Revised Project Proposal
on

IMPACT OF CLIMATE CHANGE ON WATER RESOURCES IN RIVER BASINS FROM TADRI TO KANYAKUMARI

Submitted to
Ministry of Water Resources
(Government of India)

Submitted by

Indian Institute of Technology Bombay Powai, Mumbai -400076

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Note: "As the objectives and methodologies are similar to the other proposal submitted by IIT Bombay for Godavari River basin, there will be some similarities in this proposal with the same, with specific modifications required for Tadri to Kanyakumari".

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4. Brief bio data of the Investigators: Enclosed

5. Project Title: ***Impacts of Climate Change on Water Resources in River Basins from Tadri to Kanyakumari***

6. Track Record and Workload Assessment of the PI

Sponsored Projects only - Schemes completed:

1) 'Development of Numerical Models for the Prediction of Hydrodynamics & Salinity Transport in Branched Estuary Channels', Department of Science & Technology, India, 2002-2005.
2) 'Scope of Integrated Watershed Modeling Using IRS Data & GIS', ISRO Project, 2003-2004.
3) 'Integrated Watershed Modeling Using IRS Data & GIS', ISRO Project, 2004-2008.

- More than 50 major consultancy projects completed for various industries and government agencies in the past 15 years at IIT Bombay.

Sponsored Projects - Schemes ongoing:

a) "Integrated Flood Assessment Modeling for Urban Watershed Suing Finite Element method, GIS and Remote Sensing", **DST Sponsored research project**, (completed; 2009-2014).

b) "Hydraulic Model Investigations for Design of Raft Foundations for Bridges", Ministry of Shipping, Road Transport & Highways, New Delhi. (completed; 2009-2013).

- Presently 6 industrial research projects are ongoing.

7. If the scheme is sanctioned, in whose name the cheque is to be issued:

The Registrar, IIT Bombay. (for IIT Bombay)

8. Category of R&D Activity (Tick those which are appropriate):

a. Basic Research
b. Applied Research√
c. Action Research
d. Education and Training
e. Mass Awareness Programme
f. Infrastructure Development
g. Creation of Centres of Excellence

9. Description of the Research Proposal

As is already well known, the hydrologic cycle is inherently linked with climate and changes in the climate system are likely to affect water resources and regional development. Increased evaporation, combined with regional changes in precipitation patterns, can affect mean runoff, frequency and intensity of floods and droughts, soil moisture, and water supplies for irrigation and hydroelectric power generation. Conventional tools for water resources management assume a hydrologic time series to be stationary, however "stationarity is dead because substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers"[1]. General Circulation Models (GCMs) provide three-dimensional simulations of the earth's climate system under increased greenhouse gas emission scenarios. The 'four holes' of climate science, as reported in literature[2] are regional modelling, precipitation, aerosol and tree ring controversies, among which, the first two can directly impact river basin water resources. GCMs operate, and simulate climate variables, at a coarse resolution and their projections for precipitation or other hydrologic variables at finer scales are not reliable. Furthermore coarse scale precipitation simulations do not serve the purpose in India, when, the summer monsoon rainfall is characterized with the increase of spatial variability[3]. This necessitates downscaling, that is, obtaining finer scale hydroclimatic variables from the large-scale GCM simulations for impacts assessment.

Statistically downscaled GCM simulations will be used in the proposed work in conjunction with hydrologic simulations by the Variable Infiltration Capacity (VIC) model[4] (a grid based hydrologic model to simulate hydrologic variables such as, soil moisture, runoff) or SWAT (Soil Water Assessment Tool), which are useful for agricultural water management, drought forecasting etc. The downscaling relationship obtained between the large scale climate variables that are well simulated by the GCMs, and the fine scale rainfall will be applied to GCM projections and the downscaled variables will serve as input to the hydrologic model. The proposed work will also analyse land use land cover changes and their impact on micro climate and hydrologic processes. The hydrologic variables such as runoff or soil moisture or evapotranspiration, simulated with GCM projections, can be further used in specific applications such as understanding behaviour of extremes, water demand analysis, assessment of water

quality, etc. All the generated outputs will be made available to the Central Water Commission (CWC) and Ministry of Water Resources (MOWR), which may further be used by end users, such as water resources planners, agricultural managers for adaptation strategies. Additionally, if time permits, some key research questions can be addressed with the proposed work, such as exploring reasons of changes in regional precipitation patterns, or changes in risks associated with extremes under climate change.

The proposed work aims at assessment of impacts of climate change on the water resources of the river basins from Tadri to Kanyakumari. Most of the Rivers in this area are flowing to west joining Arabian Sea. The Rivers are mainly in Kerala, Karnantaka, and Tamilnadu.

9.1 Project Area Details: West flowing Rivers South of Tadri

The basin extends over states of Kerala, Karnataka, Tamil Nadu and Puducherry having an area of about 56,177 Sq.km which is 1.73 % of total geographical area of the country with a maximum length and width of 777 km and 135 km. It spreads between 74°25' to 77°36' east longitudes and 8°3' to 14°24' north latitudes. The basin is bounded by Sahyadri hills on the north, by the Western Ghats on the east, by Indian Ocean on the south and by the Arabian Sea on the west (**http://india-wris.nrsc.gov.in)**. Large number of River basins are there for the area considered between South of Tadri to Kanyakumari (Fig. 1). The major part of basin is covered with agriculture accounting to 50.82% of the total area while 3.65% is covered by water bodies. Most of the Rivers are in the states of Karnataka and Kerala. Few small River basins are also there in Tamilnadu and Puducherry. The important River basins in the area are listed below.

West flowing Rivers of Karnataka

Major rivers (North to South): 1) Tadri (Agnashini); 2) Saravathi; 3) Chakra; 4) Varahi (Haladi); 5) Netravathi.

There are numerous independent small streams that directly join the Arabian Sea. They can be classified into independent catchment between the main rivers.

a. Independent catchment between Sharavathi and Chakra river.

1) Kollur River (Souparnika); 2) Ghantihole ; 3) Venkatapur ; 4) Baindurhole; 5) Shankargundi; 6) Kumbarhole; 7) Yedamavinahole

b. Independent catchment between Varahi and Netravathi river.

1) Seethanadhi; 2) Uppunda; 3) Swarna; 4) Sambhavi; 5) Udyawara; 6) Mulki river ; 7) Pavanje (Nandini); 8) Nadisalu ; 9) Gurpur (Phalguni); 10) Yennehole ; 11) Madisalhole.

West flowing Rivers of Kerala

1. Manjeswar; 2. Uppala; 3. Shiriya; 4. Mogral; 5. Chandragiri; 6. Chittari; 7. Nileswar; 8. Karingode; 9. Kavvayi; 10. Peruvamba; 11. Ramapuram; 12. Kuppam; 13. Valapattanam; 14. Anjarakandy; 15. Tellicherry; 16. Mahe; 17. Kuttiady; 18. Korapuzha; 19. Kallayi; 20. Chaliyar; 21. Kadalundi; 22. Tirur; 23. Bharathapuzha; 24. Keecheri; 25. Puzhakkal; 26. Karuvannur; 27. Chalakkudy; 28. Periyar; 29. Muvattupuzha; 30. Meenachil; 31. Manimala; 32. Pamba; 33. Achencoil; 34. Pallickal; 35. Kallada; 36. Ithikkara; 37. Ayroor; 38. Vamanapuram; 39. Mamom; 40. Karamana; 41. Neyyar

West Flowing Rivers of Tamil Nadu

1. Kodayar ; 2. Pazhayar

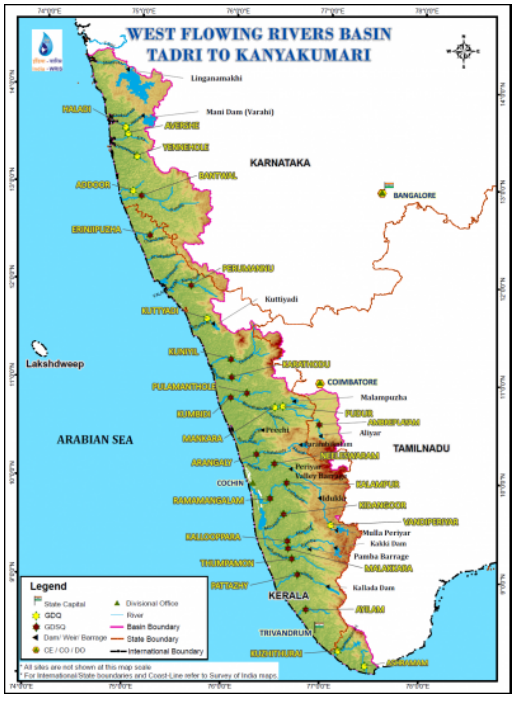

Fig. 1. West Flowing Rivers from Tadri to Kanyakumari (Ref: http://india-wris.nrsc.gov.in/)

9.2 Rainfall, Land Use Land Cover Pattern & Geology

Rainfall

Most of the River basins in the area lies in Wester Ghats which lies in the tropical South Asian monsoon tract characterized by wet summers and dry winters. The principal rain-giving seasons across the Western Ghats are the Southwest Monsoon (June - September) and Northeast Monsoon (October - November). The pre-monsoon months (March - May) account for the major thunderstorm activity in the state and the winter months (December - February) are characterized by minimum clouding and rainfall. The Western Ghats receives heavy annual rainfall ranging from 1500 to 7800 mm in its varied stretches. The total annual rainfall increases from south to north and from west to the east.

