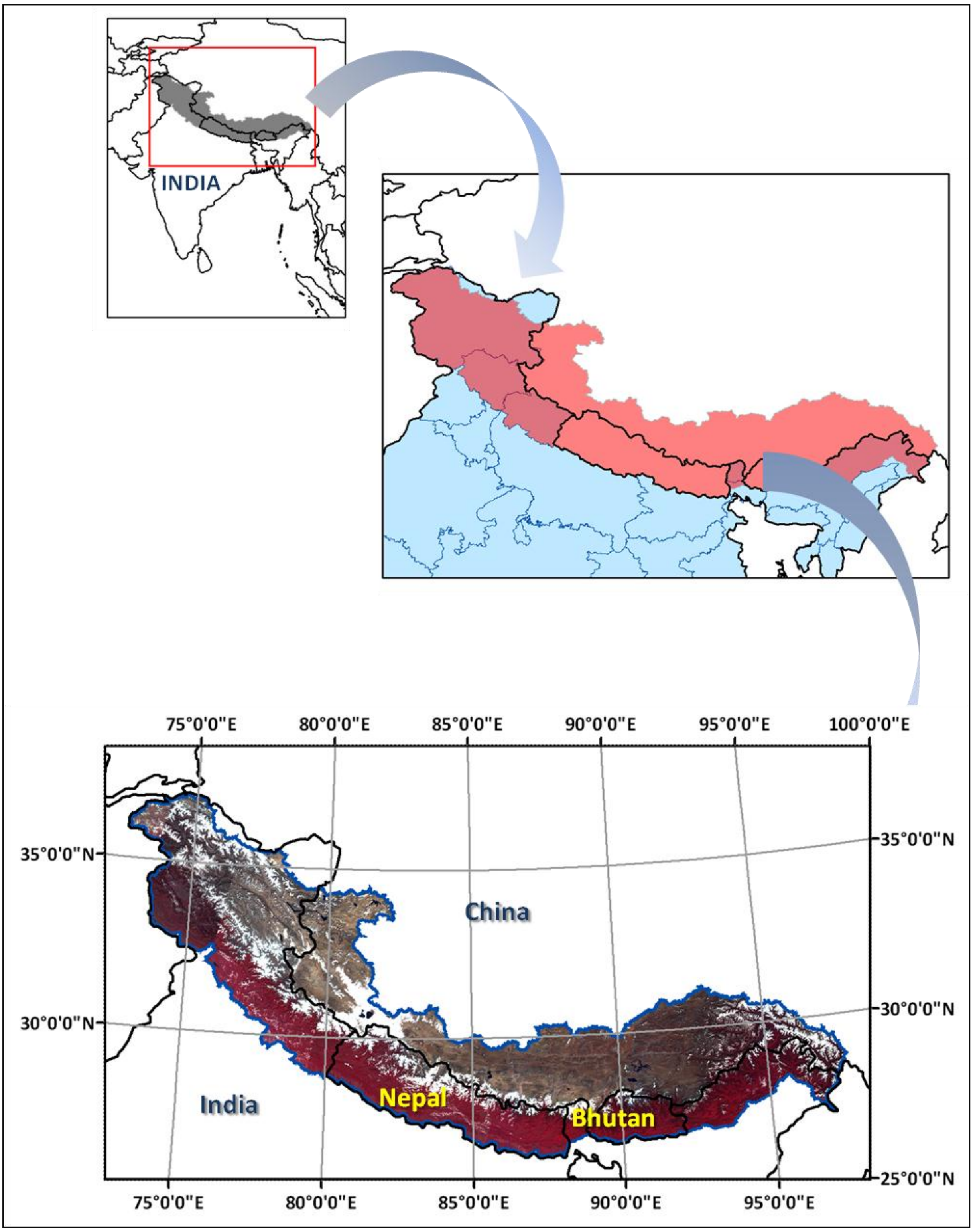


Figure 1. Index map of study area

5. Approach Methodology

The snowmelt is calculated spatially using the remote sensing based inputs from various sources based on the energy balance approach (refer Fig.2). The model development and the validation will be carried out for Chenab, Beas, Satlaj, Yamuna and Ganga basins. The study will be extended to entire Himalayas after model validation in subsequent years.

Snow cover: The snow cover present in the study area will be mapped using Suomi-NPP satellite data. Maximum possible snow cover map, which is generated in another ongoing project of NRSC will be used in the present study. From the daily data, 8-day/3-day time composites of snowcover map will be generated. The other inputs for energy balance approach will also be Suomi-NPP VIIRS derived products (land surface albedo, land surface temperature, etc.). The data from 1st April to 30th June will be used in the present project. For seasonal forecast, historic snow cover from MODIS will also be used in the model development.

Net radiation: The total net energy flux is primarily contributed by incoming solar radiation and outgoing longwave radiation. The incoming solar radiation is a function of location of a pixel (latitude, longitude), elevation, Julian day and time. The longwave radiation is function of surface temperature, air temperature, and emissivity.

The incoming solar radiation will be computed using SRTM/ASTER DEM as input. The insolation will be corrected for atmospheric transmittance / scattering and cloud absorption/scattering. The present analysis plans to use historic LST data from either NPP-Suomi or MODIS in indirect manner to calculate the atmospheric losses. As research activity, analysis will be carried out to incorporate real time cloud cover data in estimation of solar radiation. The incoming solar radiation will also be corrected for influence of landcover. The net shortwave radiation is computed as a difference of corrected incoming solar radiation and outgoing shortwave radiation computed using snow albedo. For the purpose of estimating longwave radiation, the Land Surface Temperature (LST) product of Suomi-NPP / MODIS will be used. The snow emissivity will be computed.

Snow melt: The energy balance equations shall be used to compute net energy available for snow melt at each pixel. Gridded output indicating snow melt at each grid will be generated. Snow melt runoff will be calculated at discharge locations and validated with the river discharge data obtained from CWC and its field offices.

Snowmelt forecast: The snowmelt runoff which comprises of runoff from snow as well as rainfall will be forecasted based on the rainfall forecast and temperature forecast (3 days) available from suitable sources (such as IMD / MOSDAC / GEFS / etc.). In case of non availability of near real time forecast of rainfall and temperature, historical averages will be used as input for modeling. The hydrometeorological and discharge data from CWC/field organisations will be used in the study. Seasonal forecast will be issued based on the average of historic database inputs.

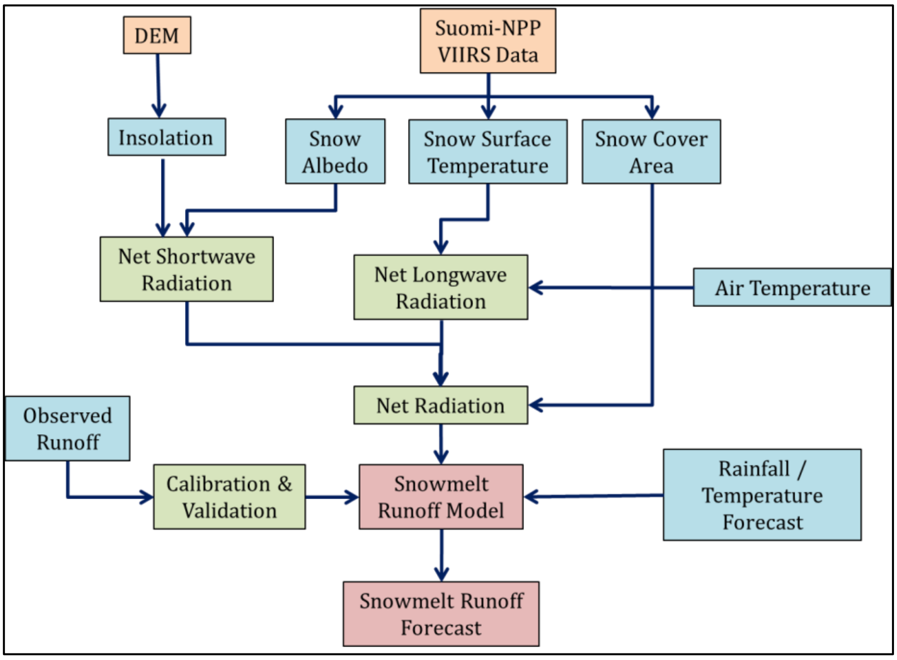


Figure 2. Brief methodology for estimation of snowmelt runoff

6. Deliverables

1. Daily Snow cover map at 1km resolution using NPP Suomi or equivalent satellite data.
2. Forecast models for short term and seasonal snowmelt for Indian Himalayas.
3. Spatial daily gridded snowmelt product.
4. Spatial gridded 3-day snowmelt forecast product.
5. Short term snowmelt runoff forecast at selected basin outlets during snow melt season.
6. Seasonal forecast at selected basin outlets during snow melt season.

