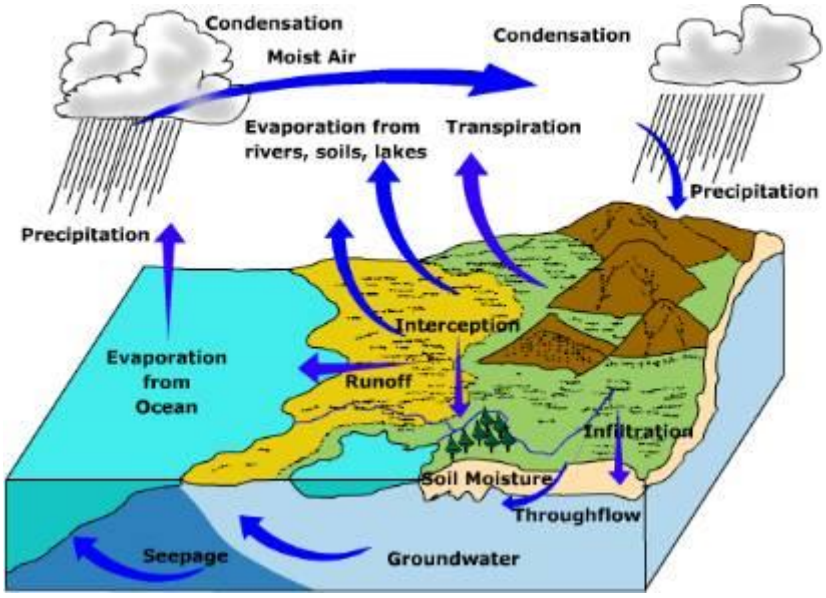
AGENDA AND AGENDA NOTES FOR THE 45th MEETING OF THE WORKING GROUP OF NIH

MAY 11-12, 2017
AT 1100 HRS



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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 45th MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

ITEM NO. 45.1 Opening Remarks by the Chairman

ITEM NO. 45.2 Confirmation of the minutes of 44th meeting of the Working Group

The 44th meeting of the Working Group was held during 18-19 April 2016. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/WG/NIH-10 dated 01 June 2016**. No comments were received on the circulated minutes. A copy of the minutes of the 44th Working Group is given in **Annexure A.**

The Working Group may please confirm the minutes.

ITEM NO. 45.3 Action taken on the decisions/ recommendations of the previous Working Group meeting

During the 44th Working Group meeting, recommendations/ suggestions were made by the Working Group members and the actions taken shall be informed by the respective Divisions during the meeting.

ITEM NO. 45.4 Presentation and discussion on the status and progress of the work programme for the year 2016-2017.

The approved Work Programme of the six Divisions of the Institute for the year 2016-17 has been given in the **Annexure B** in the following order**:**

The number of studies/projects handled by each Division under different categories are given below:

Division	**No. of Studies/Projects During the Year 2016-17**					
	New		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	-	1	3	2	**06**	**2**
Ground Water Hydrology	2	3	4	2	**11**	**-**
Hydrologic Investigation	2	1	3	3	**09**	**8**
Surface Water Hydrology	3	-	13	2	**18**	**-**
Water Resources System	-	2	11	-	**13**	**-**
Research Management & Outreach	-	2	2	1	**05**	**-**
Total					**62**	**10**

During the present meeting, Division-wise progress and status of the work programme for the year 2016-17 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2016-17.

ITEM NO. 45.5: Presentation and finalization of the work programme for the year 2017-18.

The proposed Work Programme of the six Divisions of the Institute for the year 2017-18 has been given in the Annexure-B in the following order:

The work programme has been categorized into three groups: (a) Internally funded studies, (b) Sponsored projects and (c) Consultancy Projects. During the present meeting, Division-wise proposed work programme for the year 2016-17 shall be presented.

	No. of Studies/Projects During the Year 2017-18					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	-	1	1	2	**4**	**1**
Ground Water Hydrology	1	5	2	3	**11**	**2**
Hydrologic Investigation	-	6	4	1	**11**	**9**
Surface Water Hydrology	4	-	10	-	**14**	**-**
Water Resources System	-	4	9	7	**20**	**-**
Research Management & Outreach	-	2	2	1	**5**	**-**
Total						

ITEM NO. 45.6: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 44th MEETING OF WORKING GROUP

MINUTES OF THE
44TH MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING APRIL 18-19, 2016

The 44th meeting of the Working Group of NIH was held at NIH, Roorkee, during April 18-19, 2016 under the Chairmanship of Director, NIH. The list of the participants of the meeting is given in Annexure-I.