Land Use and Land Cover

There are four major forest types in the Western Ghats: evergreen, semi-evergreen, moist deciduous, and dry deciduous. With its high rainfall regime, the western slopes of the Ghats have a natural cover of evergreen forest, which changes to moist and then dry deciduous types as one comes to the eastern slopes Together the forests cover approximately 20 percent of the total area of the Western Ghats. Among the four broad vegetation types, moist deciduous forests occupy the largest area followed by semi evergreen, dry deciduous, and finally evergreen. The majority of the area under moist forest types falls within the southern states of Kerala and Karnataka. Together they account for 80 percent of the evergreen forest and 66 percent of the moist deciduous forests in the Western Ghats (IIRS, 2002).

Geology, Physiography and soil

Geologically the Ghats fall into two sections corresponding to two major categories of rock formation. The Western Ghat segment of relatively fragile rocks and flat hill tops north of the river Tadri corresponds to the basaltic lava flows of the Deccan Trap. The hills do not rise much beyond 1500 m in this tract. South of Tadri is the region of the highly varied Precambrian Archaean crystalline rocks which are much harder. The hills tend to be rounded and rise to 2000 m or more in this segment. The Western Ghats are essentially the Western edge of the Indian peninsular plateau, which is the stable mark of Archaean and Pre-Cambrian formations, where the mountain building has ceased in the Pre-Cambrian times. The Western Ghats presents an almost sheer, abrupt and straight face along its eastern edge to the south of the Palghat gap up to the Shencottah gap. Most of the exposed gneisses of the Western Ghats are 2,500 million years old. The nonmetamorphic sedimentary formations are

very rare and found only along the coastal belt (WGEEP, 2011). The Hills of the Western Ghats are generally of elevations between 600 and 1000 m. Peaks over 2000 m are found only in the mountain ranges of Nilgiris, Palanis and Anaimalais. The Western Ghats display an extremely steep western face in contrast with its more gently descending eastern slopes which proceeds to merge with the Deccan Plateau. But far in the south, the east and west slopes are equally steep but with drastically different ecological conditions (Nair, 1991). The soil mainly consists of the derivatives of the ancient metamorphic rocks in India, rich in iron and manganese (Pascal, 1988). There are seven main soil groups found in the region viz. laterites (high and low), red loam, medium black soils, hill soils, red gravelly soils, alluvial soils including coastal alluvium, mixed red and black soils. Soils vary from humus rich peat in the montane areas to laterite in the lower elevation and high rainfall belts. Soils are generally acidic. Along the coastal hills there are exposed lateritic rocks which are barren and mostly unfit for plant growth.

Table 1 gives the salient features of the study area.

Table 1: Salient Features (http://india-wris.nrsc.gov.in)

Basin Extent	
Longitude	74° 25’ to 77° 36’E
Latitude	8° 3’ to 14° 24’ N
Length of River (Km)	Many independent rivers flowing
Catchment Area (Sq.km.)	56177
Average Water Resource Potential (MCM)	113530
Utilizable Surface Water Resource(MCM)	24300
Live Storage Capacity of Completed Projects (MCM)	10236.16
Live Storage Capacity of Projects Under Construction (MCM)	1317.54
Total Live Storage Capacity of Projects (MCM)	11553.70
No. of Hydrological Observation Stations	29
No. of Flood Forecasting Stations	0

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3. Ghosh et al. (2012), Lack of uniform trends but increasing spatial variability in observed Indian rainfall extremes, *Nature Climate Change*, DOI: doi:10.1038/nclimate1327
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10. Objectives

The proposed work aims to assess the impacts of climate change on the water resources of the river basins on grid basis from Tadri to Kanyakumari. Most of the Rivers in this area are flowing to west joining Arabian Sea. The Rivers are in Kerala, Karnantaka and Tamilnadu. The details of important River basins are given in the earlier sections.

Following are the objectives of the proposed project:

- Preparation of base line data, information and past studies for the concerned River basins
- Parametric/non-parametric tests for trend detection for hydro-meteorological and hydrological variables.

- Preparation of calibrated and validated hydrological model(s) using Variable Infiltration Capacity (VIC)/ Soil and Water Assessment Tool (SWAT) models
- Study of climate change impacts on water availability at various gauging sites within the basin (in terms of change in flow duration curves) using VIC/ SWAT models,
- Study of impacts on irrigation water demands,
- Identification of hydrological extremes based on the base line data
- Study of impacts on meteorological & hydrologic droughts (in terms of change in frequencies of occurrence)
- Analysis of uncertainties in the impacts.
- The impacts and the associated uncertainties must be assessed for near-future (2015-2040) and for distant future (2040-2100), and
- Recommendations for adaptation measures/options
- Organization of Training and National Level Workshops to impart the knowledge generated and disseminate the climate change impact information to various states and central government agencies and Scientists and Engineers.

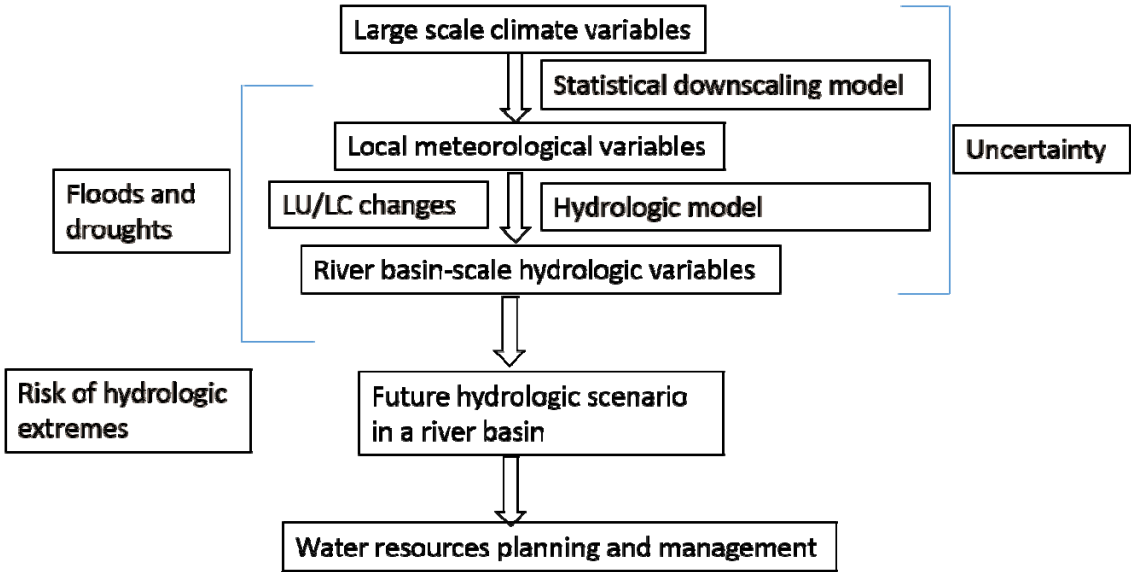

Fig. 2 Research Methodology – an Overview

11. Contribution to Water Resources Development & Management

In many organizations in India, research works have been started in full phase on assessment of impacts of climate change on water resources and on various adaptation and mitigation approaches. However, most of the studies are not comprehensive and disjoint in nature. Applications of end-to-end analyses starting with simulation of climate models to downscaling and further hydrologic modelling are only limited for few River basins in India. Several studies on the other hand consider hypothetical scenarios which may not present a realistic possibility of future, thereby necessitating the use of climate model runs in regional impact assessment studies. Through this project, we will try to achieve the following: development of extensive database for the River basins considered; climate change and impacts for the River basins considered; validation and calibration of hydrological models for future scenarios and climate change impact assessment for the basins considered. Efforts will be made to make available all the outputs and data for water resources communities for further research, impacts analysis and adaptation.