7. Quality Assurance Mechanism

Quality Evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards. Project team will first ensure the quality of the product which will be checked / validated by the internal quality team of WRG.

8. Magnitude of Work and Manpower

The study involves analysis of satellite data, preparation of geospatial database and generation of desired outputs including analysis of the outputs for fulfilling the objectives of the study. NRSC will execute the project using existing scientific manpower along with Project Scientists to be recruited under the project.

9. Project Execution Plan

The project will be executed by NRSC as per the project execution plan that will be prepared as per the ISO guidelines. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

10. Time schedule

The project activity will be from Apr, 2016 to Dec, 2023 and the tentative schedule & milestones of the project are shown in Table 1.

11. Project Review and Reporting

Project Management Committee (PMC) consisting of NRSC and MoWR senior Officials will be constituted for periodic review of study activities, progress monitoring and related issues.

12. Budget

The total budget for this project is Rs. 363.0 Lakhs. The year-wise budget details are provided in Table.2.

13. Project limitations

- The net shortwave and net longwave radiation components are used for estimation of snowmelt runoff. Since input data is not available, an assumption is made for other Energy components. It is assumed that other components constitute about 40% of total energy input – based on literature.

- The accuracy of snowmelt runoff is influenced by the accuracy of available rainfall forecast and temperature forecast.
- Non-availability of cloud free snow maps may limit snowmelt runoff forecast.

14. Work sharing

Responsibility of NRSC

- NRSC is responsible for overall execution of the project including satellite data procurement, processing, analysis, outputs, report generation, etc.
- NRSC will provide the outputs as outlined in the deliverables section of the project proposal within the period mentioned thereof.
- NRSC will take up the study on receipt of advance payment from CWC.

Responsibility of MoWR, RD & GR

- MoWR, RD & GR shall provide the boundary of all the river basins in the study area and other related maps available with them that will be useful for the study.
- MoWR, RD & GR will provide daily rainfall, discharge, snowfall data at all the selected basin outlets and also the historic data for model buildup.
- MoWR, RD & GR will enable the AWS data from different locations available in Indian Himalayas.
- MoWR, RD & GR is required to pay advance payment of the project cost to NRSC.
- All kind of local logistic support during the course of fieldwork needs to be provided.

Table 1: Time schedule for the project

Activity	2016			2017				2018				2019				2020				2021				2022				2023			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Preparation of data base																															
Collection of satellite derived products & Discharge data at selected points from field.																															
Estimation of solar radiation on daily basis																															
Data for model development																															
Model development																															
Model calibration & validation																															
Forecast simulation																															
Spatial snow melt product Generation.																															
Analysis of results and Interim report preparation																															
Model updation and refinement																															
Preparation of data inputs for the next season																															

Table 2: Project budget

S.No.	Item Description	Cost (Rs in Lakhs)								
		2016-17	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**2023-24**	**Total**
1	Satellite Date - free download	-	-	-	-	-	-	-		-
2	Geo-spatial data processing and analysis	2	4	4	4	4	4	4	4	30
3	NRSC Manpower	2.1	1.9	2.1	2.3	2.5	2.7	3	3.3	19.9
4	Project Scientist	0	23.9	23.9	23.9	23.9	23.9	23.9	23.9	167.3
5	Ground truth, Travel, Outputs	1	4	4	4	4	4	4	4	29
6	Hardware & Software	15	17	1	3.2	3.2	3.2	3.2	3.2	49
7	Training & conferences (Domestic & Overseas)	0	2	12	12	2	2	2	2	34
	Sub-Total1	20.1	52.8	47	49.4	39.6	39.8	40.1	40.4	329.2
	Project Management @ 5% on Sub-Total 1	1.005	2.64	2.35	2.47	1.98	1.99	2.005	2.02	16.46
	Sub-Total 2	21.105	55.44	49.35	51.87	41.58	41.79	42.105	42.42	345.66
	Organizational Overheads @ 5% on Sub-Total 2	1.05525	2.772	2.4675	2.5935	2.079	2.0895	2.10525	2.121	17.283
	Total	22.16025	58.212	51.8175	54.4635	43.659	43.8795	44.21025	44.541	363.00

Annexure 5

__Proposal__

Operational Web-based
National Hydrological Modelling System
Under
National Hydrology Project

__Submitted to__

Ministry of Water Resources
Govt. of India

June, 2016

National Remote Sensing Centre
ISRO, Govt. of India
Hyderabad-37

1. Introduction

National Hydrology Project (NHP) is being taken up of Ministry of Water Resources, Govt. of India with financial aid from World Bank. The Project is to improve reliability and accuracy of Hydrology and Ground Water data throughout India and to improve access to this information. The mission is to establish an effective and sound hydrologic database and Hydrological Information System (HIS), together with the development of consistent and scientifically-based tools and design aids to assist in the effective water resources planning and management within each to the implementing agencies based on sound scientific driven framework.

In this connection, Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR) consulted NRSC to support NHP through geo-spatial data products, services, customized applications development and capacity building to the stakeholders. NRSC participated various meetings organized by MoWR, RD&GR and World Bank and deliberated on the possible role NRSC/ISRO would play in NHP implementation. Comments and concurrence of draft EFC memo was communicated from the Office of Secretary of Dept. of Space to MoWR, RD&GR. NRSC participated in the Wrap-up Meeting of NHP World Bank Mission held during 14-15 Sep, 2015 at New Delhi and presented the details of possible Role of National Remote Sensing Centre (ISRO) under National Hydrology Project. Further, Joint Secretary, MoWR, RD&GR communicated approval of EFC Memo through D.O. No. 21/97/2015-NHP/3925 Dt. 26th Nov, 2015.

In response to the above, the present proposal is formulated, where in NRSC/ISRO is supporting NHP through geospatial data based services, water resources/hydrology applications development and capacity building. NRSC/ISRO is supporting NHP through geospatial data based services and applications development. As part of this, the present study is proposed to operationalize national level hybrid modelling framework, where the major hydrological processes are modelled through integration of geo-spatial data sets with hydro-meteorological data.

The focus is on quantifying the spatial and temporal distribution of water balance components and to provide orderly description hydrological fluxes through geo-spatial products at regular periodicity. The model derived fluxes are useful for quantifying spatial and temporal variation in basin/sub-basin scale water resources, periodical water budgeting and form vital inputs for studies on topics ranging from water resources management to land-atmosphere interactions including climate change.

2. Objectives

The objectives that are proposed to be achieved through the study are as under:

a) To establish National level hydrological modeling framework for in season hydrological fluxes estimation at daily/weekly/fortnightly time step

b) To establish a comprehensive field experimentation setup for calibration and validation of model computed flux outputs (Soil Moisture, ET)

c) To Develop of web-enabled in-season hydrological fluxes information for the entire country on India-WRIS/Bhuvan

3. Study Area

Entire India covering catchment of all Indian river basins, including trans-boundary regions and 3min gird (~5.5km) resolution will be adopted

4. Satellite and Ancillary Data bases

The following data sources will be used for Hydrological modelling

S. No.	Parameter	Data sources
1	Terrain	• Carosat-1 DEM • Aster DEM • SRTM DEM • CWC discharge sites • ALTM DEM of flood plains • Data on flood retention structures
2	Soil	• NBSS & LUP Soil Map of India (1:500,000 scale) • FAO Soil data series (5 Million scale) • NATMO Digital Soil map • Field data / Literature / Experimentation
3	Vegetation Library	• LAI (MODIS / NPOESS / JPSS) • Albedo (MODIS / NPOESS / JPSS) • Physical parameters (Field data / Literature / Experimentation)
4	Vegetation cover	• LULC (NRC-250k) • ....
5	Lake / Water body	• Water spread dynamics (Automatic Feature extraction)
6	Irrigation	• Irrigation command maps • India-WRIS
7	Meteorological data	• IMD Gridded data (historic/forecast) • IMD Surface data - hourly/daily (historic, current, forecast) • ISRO AWS - hourly/daily (historic, current) • Satellite meteorological products (TRMM, CPC, ..)