ITEM NO. 44.1: OPENING REMARKS BY THE CHAIRMAN

Er R D Singh, Director, NIH & Chairman, WG welcomed the Working Group members and the Scientists of the Institute. The Chairman informed the house about the additional responsibilities assigned to the Institute by the Ministry of WR, RD & GR. Also, he mentioned that some new projects have been sanctioned to commence in the Institute, namely- NMSHE Project (DST funded), National Hydrology Project (World Bank funded), and the Neeranchal Watershed Project (World Bank funded through DoLR, GoI) is likely to be approved soon.

The Chairman then requested the Member-Secretary to take up the agenda of the meeting.

ITEM No. 44.2: CONFIRMATION OF THE MINUTES OF 43rd MEETING OF THE WORKING GROUP

The 43rd meeting of the Working group was held during December 8-9, 2015. The minutes of the meeting were circulated to all the members and invitees vide letter No. RCMU/WG/NIH-10 dated January 22, 2016. No Comments were received. The members confirmed the Working Group minutes.

ITEM No. 44.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING

Dr V C Goyal gave a brief account of the actions taken on the recommendations/ decisions of the 43rd working group meeting.

ITEM Nos. 44.4 & 44.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR THE YEAR 2015-16 AND FINALIZATION OF THE WORK PROGRAMME FOR THE YEAR 2016-17.

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2015-16 and work programme for the year 2016-17. Accordingly, the progress of various studies and sponsored projects was presented by all Scientific Divisions on their turn during the two day deliberations of the Working Group. The Division wise minutes of each study/project presented during the meeting are given below:

ENVIRONMENTAL HYDROLOGY DIVISION

Progress of Work Programme 2015-16

S.No.	Study	Recommendation / Comments
	Internal Studies	
1.	Water Quality Modelling using Soft Computing Techniques Study Group: Rama Mehta (PI), C. K. Jain, Anju Choudhary Duration: 2 Years (05/14-05/16)	Extension granted for 3 months and report will be submitted by Aug. 2016.
2.	Himalayan River Water Quality Assessment in a Stretch from Gangotri to Haridwar Study Group: Rajesh Singh (PI), C. K. Jain, M. K. Sharma, S. P. Rai, Renoj J. Thayyan, J. P. Patra Duration: 3 Years (07/14-06/17)	Report will be submitted by May 2016 and further work will be Continued under NMSHE Project.
3.	Status Report on Phytoremediation of Wastewater Study Group: Rajesh Singh (PI), C. K. Jain Duration: 6 Months (11/15 – 04/16)	Extension granted for 1 month and report will be submitted by May 2016.
	Sponsored Projects	
1.	Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier Study Group: M. K. Sharma (PI), C. K. Jain, Renoj Thayyan, Manohar Arora, Naresh Saini, Jatin Malhotra, Rakesh Goyal, Shyam Lal Duration: 3 Years (04/14-03/17)	No comments
2.	Low Cost Technology for Purification of Arsenic and Microbes Contaminated Water using Nanotechnology Study Group: Vijaya Aggarwala, IITR (PI) Rama Mehta, NIH (Co-PI) Duration: 2 Years (04/14-03/16); Extended granted for 6 months by DST.	No comments