12. Putting the Research to Use

a) Identify the possible end-users for the results of proposed research.

The state and central agencies including the entire water resources community working in the field of water resources management for climate change scenarios will be the end users of the results from the proposed research. From the project output, following studies can be further carried out:

i) Water management for agricultural purposes and crop yield analysis
ii) Studies on drought and its management
iii) Flood management strategies for possible high intense rainfall
iv) Studies on future demands and optimal storage.

b) List the actions that will be necessary to put the results to use.

The research output and analysis (based on climate, meteorological and hydrologic variables) from the study will be huge. MOWR will have to take appropriate measures to keep these data and output for future use by stake holders, researchers and water

managers. The internet and web based database may be developed and made available to users.

c) List the difficulties/problems that may be encountered in putting the results to use.

- Availability of accurate data.
- Adaptability of the implementing agencies.
- Facility/ expertise of the Implementing agencies.

d) Are the possible end users being involved in the research? If yes then describe how, if not then explain why not.

Yes: Agency CWRDM, Calicut is agency in the state of Kerala to implement some of the results in Kerala State. The results, they can implement it through state level agencies. For River basins in Karnataka, the details should be given to Karnataka Irrigation Department.

13. Present State of Art

a) *Work at International Level:*

The General Circulation Models (GCMs) provide three-dimensional simulations of climate variables globally, in response to changes in the concentration of greenhouse gases in the atmosphere. GCMs might capture large scale circulation patterns and correctly model smoothly varying fields such as surface pressure, but it is extremely unlikely that these models properly reproduce non-smooth fields such as precipitation. Additionally, there is a scale mismatch between GCM simulations and hydrologic processes as the GCMs operate at very large scales. Therefore, for assessment of hydrologic implications of global climate change, scientists take resort to downscaling techniques. Methodologies to model the hydrologic variables at a smaller scale based on large scale GCM outputs are known as downscaling. The methodologies include dynamic downscaling, which uses complex algorithms at a fine grid-scale describing atmospheric process nested within the GCM outputs (commonly known as Limited Area Models or Regional Climate Models, RCM) and statistical downscaling, that produces future scenarios based on statistical relationship between larger scale climate features and hydrologic variables such as precipitation. The commonly used dynamic downscaling models are REGCM, WRF etc. In India, PRECIS, a dynamic downscaling model coupled with Hadley Climate Centre GCM is widely used. Statistical downscaling, on the other hand, focuses on deriving a statistical relationship between large scale predictors and the target hydrologic variables (predictands). Statistical downscaling techniques can fall into three categories: weather generators, weather typing and transfer functions. Weather generators (Hughes and Guttrop, 1993; Wilks, 1999) are based on complex random number generators, the output of which resembles daily weather data at a particular location. Weather typing approaches, on the other hand, involve grouping of local, meteorological variables in relation to different classes of atmospheric circulation. Future regional climate scenarios are constructed either by re-sampling from the observed variable distribution (conditioned on the circulation pattern produced by a GCM), or by first generating synthetic sequences of weather pattern using Monte Carlo techniques and then re-sampling from the generated data. The most popular approach of downscaling is the use of transfer function (Cannon and Whitefield,

2002) which is a regression based downscaling method that relies on direct quantitative relationship between the local scale climate variable (predictand) and the variables containing the large scale climate information (predictors) through some form of regression. The transfer functions can be either linear (such as multiple linear regression) or non-linear (complex learning techniques such as Artificial Neural Networks and Support Vector Machines) in nature. In statistical downscaling approaches, it is assumed that the relationship between the predictors and the predictand remains unchanged in future. Typically, statistically downscaled large scale climate variables are used as input to hydrologic models which in turn simulate regional hydrologic variables of interest, such as runoff and soil moisture.

b) Work at National Level:

Studies focussing on the Indian region are either mostly limited to using PRECIS output in SWAT (Gosain et al., 2006) or direct single site downscaling (Ghosh and Mujumdar, 2007, 2008; 2009), without any 'end to end' research and development. There are some river basin scale hydrologic models based on Soil and Water Assessment Tool (SWAT), which consider PRECIS output for future projections, but none of them are for near term future (2010-2040) which may be of immediate interest. Moreover, the present generation of climate models are forced with radiative forcings instead of concentrations of carbon-dioxide, thereby necessitating updating of impact analyses.

c) Difference of the Proposed Work from Earlier Works:

Scientific research efforts indeed seem to have increased as far as regional hydrologic impacts of climate change are considered. However, efforts to simulate climate, hydrologic and meteorological variables for near future seem rare and subsequent availability of the research output for follow-on researchers is limited. Furthermore, many scientific questions remain unresolved, such as, identifying the effects of sea surface temperature changes, orography and land use change on rainfall trend, requirements of finer resolution climate models or regional climate models, etc. Earlier efforts pertaining to this topic appear only a routine work of either using dynamic downscaling model output in river basin hydrologic water quality quantity model or development of statistical downscaling relationships with some uncertainty quantification. Extensive research works either on understanding the geophysics using

multiple climate run experiments or use of rigorous statistics and data driven models for river basin scale finer resolution climate simulation are lacking. The proposed study aims at addressing these specific research issues and focuses on ensured availability of research outputs available for follow-on works or for direct use by water managers.

d) References:

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14. Methodology

As per the discussion and information given by Ministry of Water Resources, the downscaled data for the considered River basins will be made available through another project. Based on this, the overall methodology to be adopted in the present study is given in Fig. 2. The methodology adopted for the present project has been considered into four parts:

Part A) Database Management - Data collection, Analysis and Database Development
B) Hydrologic Simulation - Modeling, Calibration and Validation
C) Climate Change Assessment o
D) Climate Change Impacts-Analysis and Adaptation

Based on above, a brief overview of all the works with their sub-themes and responsibilities to each participating Institutions are described below:

A) Data Base Management - Data Collections, Analysis and Database Development

A1. Data Collection and Compilation (IITB, NITK & CWRDM):

This part includes collection of hydrologic and meteorologic data (historical) of the river basin and compilation in proper format to make it usable for the participating institutes and different stakeholders in the basins. CWC and MoWR will facilitate collection of all data including hydrological data from IMD, discharge/flow data, LULC data, soil data, and project specific data. NITK will take lead to collect data for the Karnataka region and CWRDM will take lead to collect data from Kerala region. IIT Bombay will coordinate all efforts in data collection.

A2. Data Analysis (IITB, NITK & CWRDM):

This part includes analysis of patterns and trends of the historical data, data driven approaches to understand the geophysical processes associated with changing climate. All

relevant baseline data, information and past studies available on the particular river basin will be collated in the project. For the Kerala region, CWRDM will take the lead and for Karnataka region, NITK will take the lead. IITB will collate all information.

A3. Development of Database (IITB, NITK & CWRDM):

From the collected and collated data, Database for the respective River basins will be developed, together by all participating Institutes. Some of the important database include: meteorological data, toposheets, landuse, landcover, hydro-geological data, Digital Elevation Model etc.

B) Hydrologic Simulation – Modeling, Calibration and Validation

B1. LULC change detection and projections (IITB, NITK, CWRDM):

This work will be done either grid wise/ river basin wise. Changes in the Land Use and Land Cover (LULC) have significant impacts on hydrologic scenarios. In the project, the changes in LULC will be assessed over the river basins and their impacts on hydrologic processes. Remote sensing images will be used for change detection. Future land use scenarios will be generated with geo-spatial techniques which will be further used for future hydrologic scenario generation. Efforts will also be made to quantify the impacts of LULC changes on micro-climate.