		• Forecast products - 3hourly/24hrs/48 hrs/72hrs - Gridded/Surface (IMD, MOSDAC, NARL, WRF, ..)
8	River discharge	• CWC 1hr/3hr/daily gauge-discharge data (Historic/real-time)
9	Reservoir data	• Rating curves, reservoir releases (real-time, historic), operating tables, Reservoir operating tables
10	Satellite Data	• Microwave satellite data of floodplains

5. Approach Methodology

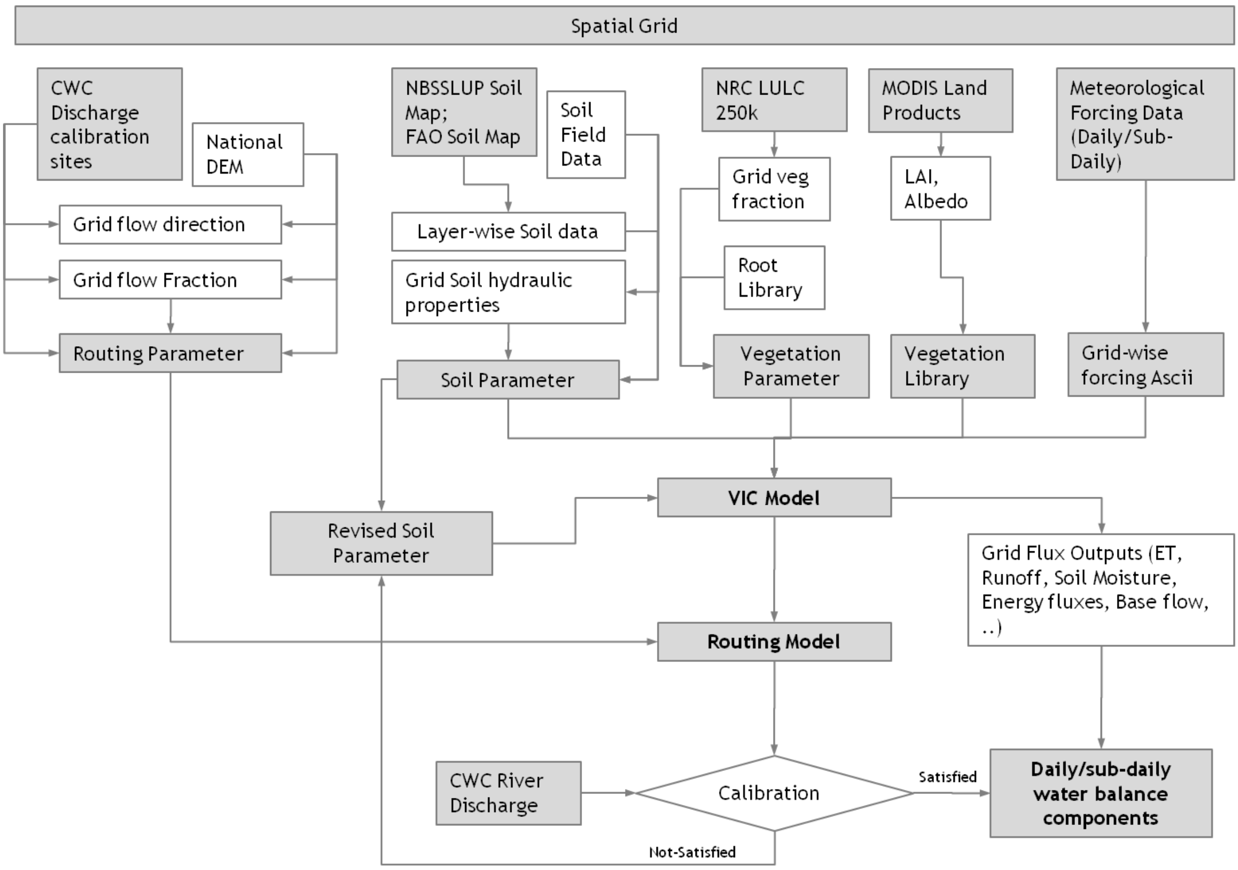
Many researchers used simple bucket models and hydrological budgeting schemes to model near-surface hydrology ranging from catchment scale studies to the global water balance and climate change scenarios (Thornthwaite, 1948; Mather, 1978; Mintz and Walker, 1993). Hydrological models are used for varying purposes: to quantify catchment water yield and to simulate consumptive use patterns (Hubert, 1997), to validate remote sensing products (Rötzer et al. 2014; dall'Amico et al. 2012), for runoff predictions in ungauged basins (Young, 2006; Zhang et al. 2009).

Among the many hydrological models developed world wide, Variable Infiltration Capacity (VIC) model is extensively used by earth observation scientific fraternity for its scientific rationale, inclusion of bio-physical processes that govern water-energy exchanges and adoptability to different regions. VIC is an open source research model, which was developed by university of Washington and Princeton University by Liang.et.al in (1994). This model has been applied to many watersheds across globe and also to study the impact of climate change on hydrologic cycle at watershed level. Employing the infiltration and surface runoff scheme in Xianjiang model (Zhao, 1980), VIC was first described as a single soil layer model by (Wood, 1992) and implemented in the GFDL and Max-Planck-Institute (MPI) GCMs. Continental implementation of the Variable Infiltration Capacity hydrologic model that combines a retrospective daily analysis of over 90 years with real-time, daily-updating simulations of land surface climate and moisture conditions is in place for entire US (Wood, 1992). VIC, a semi-distributed & physically based hydrological model, solves both the water balance and the energy balance. Model computes evaporation, transpiration, surface runoff, soil moisture, base flow, energy fluxes, etc at the predefined grid resolution (few km to hundred km).

The broad methodological steps involved are as under:

- Catchment delineation for CWC Discharge sites using DEM
- Preparation Routing Parameters file (grid-wise fraction, flow direction, ..)

- Preparation Soil Parameter file for each catchment (soil type, layer-wise depth, hydraulic properties, ...)
- Preparation of vegetation parameter (Vegetation type, fraction, ...)
- Preparation of Vegetation library (Monthly LAI, Albedo, Canopy resistance factors, Displacement height, ...)
- Meteorological forcing data preparation and generation grid-wise forcing data Ascii files
- VIC Model setup and Run
- Routing Model Run
- Calibration of simulated discharge with observed CWC discharge
- Generation of grid-wise water balance components
- Integration and Conversion of grid-wise VIC outputs into geo-spatial data sets / products



Calibration / Validation Protocols -

a) Soil Moisture

Soil moisture is an important component in the atmospheric water cycle, both on a small agricultural scale and in large-scale modelling of land/atmosphere interaction. Vegetation and crops always depend more on the moisture available at root level than on precipitation occurrence.

There are four operational alternatives for the determination of soil water content.

1) Classic gravimetric moisture determination
2) Lysimetry, a non-destructive variant of gravimetric measurement
3) Water content may be determined indirectly by various radiological techniques (Neutron scattering and gamma absorption)
4) Water content can be derived from the dielectric properties of soil, by using time-domain reflectometry.

Criteria for Stratification of Sample Collection

It is proposed to stratify the study area based on the Texture, Depth, Slope and Vegetation cover.

Frequency of Observation

Frequency of observation can vary depending on the season. During non-monsoon season 2-3 times, summer and winter monsoon season 4 times during the season. With institutional arrangement more frequent observations are envisaged.

Site Selection and Sample Size

To support grid based analysis, it is proposed to stratify the grids based on the above four criteria. The two very important parameters which controls the soil moisture are the soil type, soil depth and the slope. Since these parameters area subdivided into three classes each, the combination of these parameter will result in 27 combinations. Hence the grids will be classified as 27 strata and the soil sample will be collected from each of this 27 strata using stratified random sampling method. However all the 27 strata may not occur in one's study area and hence the number of strata will actually will be less than 27.

Number of Samples per Grid

Representation of any soil moisture observation point is limited because of the high probability of significant variations, both horizontally and vertically, of soil structure (porosity, density, chemical composition). Horizontal variations of soil water potential tend to be relatively less than such variations of soil water content. Gravimetric water content determinations are only reliable at the point of measurement, making a large number of samples necessary to describe adequately the soil moisture status of the site. To estimate the number of samples 'n' needed at a local site to estimate soil water content at an observed level of accuracy (L), the sample size can be estimated from: $n = 4 (\sigma^2/L^2)$ where σ^2 is the sample variance generated from a preliminary sampling experiment. For example, suppose that a preliminary sampling yielded a (typical) σ^2 of 25 per cent and the accuracy level needed to be within 3 per cent, 12 samples would be required from the site (if it can be assumed that water content is normally distributed across the site).

b) Evapotranspiration

ET validation will be attempted through establishment of Flux Towers at selected locations to obtain continuous and measurement of evaporative fluxes for defined foot print. The flux towers would measure net radiation, incident & reflected PAR, rain fall, air temperature, relative humidity, wind speed & direction, soil temperature, soil heat flux, barometric pressure, etc. The study proposes to use above data products for calibrating and validating evapotranspiration, radiation fluxes.

c) River discharge

Central Water Commission at present operates Nationwide Network of 945 Hydrological Observation Stations. Out of these 945 stations, 246 are Gauge Sites, 282 are Gauge and Discharge Sites, 115 are Gauge Discharge and Water Quality Sites, 41 are Gauge, Discharge and Silt Sites, while the remaining 261 are Gauge, Discharge, Silt and Water Quality Sites. The study proposes to use river discharge at selected observation sites for calibration and validation model computed surface runoff.