Approved Work Programme for the year 2016-17

S.No.	Study	Remarks
	Internal Study (New)	
1.	Assessment of suitable habitats for the aquatic species of Western Himalayan Streams *Study Group: Pradeep Kumar and C. K. Jain* Duration: 2 Years (04/16-03/18)	It was decided to change the title to "Development of habitat suitability curves for the aquatic species of Western Himalayan Streams"
	Sponsored Projects (Continuing)	
2.	Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier Study Group: M. K. Sharma (PI), C. K. Jain, Renoj Thayyan, Manohar Arora, Naresh Saini, Jatin Malhotra, Rakesh Goyal and Shyam Lal Duration: 3 Years (04/14-03/17)	-
3.	Low Cost Technology for Purification of Arsenic and Microbes Contaminated Water using Nanotechnology Study Group: Vijaya Aggarwala, IITR (PI) Rama Mehta, NIH (Co-PI) Duration: 2 Years (04/14-03/16); Extended for 6 months by DST.	-
	Sponsored Projects (New)	
4.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin Study Group: C. K. Jain (PI), Manohar Arora, M. K. Sharma, P. Kumar, R. Singh and D. S. Malik (GKU) Duration: 5 Years (04/16-03/21) Sponsored by DST under NMSHE Project Cost: 2.25 Crore	-
	Consultancy Projects (Continuing)	
5.	Petroleum Product Contamination at Akolner Village, District Ahmednagar, Maharashtra and Suggesting Remedial Measures Study Group: C. K. Jain (PI), Sudhir Kumar, B. K. Purendra, Anupma Sharma, M. K. Sharma and Rajesh Singh Duration: One Year (10/15 – 09/16) Sponsored by: MPCB, Mumbai Amount: Rs. 54.72 Lacs	-
	Consultancy Projects (New)	
6.	Study on Ash Disposal from Ramagundam STPS and Telangana STPP into Mine Void of Medapalli Open Cast Mines	-

	Study Group: C. K. Jain (PI), Sudhir Kumar, Y. R. S. Rao, Anupma Sharma, M. K. Sharma and Pradeep Kumar Duration: 15 months (03/16 – 05/17) Sponsored by: NTPC Amount: Rs. 54.96 Lacs	

GROUND WATER HYDROLOGY DIVISION

Dr. N. C. Ghosh, Scientist 'G' & Head presented an overview and progress of studies and activities carried out by the division during the period December 2015 to March 2016. While presenting the technical activities carried out by the division and progress made on different studies during last four months, he gave an account of scientific personnel available at the division and the sponsored projects being pursued by the Division. He informed that five in-house R&D studies and one sponsored study approved for the year 2015-16, which are being continued. Five new studies were proposed for the year 2016-17, out of these three were sponsored studies and two were in-house studies.

He also informed that , scientists of the division had published a number of research papers in various journals/conferences and delivered lectures in various training courses during the period and also guided/guiding M.Tech/Ph.D students.

The study-wise progress reported and suggestions emerged are given below.

1. Project Ref. Code: NIH/GWD/NIH/15-18: **Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply**

Dr. N. C. Ghosh (PI) briefed about the necessity of the study and described about the six demonstration sites to be developed at Laksar (Uttarakhand), Agra and Mathura (Uttar Pradesh), Sahebganj (Jharkhand), Bhojpur (Bihar) and Visakhapatnam (Andhra Pradesh) under the Peya Jal Suraksha Project sponsored by Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India. Dr. Surjeet Singh presented the objectives, mechanism of riverbank filtration (RBF) and the progress of the study made so far for the Agra, Mathura and Laksar sites. The progress for the other three sites at Sahebganj, Bhojpur and Visakhapatnam was reported by Dr. N.C. Ghosh. No comments were received.

2. Project Ref. Code: NIH/GWD/NIH/15-18: **Development of Website and e-Portal on "Mitigation and Remedy of Arsenic Menace in India"**

Dr. N. C. Ghosh informed that the study requires funding from Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR) and also confirmation on ownership of the developed portal by MoWR. Since, no funding and official confirmation were received from the Ministry, the project activities were deferred. The study will be taken up only after getting funds and ownership confirmation from Ministry of Water Resources, River Development and Ganga Rejuvenation.

Since the above study could not be initiated so far due to non-availability of funds and ownership confirmation from MoWR, it would be appropriate that it may not be included in the Work Plan of 2016-17. The study can be included in the work plan later whenever confirmation from MoWR is received.

3. Project Ref. Code: NIH/GWD/NIH/14-17: **Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin**

Dr. Anupma Sharma (PI) presented the progress of the study. She informed about the declining groundwater levels in Baghpat, Shamli and Muzaffarnagar districts of the study area. The decline in areas near the Eastern Yamuna Canal was less. Field observations carried out for water level and water quality monitoring as well as soil surveys for estimation of groundwater recharge along Saharanpur, Shamli and Muzaffarnagar district were highlighted. Results of soil texture and soil moisture retention analyses were shown. Suggestions were made about reanalyzing field capacity values for soil samples along the Hindon River Bank.