B2. Hydrologic Modeling with Variable Infiltration Capacity Model (VIC) (IITB):

Variable Infiltration Capacity (VIC) model (Liang et al., 1994; 1996), a grid based model will be used for hydrologic simulation. Depending upon availability of data, we plan to use the model at 0.5/0.25 degree spatial resolution and daily time step. Based on CWC/ MOWR observed stream flow data, the calibration and validation of the VIC model will be carried out at daily/ weekly/ monthly. After calibration, the model will be evaluated at various locations based on the availability of the observed stream flow. Further, this hydrologic modelling framework will be used for the development of hydrologic scenarios under the projected future climate. Hydrologic scenarios for the projected future climate for the River basins will be generated for the three periods: near term (2015-2039); midterm (2040-2069), long term (2070-2099). Based on this, changes in soil moisture, surface and sub-surface runoff, evapotranspiration, and streamflow will be assessed under the projected climate. Further attempt will be done to carry out drought and flood analyses.

B3. Hydrologic Modeling with Soil Water Assessment Tool (SWAT) (NIT K, CWRDM)

Further we will also use Soil Water Assessment Tool (SWAT) for hydrologic modeling, with the climate forcing for generation of hydrologic scenarios. The modeling will involve calibration for model parameters and the uncertainty. The SWAT simulated hydrologic variables will be used for impacts assessment.

C) Climate Change Impact Assessment *(IITB, NITK, and CWRDM):*

Using the various scenarios generated based on the hydrological modeling mentioned above, impacts of climate change will be assed. The hydrologic scenarios will be developed for the three periods: near term (2015-2039); midterm (2040-2069), long term (2070-2099). For the projected climate change scenarios, changes in soil moisture, surface runoff, evapotranspiration, and stream flow etc will be assessed. We will also develop scenarios for the frequency and severity of hydrologic extremes (drought and floods).

D) Climate change Impacts - Analysis and Adaptation

D1. Uncertainty Modeling (IITB):

Assessing impacts of climate change on river basin hydrologic processes is characterized by uncertainty at different stages such as:

i) Uncertainty resulting from multiple GCMs
ii) Uncertainty resulting from multiple hydrologic models
iii) Uncertainty resulting from parameter variations of hydrologic models

Assessment of uncertainty will be carried out using appropriate models for all possible scenarios.

D2. Hydroclimatic Extremes and Risk Assessment (IITB, NITK & CWRDM):

An attempt will be made to analyze the changes in hydrologic extremes (droughts and floods). For the drought analysis, we will consider meteorological, hydrological, and agricultural droughts using the standardized precipitation index (SPI) The drought analysis will be mainly done for the monsoon season (JJAS). For the flood analysis, the results obtained from VIC/SWAT will be analyzed.

D3. Water Demand Availability Analysis (IITB, NITK, CWRDM):

For the River basins considered, the future hydrologic scenario will provide the water availability information. The water demand information will be derived from projected demographic information. Detailed water demand availability analysis will provide information for storage requirements and sustainable water management policies.

15. Cost Estimates:

Institute	**Amount (INR)**
Indian Institute of Technology Bombay	Rs. 1,28,46,372/-
National Institute of Technology Surathkal	**Rs. 65,67,792/-**
CWRDM, Kozhikode	**Rs. 65,67,792/-**
Total	Rs. 2,59,81,956/-

IIT Bombay

Total Cost of the project including over head charges (if any): INR 1,28,,46,372

15.1 Subhead wise Abstract

Subhead	Amount (Rs.)
Salary	**55,22,400/-**
TE	600,000
Infrastructure/Equipment	40,00,000
Organization of training course/ workshops for all related projects at IIT Bombay (3 numbers)	Rs. 10,00,000/- (First year: Rs. 4 Lakhs; Second Year: 3 Lakhs; Third year: 3 Lakhs)
Sub Total	Rs. 1,11,22,400/-
Add Contingency 5%	Rs. 5,56,120/-
Total	Rs. 1,16,78,520/-
Institutional over heads (as per norms subject to total Rs 15,00,000/-)	Rs. 11,67,,852/-
Grand Total	Rs.1,28,46,372/-

(*Note:* ***In this table of abstract, it is not necessary to indicate year wise provisions. The release of funds will be tied down with milestones of progress and not with passage of time)***

15.2 Justification for Institutional Over Head charges.

Institutional overhead charges are required for infrastructural facility and maintenances.

15.3 Amount sought to be released at the start of the work with justification.

To start the work the first year funding may be released.

15.4 Subheads wise Details

Salary

Designation	Year 1			Year 2			Year 3		
	Rate/ Month	Month	Amount	Rate/ Month	Month	Amount	Rate/ Month	Month	Amount
3 no. of JRF/ RAs lead to Ph D (M.Tech/ MS)	25,000 pm/ head + 30% HRA	12	11,70,000	25,000 pm/ head + 30% HRA	12	11,70,000	28,000 pm/ head + 30% HRA	12	13,10,400
*1 RAIII (Qua:Ph. D. or M.Tech with 3years exper.)	40,000 pm/ head + 30% HRA	12	6,24,000	40,000 pm/ head + 30% HRA	12	6,24,000	40,000 pm/ head + 30% HRA	12	6,24,000
Totals			17,94,000			17,94,000			19,34,400

* Candidate with Ph.D. will be considered for RAIII (Postdoctoral Fellow). Otherwise, candidate with M.Tech and 3 years research experience will be considered.

Grand Total for Salary: Rs. 55,22,400/-

15.5 Man- months utilisation table

RAIII/ Postdoc: 36 Months

The RAIII/ Postdoc will be overall coordinating the project between various Institutions and JRFs. He/ She will look after the progress of the work, accounts and will contribute in the developmental works of database and hydrological and climate models.

JRF/RA-1

Months	Activities
1-6	Literature Review
7-9	Selection of predictors
10-19	Input data preparation
20-21	Parallel computing setup for running hydrologic models
22-30	Hydrologic modelling
31-33	Uncertainty Modeling
34-36	Report writing

JRF/RA2

Months	Activities
1-3	Collecting of Downscaled Outputs
4-9	Analysis of observed data
10-12	Evaluation of GCMs
13-18	LULC change detection
19-21	LULC projections
22-27	Analysis of extremes
28-30	Water demand availability analysis
31-33	Analysis of water quality
34-36	Report writing and compilation of products (data)

JRF/ RA-3

Months	Activities
1-3	Literature Review
4-9	Population Projections
10-12	Water Demand and Availability Analysis

13-18	Storage requirement analysis
19-21	Reservoir operation for near future
22-27	Extreme value analysis
28-30	Future Extremes projections
31-33	Assessment of risk to water resources management
34-36	Report writing and compilation of products (data)

15.6 Travel Expenditure (TE): Rs 6,00,000/-

S. No.	Particulars	Year I	Year II	Year III	Total
A	Attending the review meeting	60000	60000	60000	180000
B	Conference	90000	90000	90000	270000
C	Data Collection	50000	50000	50000	150000
	Total				600000

15.7 Infrastructure (Purchased items of a permanent nature like equipment, software or data; construction of any buildings etc.)

Sl. No.	Equipment	Quantity	Cost (Rupees)	Proposed year of purchase
1	Software (Erdas, MIKEBASIN, GMS, WMS)	1	15,00,000	1st
2	Workstation (1)/ PCs (4)/ Laptops (4)	9	4,50,000	1st
3	Apple Mac Pro 12 cores machine for VIC run	1	3,50,000	1st
4	Data (Satellite and meteorologic data, to be shared		15,00,000	1st

	with other team members)			
5	Consumables		2,00,000	1st, 2nd and 3rd
	Total		40,00,000	

15.8 Organization of training course/ workshops

Rs. 10,00,000/- for all related projects at IIT Bombay (3 numbers)
(First year: Rs. 4 Lakhs; Second Year: 3 Lakhs; Third year: 3 Lakhs)

This is required for organization of Training and National Level Workshops to impart the knowledge generated and disseminate the climate change impacts to various states and central government agencies and Scientists and Engineers.