6. Deliverables

a) Grid-wise periodic Water Fluxes (Evapotranspiration, Soil Moisture, Runoff) daily/weekly/fortnightly time step
b) Web based geo-spatial hydrological products and services
c) Forecast of inflows into selected reservoirs & corresponding reservoir storage estimation
d) Runoff forecast at selected river reaches across the country

7. Quality Assurance Mechanism

Quality Evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards. Internal and external quality evaluation teams will be constituted to evaluate and certify the quality assurance in the work procedures/processes adopted in the study through quantitative measures. The outputs/deliverables will be denoted with accuracy measures.

8. Magnitude of Work and Manpower

NRSC will execute the project using existing scientific manpower along with Project Scientists/JRFs to be recruited under the project. Also, suitable collaborating partners (Universities, Research Organizations) will be identified and joint research will be carried out for meeting project specific research elements.

9. Project Execution Plan

The project execution plan will be prepared as per the ISO guidelines practiced within NRSC. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

The tentative schedule & milestones of the project are:

Activity	2016-17		2017-18		2018-19		2019-20		2020-21		2021-22		2023-24		2023-24	
	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2	HY1	HY2
Establishment of National level hydrological modeling frame work	■	■	■													
Design of field experimentation (SM, ET)			■	■												
In-season field experimentation					■	■	■	■	■	■	■	■	■	■	■	■
Validation and calibration of Model SM & ET						■	■	■	■							
Calibration and validation of rainfall runoff			■	■	■	■	■	■								
Reservoir inflow forecast (Rainfall catchment basins)					■	■	■	■	■	■	■	■	■	■	■	■
Calibration and validation of snowmelt runoff					■		■									
Reservoir inflow forecast (Snowmelt catchment basins)							■	■	■	■	■	■	■	■	■	■
In-season implementation and daily model computations			■	■	■	■	■	■	■	■	■	■	■	■	■	■

HY1: Apr-Sep; HY2: Oct-Mar

10. Time schedule

The project activity will be from Apr, 2016 to Mar, 2024

11. Project Review and Reporting

Project Management Unit will be constituted for periodic review of project progress and necessary guidance during the project execution. Project Management Committee (PMC) consisting of NRSC and MoWR senior Officials will be constituted for the NRSC-NHP project for periodic review of all study activities, progress monitoring and related issues.

12. Budget

The total budget estimate is Rs. 768.9 lakhs. Details given in the following pages

Details of Budget

S. No.	Item Description	Financial Year-wise Budget (Lakh Rs.)								Total
		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	
1	Landuse/landcover, Soils,DEM	Available databases will be used (NRC, MODIS, NBSS&LUP, FAO, Field data, etc)								
2	Meteorological data	To be obtained from IMD under NHP								
3	Satellite data	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	21.0
4	Field Experimentation	0.0	5.0	120.0	90.0	35.0	35.0	35.0	35.0	355.0
5	NRSC Manpower	2.8	8.2	8.2	8.2	8.2	8.2	8.2	8.2	60.2
6	Project Scientists (2 No.s)	0.0	18.5	18.5	18.5	18.5	18.5	18.5	18.5	129.5
7	Computer Hardware	12.0	33.0	1.0	4.1	4.1	4.1	4.1	4.1	66.4
8	Arc GIS & Image Analysis Software	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	15.0
9	Training & Workshops	0.0	5.0	12.0	12.0	5.0	2.0	2.0	2.0	40.0
10	Field Visits	1.0	1.3	1.3	1.3	1.3	1.3	1.3	1.3	10.1
10	Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Total 1		16.8	76.0	166.0	139.1	77.1	74.1	74.1	74.1	697.4
Project Management @ 5% on Sub-Total 1		0.8	3.8	8.3	7.0	3.9	3.7	3.7	3.7	34.9
Sub-Total 2		17.6	79.8	174.3	146.1	81.0	77.8	77.8	77.8	732.3
Organizational Overheads @ 5% on Sub-Total 2		0.9	4.0	8.7	7.3	4.0	3.9	3.9	3.9	36.6
Grand Total		18.5	83.8	183.0	153.4	85.0	81.7	81.7	81.7	768.9

Annexure 6

Proposal

Satellite data based inputs for Irrigation Scheduling for a selected Irrigation Project command area

Under

National Hydrology Project

Submitted to

Ministry of Water Resources
Govt. of India

June, 2016
National Remote Sensing Centre
ISRO, Govt. of India
Hyderabad-37

1. Introduction

National Hydrology Project (NHP) is being taken up of Ministry of Water Resources, Govt. of India with financial aid from World Bank. The Project is to improve reliability and accuracy of Hydrology and Ground Water data throughout India and to improve access to this information. The mission is to establish an effective and sound hydrologic database and Hydrological Information System (HIS), together with the development of consistent and scientifically-based tools and design aids to assist in the effective water resources planning and management within each to the implementing agencies based on sound scientific driven framework.

In this connection, Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR) consulted NRSC to support NHP through geo-spatial data products, services, customized applications development and capacity building to the stakeholders. NRSC participated various meetings organized by MoWR, RD&GR and World Bank and deliberated on the possible role NRSC/ISRO would play in NHP implementation. Comments and concurrence of draft EFC memo was communicated from the Office of Secretary of Dept. of Space to MoWR, RD&GR. NRSC participated in the Wrap-up Meeting of NHP World Bank Mission held during 14-15 Sep, 2015 at New Delhi and presented the details of possible Role of National Remote Sensing Centre (ISRO) under National Hydrology Project. Further, Joint Secretary, MoWR, RD&GR communicated approval of EFC Memo through D.O. No. 21/97/2015-NHP/3925 Dt. 26th Nov, 2015.

In response to the above, NRSC/ISRO is supporting NHP through geospatial data based services, water resources/hydrology applications development and capacity building. As part of this, the present study is proposed to operationalize utilization of satellite based data integrated with hydro- meterological and geo- spatial data sets for assessment of crop water needs of a selected Irrigation Project Command Area

The study aims at estimation of the spatial and temporal water requirements in an irrigated command area in near-real-time. It will help in scientific allocation of water resources and improved water management leading to enhanced water use efficiency.

2. Objectives

The objectives that are proposed to be achieved through the study are as under:

a) To estimate in-season cropping pattern and crop condition using near-real-time satellite data

b) To estimate in-season irrigation water demand at weekly/fortnightly time-step

c) To quantify the water productivity variations across the command area and evaluate the performance of irrigation system.

d) Development of a decision support system for irrigation scheduling.

3. Study Area

An Irrigated Command Area in Krishna or Godavari Basin will be identified. MoWR and NRSC will consult & coordinate this with the concerned State Governments and will be finalized within 3 months of project initiation.

4. Satellite and Ancillary Data bases

i. *Static database:*
   Irrigation distribution system and corresponding hydraulic particulars, soils, terrain information, designed water distribution and field application efficiencies, etc

ii. Historic database:
   Spatial cropping pattern during historic years, crop calendar variations, varietal preferences, crop water requirements, weather/meteorological data, reservoir storages, canal operation plans, canal discharges, etc.

iii. Dynamic database:
   In-season satellite data derived cropping pattern, cropped area and crop calendar variations, AWS meteorological data, weather predictions, real-time ground truth information, field-scale experiments data on canal water distribution and water application, crop water requirements, productivity, water use efficiencies, etc.

The following data sources will be used for assessment and scheduling of irrigation

S. No.	Parameter	Data Types
1	Satellite Data	• One set of high resolution satellite data • In-season Medium / Coarse resolution satellite data
1	Terrain	• Carosat-1 DEM • SRTM DEM
2	Soil	• NBSS & LUP Soil Map of India (1:500,000 scale) • Field data / Literature / Experimentation
3	Irrigation	• Irrigation command maps • Canal network

		• Field Discharge • Canal Operation Plans • Conveyance and distribution efficiency
6	Reservoir	• Reservoir Storage & Release
7	Crop data	• Cropping Pattern • Crop Calendar variations • Crop water Requirements
8	Meteorological data	• IMD AWS Data –daily • Satellite RF products (GPM, CPC) • Forecast products – (IMD, MOSDAC,GEFS)