4. Project Ref. Code: NIH/GWD/NIH/15-16: **Alternate Water Supply Management Strategies in Arsenic Affected/ Vulnerable Areas: Mapping of Arsenic Affected Zones/ Regions in Eastern U.P.**

Mr. Sumant Kumar (PI) presented the objectives, progress and future plans of the study. PI seeks extension of 6 months for completion of study and permission was granted. Dr. Bartarya suggested that risk zone mapping can be done based on arsenic concentration in the study area. Director, NIH asked PI to do sampling for all the blocks of Ballia district to prepare Arsenic risk map. WG members enquired about the instrument and its principle for arsenic analysis and same was clarified by PI.

5. Project Ref. Code: NIH/GWD/NIH/15-16: **Web Enabled "Groundwater Recharge Estimation Model (WE-GREM)"**

Ms. Suman Gurjar (PI) demonstrated the completed study on Web Enabled "Groundwater Recharge Estimation Model (WE-GREM)" and explained about objectives, methodology and scope of the project. Working group members appreciated and approved to host it in public domain. They also suggested to publicize it as much as possible.

6. Project Ref. Code: NIH/GWD/NIH/16-17: **Groundwater fluctuations and conductivity monitoring in Punjab**

Dr. Gopal Krishan presented the progress made under the study and presented the future work plans. He also clarified the action taken on the comments of experts made during the 43rd WG meeting. Dr. S.S. Grewal suggested to take the meteorological data from RRSKA, Ballowal Saunkhri and KVK, Kapurthala.

7. Project Ref. Code: NIH/GWD/NIH/16-17: **Baseline data collection and analysis of Mewat district, Haryana**

Dr. Gopal Krishan (PI) presented the background, statement of the problem, objectives, methodology and future plans of the study. Dr. J.V. Tyagi, Sc. G suggested to modify the title. Dr. D.V. Reddy (NGRI) suggested to plot conductivity, water level and rainfall together. Dr. D.V. Reddy (NGRI) and Dr. S.K. Mittal, CSIO, Chandigarh asked about the role of Sehgal Foundation, Gurgaon. Dr. N.C. Ghosh (Head, GWHD) replied that the Sehgal Foundation has motivated NIH to take up the study and will provide the historical data as they are working on Mewat area since last 15 years.

8. Project Ref. Code: NIH/GWD/NMSHE/16-21: **Study of river - aquifer interactions and groundwater potential in the upper Ganga basin up to Dabrani**

Dr. Surjeet Singh (PI) presented the research needs, objectives, future plans and scope of the study. He described about the field visit made during the month of March, 2016 and also the topography, formations type and existing hand pumps in the higher altitudes of the Himalayan basin. No comments were received.

9. Project Ref. Code: NIH/GWD/NIH/16-16: **Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR"**

Ms. Suman Gurjar (PI) proposed new study on Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR" and explained about objective, methodology and scope of the project. Working group members suggested to merge this with the WEGREM but looking at its scope and after discussions they agreed to make it as the new study and extension of WEGREM. They suggested to host it as Version 2 in public domain.

10. Project Ref. Code: NIH/GWD/NIH/16-16: **Evaluation of Saryu Nahar Pariyojna (SNP) National Project in Uttar Pradesh**

Dr. N. C. Ghosh had informed that MoWR, RD & GR has sponsored the study with timeline of six months starting from March, 2016. Dr. Ghosh gave a brief objective of the study and expected deliverables. He elaborated the results of field visit undertaken during 11-13th April, 2016 along with a team.

11. Project Ref. Code: NIH/GWD/NIH/16-17: ***Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply"**

The training course was sponsored by DST, Govt. of India to organize foure training courses with a cost of Rs.36.4 lakhs . Dr. Ghosh informed the objectives and methodologies of the training courses. He informed that first training course shall be organized during the month of September, 2016 and the second course shall be organized during February, 2017. The calendar for the 3rd and 4th training courses shall be decided later on.