NIT Surathkal

Budget

Subhead	**Amount (Rs.)**
Salary	22,46,400
Travelling Expenses	4,24,000
Infrastructure/Equipment	3,00,000
Experimental Charges	27,16,000
Sub Total	**56,86,400**
Add Contingency 5%	2,84,320
Total	**59,70,720**
Institutional over heads (as per MOWR, upto maximum of 20% of project budget or Rs 5,00,000/- whichever is less)	5,97,072
Grand Total	**65,67,792**

Details of Budget

(i) Salary

Two Junior Research Fellows (M.Tech Qualifications) with a salary of Rs. 25,000 + HRA (20%) for a period of two years. 2x (25000+0.2×25,000) ×2years×12 months + 2(28000+0.2×28,000) ×12 =**Rs. 22,46,400**

(ii) Travel Expenses

The project involves significant collaborative effort among the partner Institutions. It requires frequent domestic travel to attend the interactive meetings among the partner Institutions. The travel expenses will also be used to attend seminars and conferences to disseminate the preliminary results and obtain feedback. The project also requires field visit to discuss with the field staff in various projects located in the basin.

Travel expenses to attend meetings of the Project Coordination team:

2 travels per year × 3 years × 2 persons (@Rs 12000 per person per trip) = Rs. 1,44,000

Travel expenses for field visits:

10 trips × 2 persons (@ Rs. 6000 per trip per person) = Rs. 1,20,000

Travel expenses for organising workshop:

One workshop with 20 participants @ Rs. 8000 per participant = Rs. 1,60,000

Total Travel Expenses: = **Rs. 4,24,000**

(iii)Infrastructure/ Equipment

The project needs dedicated fast computing facilities for successful and timely completion of the project. All the project staffs need to be provided with computers and accessories.

Two laptops and other accessories = Rs. 1,50,000

One workstation = Rs. 1,50,000

Total = **Rs. 3,00,000**

(iv)Experimental Charges

Secretarial Assistance for the period of 3 years (@Rs. 6000 per month): = Rs. 2,16,000
Consumables and contingencies: = Rs. 2,00,000
Acquisition of hydrological data, toposheets and other relevant data from different agencies: =Rs. 8,00,000
Satellite Imageries: =Rs. 10,00,000
Creation of GIS layers (Creation/Outsourcing/Acquisition): = Rs. 4,00,000
Expenditure for organising workshop: = Rs. 1,00,000
Total: =**Rs. 27,16,000**

CWRDM Kozhikode

Budget

Subhead	**Amount (Rs.)**
Salary	22,46,400
Travelling Expenses	4,24,000
Infrastructure/Equipment	3,00,000
Experimental Charges	27,16,000
Sub Total	**56,86,400**
Add Contingency 5%	2,84,320
Total	**59,70,720**
Institutional over heads (as per MOWR, upto maximum of 20% of project budget or Rs 5,00,000/- whichever is less)	5,97,072
Grand Total	**65,67,792**

Details of Budget

(i) Salary

(ii) Two Junior Research Fellows (M.Tech Qualifications) with a salary of Rs. 25,000 + HRA (20%) for a period of two years. 2x (25000+0.2×25,000) ×2years×12 months + 2(28000+0.2×28,000) ×12 =**Rs. 22,46,400**

(iii)Travel Expenses

The project involves significant collaborative effort among the partner Institutions. It requires frequent domestic travel to attend the interactive meetings among the partner Institutions. The travel expenses will also be used to attend seminars and conferences to disseminate the

preliminary results and obtain feedback. The project also requires field visit to discuss with the field staff in various projects located in the basin.

Travel expenses to attend meetings of the Project Coordination team:

2 travels per year × 3 years × 2 persons (@Rs 12000 per person per trip) = Rs. 1,44,000

Travel expenses for field visits:

10 trips × 2 persons (@ Rs. 6000 per trip per person) = Rs. 1,20,000

Travel expenses for organising workshop:

One workshop with 20 participants @ Rs. 8000 per participant = Rs. 1,60,000

Total Travel Expenses: = **Rs. 4,24,000**

(iv) Infrastructure/ Equipment

The project needs dedicated fast computing facilities for successful and timely completion of the project. All the project staffs need to be provided with computers and accessories.

Two laptops and other accessories = Rs. 1,50,000

One workstation = Rs. 1,50,000

Total = **Rs. 3,00,000**

(v) Experimental Charges

Secretarial Assistance for the period of 3 years (@Rs. 6000 per month): = Rs. 2,16,000

Consumables and contingencies: = Rs. 2,00,000

Acquisition of hydrological data, toposheets and other relevant data from different agencies: =Rs. 8,00,000

Satellite Imageries: =Rs. 10,00,000

Creation of GIS layers (Creation/Outsourcing/Acquisition): = Rs. 4,00,000

Expenditure for organising workshop: = Rs. 1,00,000

Total: =**Rs. 27,16,000**

16. Work Schedule

a) **Probable Date of Commencement:** From the date of acceptance

b) **Duration of Study:** 3 Years

c) Project Implementation Stages

Activities	Months											
	0 to 3	4 to 6	7 to 9	10 to 12	13 to 15	16 to 18	19 to 21	22 to 24	25 to 27	28 to 30	31 to 33	34 to 36
A. Data Base Development												
A1 Data Collection and Collation												
A2 Data Analysis												
A3 Development of Database												
B Hydrologic Simulation												
B1 a LULC Analysis												
B1b LULC Projection												
B2a. VIC Model – Data preparation												
B2b. VIC Model Calibration												
B2c. VIC Simulation for Observed Condition												
B2d. VIC Runs for Future Scenarios												
B3a. SWAT Model - Data Preparation												
B3b. SWAT Model Calibration												
B3c. SWAT Simulation for Observed Condition												
B3d. SWAT Runs for Future Scenarios												
C1. Climate Change Impact Assessments												
C1a. Short/ Middle term projection												
C1b. Long term projection												
D Climate Changes Impacts												
D1 Uncertainty Analysis												
D2 Hydro-climatic extremes and risk analysis												
D3. Water Demand -availability analysis												
E Report Writing and Output Preparation												

d) Declaration

1. I have carefully read the terms and conditions of the research grant and I agree to abide by them.

2. This is to certify that I have neither submitted this proposal elsewhere for financial support nor have undertaken it at the request of any commercial agency) or as a consultancy.

Date: 24 August 2015

Time 17:00 Hours

Signature of PI

Dr. Eldho T.I.

Endorsement forms from the Head of the institutions

(attached below)

प्राध्यापक-PROFESSOR
सिविल अभियांत्रिकी विभाग
Department of Civil Engineering
भारतीय प्रौद्योगिकी संस्थान मुंबई
Indian Institute of Technology Bombay
Powai मुंबई/Mumbai- 400 076 INDIA

भारतीय प्रौद्योगिकी संस्थान मुंबई
पवई, मुंबई - 400 076, भारत
Indian Institute of Technology Bombay
Powai, Mumbai - 400 076, India

दूरभाष/Phone : (+91-22) 2572 2545
फैक्स/Fax : (+91-22) 2572 3480
वेबसाईट/Website : www.iitb.ac.in

IIT Bombay

Endorsement from the Head of Institution

Project Title: Impacts of Climate Change on Water Resources in River Basins from Tadri to Kanyakumari

1. The Institute welcomes the participation of **Prof. T I Eldho** from Dept. of Civil Engineering as the Principal Investigator and Prof. Subimal Ghosh, Prof. RAAJ Ramsankaran and Dr. Arpita Mondal from Dept. of Civil Engineering and Prof. Subhankar Karmakar from Centre for Environmental Science & Engg., IIT Bombay as the Principal Co-Investigator for the above project and that in the unforeseen event of discontinuance by the Principal Investigator, the Principal Co-Investigators will assume the responsibility of the fruitful completion of the project (with due information to MoWR).

2. The necessary equipment and institutional support as described in item 15.2 will be made available as and when required for the purpose of the project to ensure that the work is taken upto on priority and completed on schedule.

3. The Registrar of permanent and semi-permanent assets acquired out of grants from MoWR will be maintained in Form GFR-19.

Date: August 18, 2015
Place: Mumbai

Signature of Head of Institution
Name: Prof. Krishna P. Kaliappan

सह. संकायाध्यक्ष, शोध एवं विकास
Associate Dean, Research and Development
कृते निदेशक, आय आय टी मुंबई
For Director, IIT Bombay

Annexure-2

Endorsement from collaborating Institution/Agency

I have gone through the Research proposal entitled "**Impact of Climate Change on Water Resources in River Basins from Tadri to Kanyakumari**" submitted byProf.AmaiMahesha(Name of PI) of Department of Applied Mechanics & Hydraulics, N.I.T.K., Surathkal (Name of the collaboratingInstitution/Agency)for MoWR funding and noted the obligations and responsibilities indicatedin our name which are as below:

a. Proposed activities of research work (list activities):The major research activities include Preparation of base line data, information and past studies for the concerned RiverBasins, Parametric/non-parametric tests for trend detection for hydro-meteorological and hydrological variables,Preparation of calibrated and validated hydrological model(s) using Variable Infiltration Capacity (VIC)/ Soil and Water Assessment Tool (SWAT) models,Study of climate change impacts on water availability at various gauging sites within the basin (in terms of change in flow duration curves) using VIC/ SWAT models

b. Estimated cost for the proposed activities (mention amount in Rs.)