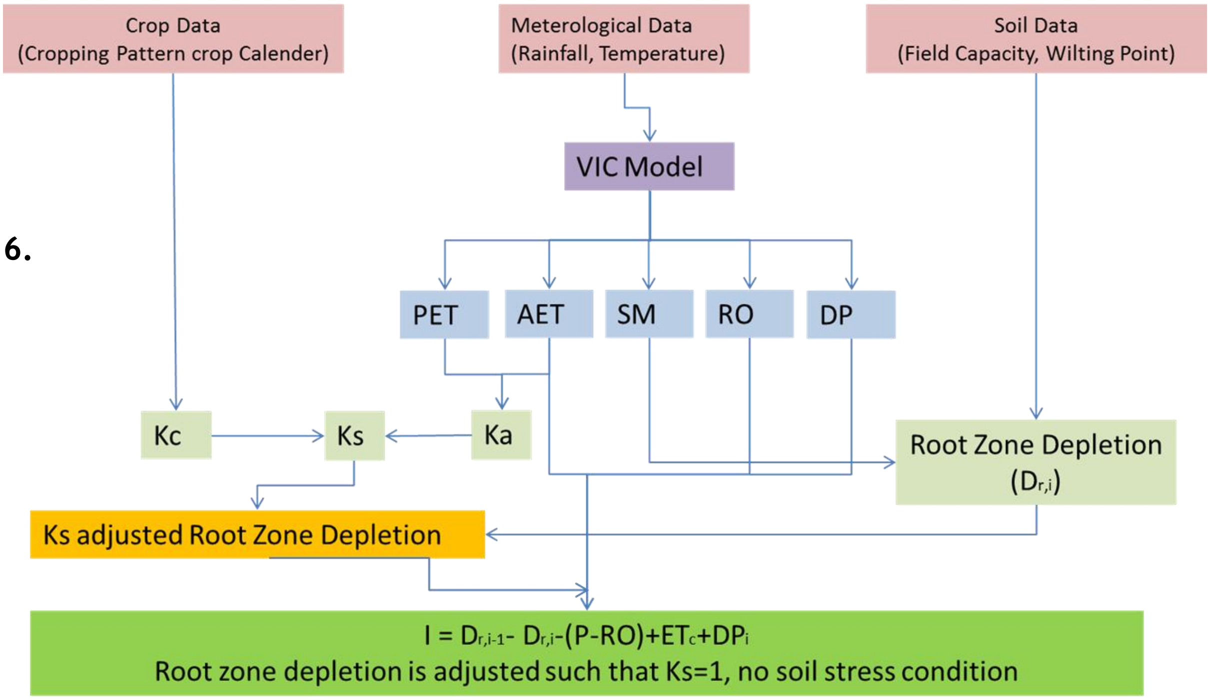
5. Approach Methodology

Higher irrigation water use efficiencies are achieved through better synchronization of irrigation releases and crop water requirements. For many irrigation systems, the irrigation water distribution strategies are based on heuristic approaches considering the past experience, rule books, project guidelines and other qualitative information. Studies have demonstrated usefulness of satellite data for generating in-season information on crop and irrigation for improving irrigation water allocation (George et al., 2004; Raju et al., 2008; Kamble et al., 2013) and for performance assessment (Shah and Dalwad, 2011; Sander and Leclert., 2009, NRSC, 2001). Recent studies ad also demonstrated the utilization of remote sensed and field data for development of irrigation scheduling decision support for field scale(Doughlas et. al 2012)

The methodology essentially consists of estimation of irrigation water requirements at canal command level using satellite and field data for different canal command areas.

- Extraction of canal network using high resolution satellite data
- Delineation of command boundaries using canal network, drainage and project maps.
- Analysis of temporal medium and coarse resolution satellite data for estimation of cropped, cropping pattern and crop calendar.
- Estimation of Reference Evapotranspiration (ETo) using long term meteorological data.
- Estimation of Crop Evapotranspiration (ETc) using ETo and cropping pattern (satellite data) and crop calendar (field)
- Assessment of Crop Water Requirements (CWR) using ETc and cropped areas (satellite data)

- Estimation of ETc adjusted for soil water stress by considering root zone depletion factor.
- Estimation of Field Irrigation Water Requirement from the soil water balance.
- Estimation of Net Irrigation Requirement after application of efficiencies derived from field experimentation



6. Deliverables

1. Cropping pattern and crop condition at tertiary canal level (in-season) during the rabi seasons 2018-19 to 2023-24
2. Weekly /Fortnightly irrigation water requirements at tertiary canal (in-season) during rabi seasons 2019-20 to 2023-24
3. Irrigation system performance assessment for the rabi seasons 2019-20 to 2023-24
4. Decision support system for irrigation scheduling.

7. Quality Assurance Mechanism

Quality Evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards. Internal and external quality evaluation teams will be constituted to evaluate and certify the quality assurance in the work procedures/processes adopted in the study through quantitative measures. The outputs/deliverables will be qualified with accuracy measures.

8. Magnitude of Work and Manpower

NRSC will execute the project using existing scientific manpower along with Project Scientists/JRFs to be recruited under the project. Also, suitable collaborating partners (Universities, Research Organizations) will be identified and joint research will be carried out for meeting project specific research elements.

9. Project Execution Plan

The project execution plan will be prepared as per the ISO guidelines practiced within NRSC. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

The tentative schedule & milestones of the project are:

Activity	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24
Generation of Geo-spatial Database from historical satellite, meteorological and other thematic datasets								
Field Experimentation								
Generation of in-season cropping pattern, crop condition and irrigation water demand using near-real-time satellite data and meteorological inputs								
Validation of the estimated crop water requirement with the field observed values								
Performance assessment indicators								
Inseason implementation weekly/fortnightly estimation of irrigation requirement for different commands								

10. Time schedule

The project activity will be from Apr, 2016 to Mar, 2024

11. Project Review and Reporting

Project Management Unit will be constituted for periodic review of project progress and necessary guidance during the project execution. Project Management Committee (PMC) consisting of NRSC and MoWR senior Officials will be constituted for the NRSC-NHP project for periodic review of all study activities, progress monitoring and related issues.

12. Budget

The total budget estimate is Rs. 348.8 lakhs. Details given in the following pages

Details of Budget

S. No.	Item Description	Financial Year-wise Budget (Lakh Rs.)								Total
		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	
1	Landuse/landcover, Soils,DEM	Available databases will be used (NRC, MODIS, NBSS&LUP, FAO, Field data, etc)								
2	Meteorological data	To be obtained from IMD under NHP								
3	Satellite data	2.0	52.0	2.0	2.0	2.0	2.0	2.0	2.0	66.0
4	Field Experimentation	0.0	1.0	2.0	2.0	2.0	1.0	1.0	1.0	10.0
5	NRSC Manpower	1.6	5.1	5.1	5.1	5.1	5.1	5.1	5.1	37.0
6	Project Scientists (2 No.s)	0.0	17.1	17.1	17.1	17.1	17.1	17.1	17.1	119.7
7	Data Analysis	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	8.0
8	Hardware and Software Maintenance	7.0	17.0	1.0	2.5	2.5	2.5	2.5	2.5	37.7
9	Training & Workshops	0.0	3.0	10.0	5.0	5.0	0.0	0.0	0.0	23.0
10	Field Visits	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	15.0
Sub-Total 1		12.6	98.2	40.2	36.7	36.7	30.7	30.7	30.7	316.4
Project Management @ 5% on Sub-Total 1		0.6	4.9	2.0	1.8	1.8	1.5	1.5	1.5	15.8
Sub-Total 2		13.2	103.1	42.2	38.5	38.5	32.2	32.2	32.2	332.2
Organizational Overheads @ 5% on Sub-Total 2		0.7	5.2	2.1	1.9	1.9	1.6	1.6	1.6	16.6
Grand Total		**13.9**	**108.3**	**44.3**	**40.5**	**40.5**	**33.8**	**33.8**	**33.8**	**348.8**

Annexure 7

Operational Hydrological Drought Services using Remote Sensing data

Project Proposal

Submitted to

Ministry of Water Resources, River Development and Ganga Rejuvenation

Water Informatics & Quality Division
Water Resources Group
Remote Sensing Applications Area
National Remote Sensing Centre
Dept. of Space, Govt. of India
Hyderabad - 500 037

August, 2016

Operational Hydrological Drought Services using Remote Sensing data

1. Background

Drought is a stochastic natural phenomenon that arises from considerable deficiency in precipitation. Drought can generally be defined as the extreme persistence of precipitation deficit over a specific region for a specific period of time. By implementing an operational definition of drought, three main physical drought types were established: meteorological, agricultural, and hydrological droughts. In a broad definition, these droughts occur in a particular order; precipitation deficiency instigates meteorological drought, which subsequently impacts soil moisture content (i.e., agricultural drought). Low recharge from the soil to water features such as streams and lakes causes a delayed hydrological drought (Amin Zargar et al, 2011). The present study is proposed to assess the hydrological drought conditions using satellite derived surface water bodies' information and water balance components at regional level.

Generally drought scenarios are analyzed in terms of drought frequency, severity, and duration for a given return period (Mishra and Singh, 2009). Some of the commonly used definitions are: (i) The World Meteorological Organization (WMO, 1986) defines 'drought means a sustained, extended deficiency in precipitation.' (ii) The UN Convention to Combat Drought and Desertification (UN Secretariat General, 1994) defines 'drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.' (iii) The Food and Agriculture Organization (FAO, 1983) of the United Nations defines a drought hazard as 'the percentage of years when crops fail from the lack of moisture.' (iv) The encyclopedia of climate and weather (Schneider, 1996) defines a drought as 'an extended period – a season, a year, or several years – of deficient rainfall relative to the statistical multi-year mean for a region.' (v) Gumbel (1963) defined a 'drought as the smallest annual value of daily streamflow.' (vi) Palmer (1965) described a 'drought as a significant deviation from the normal hydrologic conditions of an area.' (vii) Linseley et al. (1959) defined 'drought as a sustained period of time without significant rainfall.' However, drought definitions vary, depending on the variable used to describe the drought.