The work program of the division for the year 2016-17, as recommended by the Working Group, is given below:

WORK PROGRAM FOR THE YEAR 2016-17

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/ NIH/15-18	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.	N.C. Ghosh (Project Coord. & Leader) C.P. Kumar, B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, S.P. Indwar, R.P. Singh, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff SW Lab	21/2 year (11/15 – 4/18) **Status: In progress**.	Sponsored by MoWR, RD & GR under Plan Fund.
2. NIH/GWD/ NIH/14-17	Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin	Anupma Sharma (PI), N.C. Ghosh (Coordinator), Deepak Kashyap, IITR (Technical Consultant)	3 years (12/14 – 11/17) Status: **In progress**.	Internal Funding.
3. NIH/GWD/ NIH/15-16	Alternate water supply management strategies in arsenic affected/ vulnerable areas: Mapping of Arsenic affected zones/regions in Eastern U.P	Sumant Kumar (PI) N.C. Ghosh, Rajesh Singh, R.P. Singh, Suman Gurjar, S.L. Srivastava, Anju Choudhary	1 year (04/15 – 3/16) **Status: In progress.**	Internal Funding.
4. NIH/GWD/	Web Enabled "Groundwater Recharge	Suman Gurjar (PI), N.C. Ghosh, Sumant Kumar, Surjeet Singh,	1 year (08/15 – 3/16)	Internal Funding.

NIH/15-16	Estimation Model (WE-GREM) ".	Anupma Sharma	**Status: In progress.**	
5. NIH/GWD/ NIH/16-17	Groundwater fluctuations and conductivity monitoring in Punjab.	Gopal Krishan (PI), N.C. Ghosh, Surjeet Singh, Dan Lapworth (PI from UK) Alan MacDonald (Project Coordinator)	1 year (01/16 – 12/17) **Status: In progress.**	NIH in association with BGS, UK
Proposed New Study				
6. NIH/GWD/NIH/ 16-17	Baseline data collection and analysis of Mewat district, Haryana.	N.C. Ghosh (Project Coordinator), Gopal Krishan (PI), Surjeet Singh, C.P. Kumar, Brijesh Yadav (IITR), Lalit Mohan Sharma (Sehgal Foundation, Gurgaon)	1 year (03/16 – 03/17) **Status: New.**	Internal Funding.
7. NIH/GWD/NMSHE/16-21	Study of river - aquifer interactions and groundwater potential in the upper Ganga basin up to Dabrani.	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, S. P. Rai, Manohar Arora, Gopal Krishan,	1 year (03/16 – 02/21) **Status: New.**	Sponsored by DST under NMSHE.
8. NIH/GWD/NIH/ 16-16	Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR".	Suman Gurjar (PI), N.C. Ghosh, Sumant Kumar, Surjeet Singh, Anupma Sharma	08 Months (04/16 – 11/16) **Status: New.**	Internal Funding.
9. NIH/GWD/NIH/ 16-16	Evaluation of Saryu Nahar Pariyojna (SNP) National Project in Uttar Pradesh.	N. C. Ghosh (PI), Gopal Krishan, R.P. Singh, J. K. Mishra	06 Months (03/16-08/16) **Status: New.**	Sponsored by MoWR, RD & GR.
10./NIH/GWD/16-17	*Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply"	N. C. Ghosh, Lead Other Scientists of the division	2 years (02/16 – 12/17) 4 training courses	Sponsored by DST

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr. Sudhir Kumar, Scientist G and Head, presented an overview and progress of studies and activities carried out by the Hydrological Investigations Division during the year 2015-16. He informed that out of 7 internal R&D studies, 4 have been completed. Out of the 5 sponsored studies, one project has been completed, while 4 studies are being continued. He further informed that the scientists of the division have also completed 1 consultancy project, conducted 4 training programs / workshops / National Seminar and published more than 20 papers in Journals and conferences.

Dr. Sudhir Kumar informed that for the next year, i.e., 2016-17, 3 internal studies, 4 sponsored projects, and 8 consultancy project shall continue from the year 2015-16. Further, 2 new internal studies and one sponsored project has been proposed for the year 2016-17. Also, many consultancy projects have been submitted by the scientists of the division and expected to be started during 2016-17.

The study-wise progress reported and suggestions emerged are given below.