Subhead	Amount (Rs.)
Salary	22,46,400
Travel Expenses	4,24,000
Infrastructure / Equipment	3,00,000
Experimental Charges	27,16,000
Sub Total	**56,86,400**

c. Share of Overhead charges and Contingency(Taken together)

Add Contingency 5%	2,84,320
Institutional overheads (10%)	5,97,072
Grand Total	**65,67,792**

I hereby affirm that my organization is committed to participate in theresearch scheme to the full extent with above mentioned obligations andresponsibilities.

18/08/2015

(Head of the collaborating Institution/Agency)
Dean (Planning & Development)
National Institute of Technology Karnataka
Surathkal, Post Srinivasnagar
MANGALORE-575025

Seal/Stamp

CENTRE FOR
WATER
RESOURCES
DEVELOPMENT AND
MANAGEMENT
An Institution of the Kerala State Council for Science, Technology and Environment, Government of Kerala

CWRDM

Ref: GMD/CWRDM/ R&D/MOWR/8-2015 Date: 12.08.2015

Endorsement from the Head of Institution

Title of the Project: " Impact of Climate Change on Water Resources in River Basins from Tadri to Kanyakumari"

I have gone through the research project entitled 'Impact of Climate Change on Water Resources in River Basins from Tadri to Kanyakumari' submitted by Dr Dinesan V P jointly with Prof. Eldho T I, IIT Bombay and Dr. A Mahesha , NIT, Surathkal for MoWR funding and noted the obligations and responsibilities (jointly with the Collaborating Institutions IIT Bombay, NIT, Surathkal and CWRDM, Calicut) indicated in our name which are as below.

a. Data collection, Analysis and Database Development
b. Hydrologic Modelling
c. Assessment of Climate Change Impacts
d. Impact Analysis and adaption

Estimated cost for the proposed activities : Rs.65,67,792/-
Share of Overhead and Contingency charges (Taken together) : Rs 8,81,392/-

I hereby affirm that my organization is committed to participate in the research scheme to the full extent with above mentioned obligations and responsibilities.

Head of the Collaborating Institution

Dr. NB Narasimha Prasad,
Executive Director i/c
CWRDM
Kunnamangalam. P.O
Kozhikode 673 571, Kera

Place: Calicut
Date: 12 August 2015

Ph: 91-495-2351800, 2351801, Fax: 91-495-2357827, 2351808 Website: www.cwrdm.org
KUNNAMANGALAM, KOZHIKODE, PIN - 673 571 KERALA (INDIA)

Brief Bio-Data of PI

Name	**ELDHO T.I.**
Nationali**t**y	Indian
Present position	Professor, Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai 400 076.
Mailing address	Dr. Eldho T.I., Professor, Department of Civil Engineering, Indian Institute of Technology, Bombay Powai, Mumbai, 400 076, INDIA. Phone.: 022-2576-7339 (Off.), 022-2576-8339 (Res.) Fax: 022-2576 7302 Email: eldhoti@yahoo.com; eldho@civil.iitb.ac.in
Date of birth	May 20, 1966

Academic Qualification:

B.Tech Civil Engineering (M.G. University, Kerala, 1988)
M.Tech Civil Engg. – Water Resources (I.I.T. Bombay, 1992)
Ph.D. Civil Engg. – Water Resources (I.I.T. Bombay, 1995)

Field of Specialization: Water Resources and Environmental Engineering

Professional Experience:

1. 2009 March – Present — Professor, Dept. Civil Engineering, IIT Bombay

2. 2005 March – February 2009 — Associate Professor, Department of Civil Engineering, IIT Bombay

3. 2001 May – February 2005 — Assistant Professor, Department of Civil Engineering, IIT Bombay

4. 2000 Aug. – 2001 May — Assistant Professor, Department of Civil Engg., IIT Khragpur, India

5. 1999 Feb.– 2000 Aug. — Senior Postdoctoral Scientist
Hydrotech Research Institute, National Taiwan University, Taipei, Taiwan

6. 1998 July– 1999 Jan. — Water Resources Planner and Modeler (Scientist)
Mott MacDoanld International, Cambridge, UK.

7. 1996 Jan.- 1998 June — Postdoctoral Scientist
Institute for Hydromechanics, University of Karlsruhe, Germany

8. 1995 (July-December) — Lecturer, Bombay University (SPCE), India

9. 1990 – 1995 — Research and Teaching Assistant, Department of Civil Engineering, Indian Institute of Technology, Bombay

Recognition of Achievements by Awards/Prizes:

a) Gold medal for first position in SSLC examination in the school (1981)
b) Govt. of India - National Merit Scholarship for higher studies (1981-88)

c) Govt. of India - GATE Scholarship for Postgraduate studies (1990-92)
d) Govt. of India - Research Scholarship for Ph.D. studies (1992-95)
e) German Research Fellowship (DFG) for Postdoctoral research (1996-98)
f) Taiwan National Science Council Fellowship for Postdoctoral research (1999-2000)
g) **Best poster paper award of the 2002 Stockholm Water Symposium**. Stockholm, Sweden. 12-15th.08. 2002 (with Mr. Anupam K. Singh & F. Nestmann)
h) DAAD Fellowship for research in Germany, 2007.
i) SIWI Fellowship for World Water Week, 2005, 2007.
j) Certificate of Merit Award by The Institution of Civil Engineers for the paper published in the Journal of Institution of Engineers (India) entitled "Hydrodynamics Modeling of Estuaries Using an Implicit Finite Element Model", 2006-2007
k) Best research paper award: 2011 – ISH Journal of Hydraulics Engineering

Journal Editorship

- Associate Editor of International Journal of Ecology and Development.
- Associate Editor of ISH Journal of Hydraulic Engineering.
- Chief Editor of the Journal "International Journal of Water Resources and Environmental Management" Research Science Press (India).

Research Projects/ Theses Supervised:

No. of Doctoral Theses Guided –	14
Presently Guiding/ co-guiding	12
No. of M.Tech Theses Guided	35
Presently Guiding/ co-guiding	2
No. of B.Tech Projects Guided	25

No. of International Projects Completed	7
No. of Research Projects Completed in India/ongoing	9
No. Consultancy Projects Completed in India	60

Number of Publications

1. Text book published : 2
2. Video Courses : 2
3. Refereed Journal papers : 119
4. Book Chapter : 6
5. International Conference papers : 134
6. National Conferences : 72
7. Monographs/ Lecture notes : 26
8. Technical Reports – Sponsored : 11
9. Technical report – Industrial/ consultancy: 78

Resume of Co-PIs

SUBIMAL GHOSH (PhD, IISc, 2007)
Assistant Professor **Office: +91 22 2576 7319; Fax: +91 22 2576 7302**
Department of Civil Engg., **Mobile: +91 99306 63969**
Indian Institute of Technology, Bombay **E-Mail: subimal@civil.iitb.ac.in**
Mumbai – 400 076, India. **subimal.ghosh@gmail.com**

EMPLOYMENT

Assistant Professor in Department of Civil Engineering, IIT Bombay from 16th November, 2007.