Hydrological drought is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system. Stream flow data have been widely applied for hydrologic drought analysis (Dracup et al., 1980; Sen, 1980; Zelenhasic and Salvai, 1987; Chang and Stenson, 1990; Frick et al., 1990; Mohan and Rangacharya, 1991; Clausen and Pearson, 1995, Ashok 2010). Meteorological drought is defined as a lack of precipitation over a region for a period of time. Precipitation has been commonly used for meteorological drought analysis (Pinkeye, 1966; Santos, 1983; Chang, 1991; Eltahir, 1992). Considering drought as precipitation deficit with respect to average values (Gibbs, 1975), several studies have analyzed droughts using monthly precipitation data. Other approaches analyze drought duration and intensity in relation to cumulative precipitation shortages (Chang and Kleopa, 1991; Estrela et al., 2000).

A number of different indices have been developed to quantify a drought, each with its own strengths and weaknesses. They include the Palmer drought severity index (PDSI; Palmer 1965), rainfall anomaly index (RAI; van Rooy, 1965), crop moisture index (CMI; Palmer, 1968), Bhalme and Mooly drought index (BMDI; Bhalme and Mooley, 1980), surface water supply index (SWSI; Shafer and Dezman, 1982), national rainfall index (NRI; Gommes and Petrassi, 1994), standardized precipitation index (SPI; McKee et al., 1993, 1995), and reclamation drought index (RDI; Weghorst, 1996). The soil moisture drought index (SMDI; Hollinger et al., 1993) and crop-specific drought index (CSDI; Meyer and Hubbard, 1995) appeared after CMI. Furthermore, CSDI is divided into a corn drought index (CDI; Meyer and Pulliam, 1992) and soybean drought index (SDI; Meyer and Hubbard, 1995), and vegetation condition index (VCI; Liu and Kogan, 1996). Besides these indices, there are indices of Penman (1948), Thornthwaite (1948, 1963). Based on the studies for drought indices, practically all drought indices use precipitation either singly or in combination with other meteorological elements, depending upon the type of requirements, which were also suggested by WMO (1975).

There are many indices to characterize hydrological drought. They aim at providing a comprehensive characterization of delayed hydrologic impacts of drought. Earlier, the sophisticated PHDI model considered precipitation, evapotranspiration, runoff, recharge, and soil moisture. The PDSI family of indices show ever lacked the snow component accumulation, which led to the development of SWSI. Later, RDI improved SWSI by incorporating temperature and hence calculated a variable water demand as input. RSDI bases its model on homogeneous drought-stricken regions that comprise several neighbouring low-flow gauging stations. RSDI first calculates the deficiency in stream flow compared with historic values and then uses cluster analysis to delineate the drought-stricken regions. Two more indices consider water balance model, namely GRI and Water Balance Derived Drought Index. The former focuses on groundwater resources and uses geo-lithological conditions information in a distributed water balance model, while the latter uses a model that artificially simulates runoff for un-gauged and low-data watersheds (Amin Zargar et al, 2011).

National Remote Sensing Centre (NRSC) is currently monitoring the status of all water bodies in the country using satellite images and provides water spread area information for every fortnight. Images from Indian remote sensing satellites, Resourcesat-2 (AWiFS & LISS III) and RISAT-1 (MRS), are processed in near real time using automated spectral and hierarchical based algorithm (Subramaniam et al, 2011), to generate spatial water information. This consists of all surface water features like reservoirs, tanks, lakes, ponds, rivers and streams. The temporal water spread information generated since 2012 is organized in a geospatial database in the form of water bodies. This data is published on Bhuvan Geo-Platform under “Water Body Information System” (WBIS) for visualization and spatial query. Further, it is planned to use ancillary data to compute storage in these water bodies. NRSC is also producing grid-based model derived water balance components (surface run-off, evapotranspiration and soil moisture) on experimental basis for entire country, which is expected to be made operational.

In this proposal, it is planned to use these remote sensing and model derived inputs for developing new indices to provide operational hydrological drought services for the country.

2. Objectives

The overall objective of this study is to provide hydrological drought services for the country. The specific objectives are

1. To characterize spatio-temporal variability of hydrological drought using satellite derived surface water spread
2. To develop hydrological drought indices based on geospatial data and hydrological model outputs and its
3. To provide operational hydrological drought services.

3. Study Area

The present study will cover entire country.

4. Data Used

4.1. Satellite Data

Hydrological drought assessment will be mainly based on temporal surface water spread information derived from currently available multi-spectral sensors of different spatial / temporal resolutions. The details of satellites and sensors proposed to be used in the present study are provided in Table 1. The minimum size of the water body that can be derived from each of sensor is also mentioned in table. The accuracy of mapping depends on area / perimeter ratio, number of land-water mixed pixels (boundary pixels), aquatic vegetation, influence of cloud, irregular response in microwave signals due to wave pattern, terrain roughness, etc. Fortnightly time composite will be generated from the available cloud free satellite datasets in the study. In addition to the sensors listed, data from multi-spectral sensors of future missions will also be used.

Table 1 Satellite data proposed to be used in the study

Satellite	Sensor	Spatial resolution (m)	Revisit period (days)	Minimum water body size (ha)
Resourcesat-2 (Optical) *from Jan 2012*	AWiFS	56	5	50
	LISS III	24	24	5
	LISS IV	5.8	48	1
RISAT-1 (Microwave) *from June 2013*	MRS	18	23	10
Landsat 8 (Optical) *from October, 2016*	OLI	30	16	10

4.2. Rainfall Data

Current and historic rainfall data collected from Indian Meteorological Department available at 0.5 degree grid level will be utilized for the study.

4.3. Reservoirs and Water Bodies Profile Data

Elevation-Area-Capacity (EAC) curves for major, medium reservoirs in India will be collected from State / Central government departments for estimating the volume of water stored in these reservoirs using satellite derived water spread. Utilization of SARAL Altika data or other altimeter based elevation information will also be explored on experimental basis for estimation of reservoir capacity. For other water bodies, information on depth and capacity will be obtained from State Governments for estimating volume of water stored in these water bodies.

4.4. Water Balance Components Information

Grid level information on hydrological model derived water balance components such as surface run-off, evapotranspiration and soil moisture generated daily by NRSC will be utilized for characterizing the hydrological drought. It is also proposed to use the near real time data planned to be generated in the future under NHP for assessing hydrological drought.

5. Methodology

The present study proposes to use mainly the satellite derived near real time surface water bodies' information along with model derived water balance components such as surface runoff, soil moisture for the assessment of hydrological drought. It is proposed to build long term data base on these parameters and develop hydrological drought indices based on these parameters for providing operation hydrological drought services at disaggregated level. The overview of the methodology is shown in flowchart (Figure.1).