INTERNAL STUDIES:

S.N.	Project Reference No.	Title of Study	Comments/Remark
1.	NIH/HID/INT/2013-15/2	Isotopic Studies for the Identification of Different Aquifer Groups and their Dynamics in Upper Yamuna River Plains	Study completed No comments received
2.	NIH/HID/INT/2013-15/4	Estimation of Radon Concentration in Waters and Identification of Paleo-groundwater in Part of Punjab Located in Satluj River Basin using Isotopes	Study completed
3.	NIH/HID/INT/2014-16/1	Interaction between groundwater and seawater along the parts of East Coast of India	No comments received
4.	NIH/HID/INT/2014-16/2:	Isotopic investigation of benchmark Himalayan glaciers	Study to be completed by June, 2016. No comments received
5.	NIH/HID/INT/2014-16	Assessment of dissolved radon concentration for groundwater investigations in Haridwar district	Study completed
6.	NIH/HID/INT/2015-16/1	Hydrological Aspects of Rewalsar Lake, Himachal Pradesh (Status Report)	Study extended upto July 2016 due to proposed summer WQ sampling. No comments received
7.	NIH/HID/INT/2015-18/1	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	No comments received.

SPONSORED PROJECTS:

	Project Reference No.	Title of Study	Comments/Remark
8.	NIH/HID/MOES/2012-15	The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates	Study extended upto July 2016 No comments received
9.	NIH/HID/IAEA-1/2012-15:	The Use of Environmental Isotopes to Assess Sustainability of Intensively Exploited Aquifer Systems in North Eastern Parts of Punjab, India	Completed
10.	NIH/HID/IAEA-2/2012-15	Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques	Study extended upto December, 2016 No comments received
11.	NIH/HID/IAEA-3/2013-15	Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains	No comments received

Three new projects proposed for the year 2016-17 were also presented as given below:

NEW STUDIES

	Project Reference No.	Title of Study	Comments/Remark
12.	NIH/HID/INT/2016-18 (Internal study)	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	No comments received
13.	NIH/HID/INT/2016-18 (Internal study)	Isotopic Investigations in parts of Upper Yamuna River Basin	No comments received
14.	NIH/HID/SPON/2016-21 (Sponsored Project)	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	No comments received

The approved program for the year 2016-17 is given below:

APPROVED WORK PROGRAMME FOR 2016-2017

S. No.	Study	Team	Duration/ Status
INTERNAL STUDIES			
1.	Interaction between groundwater and seawater along the northern part of east coast of India	M. S. Rao (PI), Sudhir Kumar Pankaj Garg	2 years (01/15 - 12/16) Continuing Study
2.	Status Report on Rewalsar Lake, Himachal Pradesh	SD Khobragade (PI) Sudhir Kumar, C. K. Jain	1 year (04/15 – 03/16) Continuing Study (to be extended upto July, 2016
3.	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	S.D Khobragade (PI); Sudhir Kumar; S. P. Rai, Senthil Kumar; Pankaj Garg	3 years (04/15 – 03/18) Continuing Study
4.	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	M. S. Rao (PI) Sudhir Kumar	3 years (04/16 – 03/19 New Study
5.	Isotopic Investigations in parts of Upper Yamuna River Basin	S. K. Verma (PI), Sudhir Kumar, S P Rai, Mohar Singh, Vishal Gupta	2 years (04/16 – 03/18) New Study
SPONSORED PROJECTS			
6	The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates	S. P. Rai (PI); M. S. Rao; Surjeet Singh; S. K. Verma; C. P. Kumar; Sudhir Kumar	3 years (06/12-03/16) Continuing Study To be extended upto July, 2016
7	Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques	S. P. Rai (PI) R. V. Kale M. S. Rao C. P. Kumar Sudhir Kumar	3 years (10/12-04/16) Continuing Study To be extended upto July, 2016