RESEARCH GUIDANCE

PhD Student: 1 (thesis submitted), 6 (ongoing)
Masters Student: 2 (completed), 1 (ongoing)

SPONSORED RESEARCH PROJECTS (AS PRINCIPAL INVETIGATOR)

1. Assessing Impact of Climate Change on Indian Subdivisional Rainfall, Funding Agency: IRCC, IIT Bombay. [2007-2010, Completed]
2. Multi-site Statistical Downscaling using Copula for Climate Change Impact Assessment on Hydrology, Funding Agency: Department of Science and Technology. [2008-2011, Completed, Final report pending, rated as "Excellent"]
3. Assessing Impacts of Global and Local Changes on River Basin Scale Hydrology, Funding Agency: Space Technology Cell, IITB-Indian Space Research Organization (ISRO). [2009-2012, On-going]
4. Downscaling for Projections of Indian Rainfall and Temperature at high spatial Resolution, Funding Agency: Space Application Centre, Indian Space Research Organization (ISRO). [2011-2012, Completed]
5. Impacts of Global and Local Changes on the Rainfall in a Metro City, Funding Agency: Ministry of Water Resources, Govt. of India. [2011-2014, on-going]

PUBLICATIONS (10 SIGNIFICANT)

1. Subimal Ghosh, Das, D., Kao, S-c and Ganguly, A. (2012), Lack of uniform trends but increasing spatial variability in observed Indian rainfall extremes, Nature Climate Change
2. Kannan, S. and Subimal Ghosh (2011), Prediction of daily rainfall state in a river basin using statistical downscaling from GCM output, Stochastic Environmental Research and Risk Assessment, Springer. DOI 10.1007/s00477-010-0415-y
3. Subimal Ghosh (2010), SVM-PGSL coupled approach for statistical downscaling to predict rainfall from GCM output, Journal of Geophysical Research, 115, D22102, doi:10.1029/2009JD013548.
4. Kashid S, Subimal Ghosh and Maity R. (2010), Streamflow prediction using multi-site rainfall obtained from hydroclimatic teleconnection, Journal Of Hydrology, 395, pp 23-38, doi:10.1016/j.jhydrol.2010.10.004
5. Subimal Ghosh (2010), Modelling bivariate rainfall distribution and generating bivariate correlated rainfall data in neighbouring meteorological subdivisions using copula, Hydrological Processes, 24, 3558-3567
6. Subimal Ghosh, Luniya, V. and Gupta, A. (2009), Trend Analysis of Indian Summer Monsoon Rainfall at Different Spatial Scales, Atmospheric Sciences Letter, Royal Meteorological Society, 10(4), pp. 285-290

7. Subimal Ghosh and P. P. Mujumdar (2009), Climate Change Impact Assessment-Uncertainty Modeling with Imprecise Probability, Journal of Geophysical Research- Atmosphere (AGU), 114, D18113, doi:10.1029/2008JD011648
8. Mujumdar, P. P., and S. Ghosh (2008), Modeling GCM and scenario uncertainty using a possibilistic approach: Application to the Mahanadi River, India, Water Resources Research, 44, W06407, doi:10.1029/2007WR006137.
9. Subimal Ghosh and P. P. Mujumdar (2008), "Statistical Downscaling of GCM Simulations to Streamflow using Relevance Vector Machine", Advances in Water Resources, 31(1), pp. 132-146.
10. Subimal Ghosh and P. P. Mujumdar, (2007), "Nonparametric Methods for Modeling GCM and Scenario Uncertainty in Drought Assessment", Water Resources Research, AGU, 43, W07405, doi:10.1029/2006WR005351.

AWARDS AND RECOGNITIONS

1. Reviewer of IPCC AR5 WG II Report
2. Editorial Board Member of The Scientific World Journal
3. Young Scientist Award 2012 from Indian National Science Academy (INSA) in "Engineering and Technology"
4. Young Investigator Award 2012 from Industrial Research & Consultancy Centre, Indian Institute of Technology Bombay, Mumbai
5. Indian National Academy of Engineers (INAE) Young Engineer Award 2011.
6. Institute of Engineers (India) Young Engineer (Civil) Award 2011
7. The outstanding reviewer award for Journal of Hydrologic Enginnering, American Society of Civil Engineers (ASCE), 2010.
8. BOYSCAST Fellowship (2009-10) from Department of Science and Technology, to work in Oak Ridge National Laboratory, TN, US
9. Indian Science Congress Association Young Scientist Award for 2009-2010 in "Engineering Sciences"
10. Prof. N S Govinda Rao Medal Best Ph. D. Thesis Award 2007 from Department of Civil Engineering, Indian Institute of Science, Bangalore.
11. Fast Track Project Grant for Young Scientists from Science and Engineering Research Council (SERC), Department of Science and Technology (DST), India (2007)

Subhankar Karmakar

Assistant Professor Centre for Environmental Science and Engineering Indian Institute of Technology Bombay Powai, Mumbai 400076, INDIA

EDUCATION

Doctor of Philosophy (2006) : Water Resources and Environmental Engineering, Department of Civil Engineering, Indian Institute of Science, Bangalore, India, (Doctoral Advisor –Prof. P.P. Mujumdar)

Bachelor of Engineering (1998) : Department of Civil Engineering, North Bengal University, India,

APPOINTMENTS

Assistant Professor (Dec 2007 -till date) : Centre for Environmental Science and Engineering, Indian Institute of Technology, Bombay, India,

Visiting Scholar (June 2010 -Oct 2010): Nicholas School of the Environmental, Duke University, Durham, North Carolina, USA.

Post-Doctoral Fellow (Nov, 2006 -Nov, 2007) : Department of Civil and Environmental Engineering, The University of We stern Ontario, Canada . (Post Doctoral Advisor -Prof. Siobodan p, Simonovic)

RESEARCH PROJECTS AND GRANTS

- IIT Bombay Seed Grant Project *(Principal Investigator);* Title -Uncertainty modeling in waste load allocation for a river system; Duration 2008 -2012 (Ongoing),
- Organization for Economic Co-operation and Development (OECD) project *(Co-Principal Investigator);* Title -Flood Vulnerability Assessment of Mumbai City; Duration 2009 -2010 (Completed),
- Department of Science and Technology, Govt. of India *(Principal Investigator);* Multivariate Flood Frequency Analysis: Nonparametric Approach; Duration 2011-2014 (Ongoing),
- Thane Municipal Corporation; Maharashtra Govt. *(Principal Investigator);* Evaluation of Trophic States of Lakes in Thane City; Duration 2012 -2015 (Ongoing)

SELECTED JOURNAL PUBLICATIONS

1 Subhankar Karmakar (2011) "Propagation of Uncertainties in Water Distribution Systems Modeling," Desalination and Water Treatment, 33 (1-3), pp, 107-117.

2 Subhankar Karmakar, S,P, Simonovic, A. Peck, and J. Black (2010) "An information system for risk-vulnerability assessment to flood," Journal of Geographic Information Systems, 2(3), 129-146.

3 Praveen Kumar Mishra, Rama Shankar Prasad and Subhankar Karmakar (2010) "Infrastructure Vulnerability Assessment of Mumbai City to Natural Hazards," JI. of Disaster Advances, 3(2) 7-17, 33.

4 L Subhankar Karmakar and p, p, Mujumdar (2010) "An Application of Grey Integer Programming in Floodplain Planning", Journal of Flood Engineering, Vol, 1 (2), pp, 185· 200.

5 L, Subhankar Karmakar and Slobodn P Simonovic (2009) "Bivariate flood frequency analysis, Part 2: a copula based approach with mixed marginal distributions" D0I:10,1111/j.17S3-318X,200901020,x), Journal of Flood Risk Management (Pub: Blackwell Publishing, UK), 2(1), 1-13.
6 Subhankar Karmakar and Siobodan P Simonovic (2008) "Bivariate flood frequency analysis: Part 1, Determination of marginals by parametric and nonparametric distributions" (001: 10.1111/j,17S3-318X,2008,00022,x), Journal of Flood Risk Management, 1(4), 190-200.
7 Subhankar Karmakar and P. p, M ujumdar (2007) "A two-phase grey fuzzy optimization approach for water quality management of a river system", Advances in Water Resources (Pub: Elsevier, Netherlands), Vol, 30 (5), 1218 -1235.
8 Subhankar Karmakar and P. P, Mujumdar (2006) "Grey fuzzy optimization model for water quality management of a river system", Advances in Water Resources (Pub: Elsevier, Netherlands), Vol. 29 (7), 1088 -1105.
9 Subhankar Karmakar and p, p, Mujumdar (2006) "An inexact optimization approach for' river water quality management", Journal of Environmental Management (Pub: Elsevier, Netherlands), Vol. 81 (3), 233 -248,

ACADEMIC HONORS

- BOYSCAST Fellowship 2009 -2010 from Dept. of Science and Tech., Govt., of India ,
- Fast Track Project Grant for Young Scientists from Science and Engineering Research Council (SERC), Department of Science and Technology (DST), India (2010)
- Post-doctoral fellowship for November 2006 -November 2007 from Department of Civil and Environmental Engineering, The University of Western Ontario, London, Ontario, Canada.
- Recommendation for the Upgradation of Registration from Masters to Ph, 0, degree programme by the Senate Committee, Indian Institute of Science, Bangalore, with the effect from 30th October 2002, decided on academic excellence basis