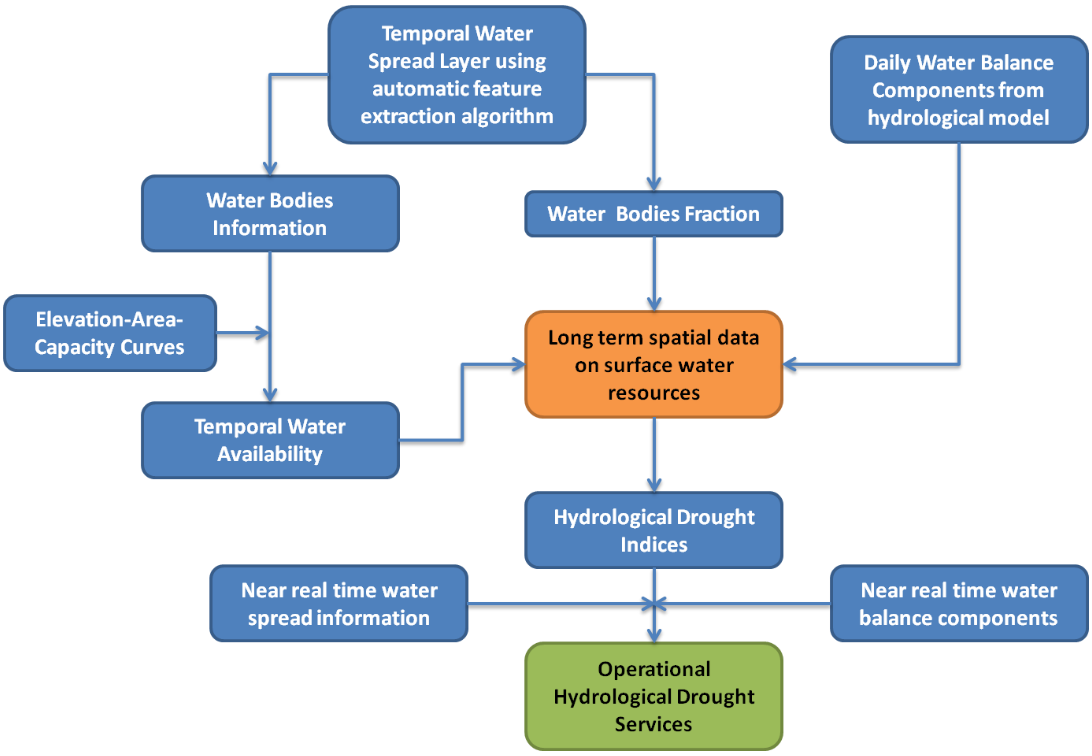


Figure 1 Overview of methodology

5.1 Generation of Temporal Water Spread Information

In the present study, spatial water spread information is one of the main inputs for hydrological drought assessment. This involves automatic processing of images from currently available multi-spectral sensors of different spatial and temporal resolutions. It is proposed to use automated spectral and hierarchical based algorithm (Subramaniam et al, 2011) developed at NRSC for processing huge number of satellite data sets in near real time. Presently, algorithms for automated processing of the Resourcesat-2 AWiFS, LISS-III, LISS-IV, RISAT-1 MRS data are in place and operational under Information Product Generation System (IPGS) of IMGEOS. This will be continued to be carried out in near real time for generation of water spread information. Evaluation of the algorithm will be continued for improving the thematic accuracy from the each sensor. Improvement in the algorithm theoretical basis will be carried as and when required. Long term database water spread will be generated using data from different sensors and the same will be analysed for spatio-temporal characterization of hydrological drought. This data will also be used for generating grid level water body fraction information and long term database will be built for further analysis. In addition to the sensors mentioned above, data from multi-spectral sensors of future missions will also be used for generating water spread information, with necessary modifications in the automated algorithm.

5.2. Generation of Temporal Water Availability Information

Presently, Water Bodies Information System (WBIS) is in place for visualizing and querying temporal water spread information for water bodies in the country. The temporal water spread information generated is converted into water body level information and stored in a geospatial database. WBIS has interface for visualizing temporal water spread dynamics for each water body as well as for any geographical/hydrological region. The scope of WBIS will be improved with additional tools for collection of field data, validation of results and regional /state wise report generation, etc. In addition to this, Elevation-Area-Capacity (EAC) curves will be collected from various State / Central departments for all major and medium reservoirs and will be used in conjunction with satellite derived water spread area for estimating water availability. Validation of the same will be taken up with the help of state / central departments. A long term data on temporal water availability for all the water bodies will be generated. This information will be analysed for spatio-temporal characterization of hydrological drought.

5.3. Use of Model Derived Water Balance Components Information

NRSC has setup a hydrological modeling framework using Variable Infiltration Capacity (VIC) model at 9 min (~16.5 km & 13709 grids) grid level for the entire country using geo-spatial data sets and historic meteorological data. The model performance has been optimized through calibration of model estimated runoff with measured stream discharge (Source: CWC) using historic gridded meteorological products from IMD (1976-2005) for selected river basins. Long-term (1951-2013) hydrological fluxes (Surface runoff, Evapotranspiration and Soil moisture) have been generated at 9 min grid level for the entire country. Since 1st June 2014, near-real-time meteorological data (Rainfall, Temperature, etc.) are collected and processed on daily basis and model computations are being carried out at daily time-step. National scale, 9min grid-wise surface runoff, evapotranspiration, soil moisture are being estimated with two-day time lag since 01 Jan 2014. Geo-spatial products of the daily water balance components are being published through Bhuvan geo-platform. In this study, it is proposed to use this information for spatio-temporal characterization of hydrological drought based on the water balance components.

5.4. Development of Hydrological Drought Indices

Hydrological drought is defines as a significant decrease in the availability of water in all its forms appearing in the land phase of the hydrological cycle (Nalbantis 2009). Hydrological drought is described as a sustained and regionally extensive occurrence of below average natural water availability (Tallaksen and van Lanen, 2004). There are many indices to characterize hydrological drought. They aim at providing a comprehensive characterization of delayed hydrologic impacts of drought. These indices considered precipitation, evapotranspiration, runoff, recharge, and soil moisture. These parameters are measured in the ground as point data and integrated over a region to assess the impact. However, in this study, it is proposed to develop appropriate hydrological drought indices considering the geospatial information on water availability, water bodies fraction and water balance components derived from satellite data and hydrological modeling.

Hydrological drought assessment will be carried out using the real time status on water availability, water bodies fraction and water balance components in comparison with reference to the historic normal data in a geospatial domain. The change in water availability, water fraction, surface runoff and soil moisture with reference to long term average will be quantified and transformed into an appropriate index representing the severity of hydrological drought.

This index will be aggregated at different hydrologic unit level to provide spatial hydrologic drought status for the country at regular intervals, either fortnightly or monthly. The weighted average of the proposed index will also be estimated to represent different administrative units for hydrological drought status. This information will be published on Bhuvan platform in near real time.

6. Deliverables

- New hydrological drought indices based on remote sensing and model derived inputs
- Operational hydrological drought services for providing fortnightly/monthly hydrological drought status for the country

7. Quality Assurance Mechanism

Quality evaluation procedures will be implemented during the project execution for ensuring and adhering to the quality standards.

8. Assessment of magnitude of work

The study involves preparation and analysis of satellite data, preparation of geospatial database and analysis of the results for fulfilling the objectives of the study. The necessary manpower and infrastructure will be used from the existing facilities at NRSC.

9. Project Execution Plan

The project will be executed by NRSC as per the project execution plan that will be prepared as per the ISO guidelines. The plan will have information on project management structure, internal and external QC teams, detailed project schedule with milestones, manpower deployment schedule, funds and other infrastructure requirements, necessary software tools, mechanism for obtaining and handling customer feedback, etc.

10. Time schedule

The total period of project execution is from April, 2017 to March, 2024. The detailed time schedule for various activities under the study is given in Annexure-1.

11. Project Review and Reporting

The progress of the project will be reviewed by Divisional Head and the same will be reported to Group Director (WRG) on regular intervals.

12. Budget

The total cost of the project is Rs. 903 lakhs *(Rs. Nine crores three Lakhs Only)*

S. No.	Item Description	Financial Year-wise Budget (Lakh Rs.)								Total
		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	
1	Geo-spatial base data (Land use/land cover, Soils, DEM, etc.)	Available databases will be used (NRC, MODIS, NBSS&LUP, FAO, Field data, etc)								
2	Meteorological data	To be obtained from IMD under NHP								
3	Satellite data	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	28.0
5	NRSC Manpower	2.5	5.1	5.1	5.1	5.1	5.1	5.1	5.1	37.9
6	Project Scientists @ 0.55 lakh/month; JRF @ 0.325/month and DEO @0.12/month	0.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	203.3
7	Data Analysis	2.0	8.0	8.0	8.0	4.0	4.0	4.0	4.0	42.0
8	Hardware & Software+ maintenance	100.0	247.0	0.0	30.6	30.6	30.6	30.6	30.6	500.0
10	Travel and Field Works	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	8.0
Sub-Total 1		105.5	294.1	47.1	77.7	73.7	73.7	73.7	73.7	819.2
Project Management @ 5% on Sub-Total 1		5.3	14.7	2.4	3.9	3.7	3.7	3.7	3.7	41.0
Sub-Total 2		110.8	308.8	49.5	81.6	77.4	77.4	77.4	77.4	860.2
Organizational Overheads @ 5% on Sub-Total 2		5.5	15.4	2.5	4.1	3.9	3.9	3.9	3.9	43.0
Grand Total		**116.3**	**324.2**	**51.9**	**85.7**	**81.3**	**81.3**	**81.3**	**81.3**	**903.2**

13. Project limitations

- Available satellites / sensors data will be considered for the study. However, the presence of cloud will hamper the frequency of observations.
- Glacial lakes and water bodies in hilly regions are not part of this study.

14. Work sharing

Responsibility of NRSC

- NRSC is responsible for overall execution of the project including satellite data procurement, processing, software development, analysis, outputs, report generation, etc.
- NRSC will provide the outputs as outlined in the deliverables section of the project proposal within the period mentioned thereof.
- NRSC will take up the study on receipt of advance payment from CWC.

Responsibility of MoWR, RD & GR

- *MoWR, RD & GR* shall provide the EAC curves for the major / medium reservoirs
- *MoWR, RD & GR* is required to pay advance payment of the project cost to NRSC.
- All kind of local logistic support during the course of fieldwork needs to be provided.