COURSES TAUGHT (2008·2011)

(1) Mathematics Foundation, (2) Environmental Studies (UG course, strength 600+), (3) Environmental Science and Engineering (PG Institute elective, strength 70+), (4) GIS for Environmental Planning and Management, (5) Environmental Systems Modeling, (6) Environmental Monitoring Laboratory, (7) Environmental Computation Laboratory, (8) Environmental Management,
(9) Water Resources and Open Channel Flow,

STUDENTS AND RESEARCH PERSONNEL DIRECTED

Ph,D. student (in progress) : 04 (as supervisor) + 02 (as co-supervisor) M, Tech, student: 04 (completed) + 01 (ongoing) M.Sc.-Ph.D, student (in progress) : 01 M .Sc. (external candidate) : 02 (completed)

RAAJ Ramsankaran
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Education
Ph.D. in Civil Engineering, Indian Institute of Technology Roorkee 2010
(Major: Remote sensing, GIS and Surface Hydrological Processes) **M.E.** in Geoinformatics, College of Engineering Guindy, Anna University, Chennai 2004
B.E. in Civil Engineering, Coimbatore Institute of Technology, Bharathiyar University, TN 2002

Employment History
Assistant Professor, Indian Institute of Technology Bombay, Mumbai, India July, 2012 – Present
Assistant Professor, Birla Institute of Technology and Science, Pilani, India May, 2010 – June 2012
Lecturer, Karunya University, Coimbatore, TN, India May, 2004 – Dec, 2004
Academic Honors

- **German Academic Exchange Service (DAAD) Long term Sandwich** Scholarship for pursing a part of my doctoral studies at German Armed Forces University, Munich.
- **National Doctoral Fellowship (NDF)** awarded by **All India Council for Technical Education** (AICTE), New Delhi, India.
- **Senior Research Fellowship** by DST, New Delhi, India.

Sponsored Research Projects
Geo-spatial based groundwater quality and vulnerability modeling in a part of Jhunjhunu district, Rajasthan, India
Role: **Co-Principal Researcher;** *Funding Agency*: Ministry of Water Resources, GoI; *Estimated Project Cost*: Rs. 22, 96,249; *Current Status*: Approved

Remote sensing and GIS based Distributed Hydrological Modelling of Upper Bhima River Basin
Role: **Principal Researcher;** *Funding Agency*: Department of Science & Technology, New Delhi, India; *Estimated Project Cost*: Rs. 26, 96,400; *Current Status*: Under review
Pre PhD Research Experience

2D Morphodynamic modelling of a Himalayan river using TELEMAC and SediMoprh at German Armed Forces University Munich, *Role*: Scientific Co-worker, *Period*: 1.10.07 - 30.9.08.

Hydrological Modeling of Himalayan watersheds under BIO-GEO DEM programme in Uttarakhand at IIT Roorkee, *Role*: SRF, *Period*: 1.02.05 - 30.06.09.

Ecological modelling of Vedranyam Coastal Stretch using Remote sensing and GIS at Institute of Remote Sensing, CEG, Anna University, Chennai. *Role*: PG scholar, *Period*: July 03 - May 04.

Consultancy Experience

Along with Prof. U.C. Kothyari and Prof. M.K. Mittal, IIT Roorkee I have involved in the following consultancy research projects for carrying out numerical modelling during my stay at IIT Roorkee.

Study on the hydrological and morphological effects due to construction of the proposed Ganga expressway along the river Ganga from Narora to Gazipur (about 850 km).

Study on the effects of bridge construction across the river Ganga.

Study on the morphological effects due to Patna Marine Drive project along the river Ganga.

List of Publications

Category	Peer Reviewed Journals		Conferences/Seminars	
	International	*National*	*International*	*National*
Published	9	1	4	4
In Press/Accepted	2	-	-	-
Communicated	2	-	-	-

Invited Presentations

1. Expert Lecture on Terrestrial Laser Scanning and its 3D Modelling Applications, National Remote Sensing Centre (NRSC), ISRO, Hyderabad, India.
2. International Meet on Impact of Climate Change on Water Resources Development and Management-Aug 2012, Karunya University, Coimbatore, India.
3. National Seminar on Climate Change & its Impacts on Indian Water Resources - 2010, Graphic Era University, Dehradun, India.
4. Annual meeting of *Ge*rman *SIN*o *U*nsteady *S*ediment transport Group (*GESINUS-2008*), Karlsruhe, Germany.

Personal Profile

Name **: RAAJ. Ramsankaran**
Date of Birth **:** 10/04/1981
Marital Status **:** Married

Arpita Mondal
Assistant Professor, Dept. of Civil Engg., IIT Bombay, Powai, Mumbai 700076.
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Education

PhD (Civil Engineering), Indian Institute of Science, Bangalore, 2014.
MTech (Water Resources Engg.), IIT Bombay, Mumbai, 2008.
BE (Civil), Jadavpur University, Kolkata, 2006 (Gold Medalist).

Awards and recognition

i) Ranked 1st in BE(Civil), Jadavpur University (2006), 2 Gold, 1 Silver and 1 Bronze Medal.
ii) Ranked 1st in MTech, among all specializations in Civil Engineering, IIT Bombay (2008).
iii) Prabhakar D Mahajan Scholarship for scoring a grade-point of 10.0 out of 10.0 in MTech first semester at IIT Bombay (2007).
iv) Recipient of Govt of Australia sponsored Endeavour Research Fellowship 2012 for carrying out a part of doctoral research at UNSW, Sydney (Jan to May, 2012).
v) Recipient of Fulbright Nehru Research Fellowship 2012-13 (not availed).
vi) Recipient of AGU Berkner Travel Fellowship - complete funding for attending the 2013 AGU Fall Meeting, San Francisco, CA (2013).

Selected peer-reviewed journal papers

1) **Mondal, A.** and P. P. Mujumdar (2014), Modeling non-stationarity in intensity, duration and frequency of extreme rainfall over India, *Journal of Hydrology*, 521, pp 217-231, doi 10.1016/j.jhydrol.2014.11.071.
2) **Mondal, A.** and P. P. Mujumdar (2014), Return levels of hydrologic droughts under climate change, *Advances in Water Resources*, 75, pp27-75, doi 10.1016/j.advwatres.2014.11.005.
3) Goly, A., Teegavarapu, R. S. V., and **A. Mondal** (2014), Development and evaluation of statistical downscaling models for monthly precipitation, *Earth Interactions*, AMetSoc, 18, pp 1-28, doi: http://dx.doi.org/10.1175/EI-D-14-0024.1.
4) **Mondal, A.** and P. P. Mujumdar (2012), On the basin-scale detection and attribution of human-induced climate change in monsoon precipitation and streamflow, *Water Resources Research*, 48, W10520, doi:10.1029/2011WR011468.
5) **Mondal, A.**, Eldho, T. I. and V.V.S. G. Rao (2010), Multi-Objective Groundwater Remediation System Design Using Coupled Finite Element Model and Non-Dominated Sorting Genetic Algorithm II, *ASCE Journal of Hydrologic Engineering*, 15(5), pp 350-359.

Experience

i) Research Associate (10/2008 to 12/2008), River basin stream flow simulation using remote sensing data (sponsor: ISRO, Ahmedabad), IIT Bombay.
ii) Project Assistant (04/2009 to 08/2009), Prediction of Streamflow at River-basin Scale under Climate Change Scenarios (sponsor: ISRO-IISc Space Technology Cell, IISc, Bangalore), IISc Bangalore.
iii) Student Assistant (08/2012 to 08/2013), Statistical Downscaling of Global Climate Model Output to Rainfall, Temperature and Streamflow in Pennar Basin in Andhra Pradesh (sponsored by APSDPS, Govt. of Andhra Pradesh, India), IISc Bangalore. Also conducted 5 lectures and all tutorials for the training program 'Statistical Downscaling for Assessment of Hydrologic Impacts of Climate Change', Center for Continuing Education, IISc Bangalore, March 25 – 29, 2013.

Professional Services

Reviewer: Journal of Hydrology, ASCE Journal of Hydrologic Engg., Journal of Hydro-environment Research, etc.