15. Miscellaneous

- **Funding and terms and conditions of payment**

The project will be completely funded by Ministry of Water Resources, River Development and Ganga Rejuvenation and the project will be initiated against 100% payment in advance for each year.

- **Training**
  Not applicable
- **Warranty**
  Not applicable
- **Project monitoring**
  The project will be monitored by Deputy Director (RSAA) once in six months. The progress of the project will be reflected in the monthly progress report.

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Annexure

Milestones of the project with time schedule

The project activity will be from Apr, 2017 to Dec, 2024 and the tentative schedule &milestones of the project are:

S. No.	Activity	2016-17				2017-18				2018-19				2019-20				2020-21				2021-22				2022-23				2023-24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Satellite data Processing in Near Real Time from various satellites/sensors	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2.	Historic data generation since 2012 and analysis	■	■	■	■	■	■																										
3.	Collection and analysis of Rainfall Data, Water balance components	■	■	■	■	■	■																										
4.	Customisation in WBIS for Integration of database, visualisation for studying hydrological drought dynamics and creation of facility for reports generation.	■	■	■	■	■	■																										
5.	Collection of EAC Curves – for Major and Medium projects	■	■	■	■	■	■																										
6.	Establishment of Methodology and parameter finalization for providing HyDAS	■	■	■	■	■	■																										
7.	Providing HyDAS on experimental base							■	■																								
8.	Monthly Service : HyDAS									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
9.	Automated Reservoir Capacity estimation using Satellite derived WSA, EAC curves							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
10.	Experimental analysis for derivation of water level using altimeter	■	■	■	■	■	■	■	■																								

Q1: Apr-Jun; Q2: Jul-Sep; Q3: Oct-Dec ; Q4 : Jan-Mar

Annexure 8

Proposal

Capacity Building
Under
National Hydrology Project

Submitted to

Ministry of Water Resources
Govt. of India

June, 2016

National Remote Sensing Centre

ISRO, Govt. of India

Hyderabad-37

1. Introduction

National Hydrology Project (NHP) is being taken up by Ministry of Water Resources, Govt. of India with financial aid from World Bank. The Project is to improve reliability and accuracy of Hydrology and Ground Water information throughout India and to improve access to the data and enhance decision making. The mission is to establish an effective and sound hydrologic database and Hydrological Information System (HIS), together with the development of consistent and scientifically-based tools and design aids to assist in the effective water resources planning and management within each implementing agencies based on sound scientific driven framework.

In this connection, Ministry of Water Resources, River Development & Ganga Rejuvenation (MoWR, RD&GR) consulted NRSC to support NHP through geo-spatial data products, services, customized applications development and capacity building to the stakeholders. NRSC participated various meetings organized by MoWR, RD&GR and World Bank and deliberated on the possible role NRSC/ISRO would play in NHP implementation. Comments and concurrence of draft Empowered Finance Committee (EFC) memo was communicated from the Office of Secretary of Dept. of Space to MoWR, RD&GR. NRSC participated in the Wrap-up Meeting of NHP World Bank Mission held during 14-15 Sep, 2015 at New Delhi and presented the details of possible Role of National Remote Sensing Centre (ISRO) under National Hydrology Project. Further, Joint Secretary, MoWR, RD&GR communicated approval of EFC Memo through D.O. No. 21/97/2015-NHP/3925 Dt. 26th Nov, 2015.

In response to the above, the proposals are formulated, where in NRSC/ISRO supporting NHP through capacity building training programs, which consists of Remote Sensing & GIS fundamentals and customized water resources applications. The present proposal is aimed at capacity building of stake holders in understanding and effective utilization of space technology products relevant to water resources.

2. Objectives

The objectivesof the proposed capacity building programs are as under:

a) To conduct two training programs (one week) per year on RS & GIS fundamentals and state of art with 25 participants per batch (2017-18 to 2023-24)

b) To conduct two customized training programs (two weeks) per year on RS & GIS applications in water resources management with 25 participants per batch (2016-17 to 2023-24)

c) Hand holding/Technical support of satellite/GIS data handling to States/UT's

3. Study Area

NA

4. Satellite and Ancillary Data bases

NA

5. Approach Methodology

The capacity building will be carried out by conducting a 1-week course on “Introduction to Remote Sensing & GIS” for Decision Makers/Senior Management Officials and a 2-week course consisting of basics of RS&GIS and Customized water resources application for working level officials.

The teaching methodology includes class room lectures and discussions, conduct of demonstrations and / or hands-on module laboratory sessions and / or ground truth collection field visits.

Both the courses cover topics, viz., Earth Observation Systems, Introduction to Remote Sensing, Digital Image Processing and Interpretation techniques, Introduction to GIS, Creation and analysis of Spatial Databases, Applications of Remote Sensing to Water resources, Introduction to Global Navigational Satellite Systems with exposure to IRNSS, basics of web based mapping covering BHUVAN, the Indian Geo-portal.

6. Deliverables

1. Two training programs (one week) per year on RS & GIS fundamentals and state-of-the-art technologies (2017-18 to 2023-24)
2. Two customized training programs (two weeks) per year on RS & GIS applications in water resources management (2016-17* to 2023-24)

** One Training Program only in 2016-17*

7. Quality Assurance Mechanism

ISO 9001:2015 quality procedures are followed to maintain the quality in the programs. At the end of each program, feedback will be collected and the same will be considered to suitably modify the content of the next programs, if required.

8. Magnitude of Work and Manpower

NRSC will execute the capacity building programs using existing scientific manpower.

9. Training Programs Execution Plan

The operational infrastructure will be procured by second half of 2016-17 and thereafter training programs will be conducted. Every year **two 1-week programs for decision makers/senior management officials and two 2-week programs for working level officials** will be conducted throughout the project period. A total of fifteen 2-week programs and fourteen 1-week programs will be conducted during the entire 8 year project period.

10. Time schedule

The capacity building activity will be from April 2016 to March 2024

11. Project Review and Reporting

NA

12. Budget

The total budget estimate is **Rs. 1094.2 lakhs**.
Details are given below.

SNo.	Item Description	Financial Year-wise Budget (Lakh Rs.)								Total
		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	
1	Course Fee	6.25*	20.0	20.0	20.0	20.0	20.0	20.0	20.0	146.25
2	Manpower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	Hardware	75.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75
4	Software	0	400	0.0	0.0	0.0	0.0	0.0	0.0	400
5	AMC of Hardware Software	0.0	0.0	0.0	33.3	33.3	33.3	33.3	33.3	166.3
6	AV Equipment & Furniture	205	0.0	0.0	0.0	0.0	0.0	0.0	0.0	205
Sub-Total -1										992.5
Project Management (5%)										49.6
Sub-Total -2										1042.1
Administrative Overheads (5%)										52.1
Grand Total										1094.2

* One 2-week course is planned in FY 2016-17.

1. Detailed Budget Estimate for course fee for 1-week course

SNo.	Item Description	Amount (Rs.)
	1-week course (minimum 25 participants per course)	
1	Registration fee @ Rs. 2000/- per participant X 25	50000
2	Tuition Fee @ Rs. 2000/- per participant X 25	50000
3	Boarding charges @Rs.500/- per day X 7 days X 29 (including 4 faculty members per day)	101500
4	Lodging charges @ Rs.50/- per day per person x 7 days X 25	8750
5	Transportation charges	50000
	TOTAL	260250

The overall inflation adjusted average and rounded course fee for 1-week course :Rs. 375000/-

2. Detailed Budget Estimate for course fee for 2-week course

SNo.	Item Description	Amount (Rs)
	2-week course (minimum 25 participants per course)	
1	Registration fee @ Rs.2000/- per participant X 25	50000
2	Tuition Fee @ Rs.3500/- per participant X 25	87500
3	Boarding charges @ Rs.500/- per day X 14 days X 29 (including 4 faculty members per day)	203000
4	Lodging charges @ Rs.50/- per day per person x 14 days X 25	17500
5	Transportation charges	75000
	TOTAL	433000

The overall inflation adjusted average and rounded course fee for 2-week course : Rs. 625000/-

Two 1-week courses and two 2-week courses will be conducted per annum and hence a total of Rs. 20 lakh per annum for 4 courses.

3. Detailed Budget Estimate for Hardware and Software

SNo.	Item	Unit price (lakh of Rs.)	No. of Units	Total amount (Lakh of Rs.)
1	**Hardware**			
	Audiovisual equipment including two laptops	-	-	15
	Furniture			190
	Workstations	3	25	75
2	**Software**			
	ArcGIS master university Labkitseach comprising 5 user licenses under educational pricing	50	5	250
	Erdas IMAGINE under educational pricing	6	25	150
3	AMC charges for H/w & S/w @0.07% of procurement cost	-	-	166
	TOTAL			846