S. No.	Study	Team	Duration/ Status
8	Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains	Sudhir Kumar (PI); S. P. Rai; S. D. Khobragade; C. K. Jain; P. K. Garg	2 years (05/13-03/16) Extended by IAEA till Jun 16
9.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	S. P. Rai (PI); Sudhir Kumar; Rajesh Singh; S. D. Khobragade; M. Arora; Dr. R. J. Thayyen; Sh. P. K. Garg	*5 Years 04/16-03/21 New Study*
CONSULTANCY PROJECTS			
1.	Hydrogeological Study for Dewatering of Jhamarkotra Mines, Distt. Udaipur	Sudhir Kumar	05/13-04/16 Continuing Study
2	Hydro-geological study for Gadarwara super thermal power project, Madhya Pradesh	SD Khobragade	07/15-06/16 Continuing Study
3	Hydro-geological study for Katwa super thermal power project, West Bengal	Sudhir Kumar	07/15 – 4/16 Continuing Study
4	Hydro-geological study for Darlipali super thermal power project, Odisha	Sudhir Kumar	9/15 – 8/16 Continuing Study
5	Hydro-geological study for Khargone super thermal power project, Madhya Pradesh	SD Khobragade	07/15 – 4/16 Continuing Study
6	Hydro-geological and isotopic study for 1x660 MW Harduaganj thermal power project, UP	Sudhir Kumar	11/15 – 10/16 Continuing Study
7.	Hydro-geological and isotopic study for 1x660 MW Panki thermal power project, UP	Sudhir Kumar	12/15 – 11/16 Continuing Study
8.	Hydro-geological study for Kudgi super thermal power project, Karnataka	Sudhir Kumar	11/15 – 10/16 Continuing Study
9.	Hydro-geological study for Jawaharpur thermal power project, Etah, UP	Sudhir Kumar	12/15 – 11/16 Continuing Study

SURFACE WATER HYDROLOGY DIVISION

Dr. Rakesh Kumar, Head, Surface Water Hydrology Division gave a brief overview of the various scientific and other technical activities carried out by the Division after the previous meeting of the Working Group. Thereafter, the Scientists of the Surface Water Hydrology Division presented the progress achieved in carrying out the various studies as mentioned below.

Work Program for the Year 2015-16

S.No. & Ref. Code	Title	Study Team	Duration
1. NIH/SWHD/ NIH/13-16	Application of DSS (P) for Integrated Water Resources Development & Management	A.K. Lohani Surjeet Singh Rahul Jaiswal D K Sonkusale Akilesh Verma	3 years (April 2013 to March, 2016)
2. NIH/SWHD/ NIH/13-16	Quantitative assessment of uncertainties in river discharge estimation	Sanjay Kumar Sharad Jain	3.5 Years (April 2013 to Sept. 2016)
3. NIH/SWHD/ NIH/13-16	Evaluation and modeling of hydrological support system for watersheds of Garhwal, Uttarakhand hills.	Avinash Agarwal Manohar Arora RK Nema	3 Years (November 2013 to October 2016)
4. NIH/SWHD/ NIH/14-16	Estimation of Water Balance for Integrated Water Resources Management in Yerrakalva Pilot Basin, A.P.	J.V. Tyagi YRS Rao	2.5 years (April 2014 to Sept. 2016)
5. NIH/SWHD/ NIH/14-17	Hydrological modelling of Brahmani Baitarani river basin using eWater Source platform	J.P. Patra Rakesh Kumar Pankaj Mani	3years (April 2014 to March 2017)
6. NIH/SWHD/ NIH/14-17	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar Vaibhav Garg, Sc C, IIRS, Dehradun Rakesh Kumar N.K. Bhatnagar	3 years (April 2014 to Sept. 2017)
7. NIH/SWHD/ NIH/14-17	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora Rakesh Kumar	3years (May 2014 to March 2017)
8. NIH/SWHD/ NIH/14-17	Effect of climate change on evaporation at point scale	Digambar Singh A. R. Senthil kumar Manohar Arora	3years (June 2014 to March 2017)
9. NIH/SWHD/ NIH/15-16	Analytical Solution for meeting of two surges or bores	Dr. S.K. Singh	1 year (April 2015 to March 2016)
10. NIH/SWHD/ NIH/15-16	Generalization and parameter estimation of GEV distribution for flood analysis	Dr. S.K. Singh	1 year (April 2015 to April 2016)
11. NIH/SWHD/ NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani	3 years (April 2015 to March 2018)
12. NIH/SWHD/ NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Achana Sarkar T. Thomas Vaibhav Garg	3 years (April 2015 to March 2018)
13. NIH/SWHD/	Study on effect of climate change on sediment yield to Pong reservoir	A. R. Senthil Kumar J. V. Tyagi	3 years (April 2015 to

NIH/15-18		Avinash Agarwal Suhas Khobragade Manohar Arora	March 2018)
14. NIH/SWHD/ NIH/15-17	Study of regional drought characteristics and long term changes in supplemental irrigation water requirement in Seonath Basin in Chhattisgarh	R.P. Pandey Rakesh Kumar	2 years (April 2015 to March 2017)
15. NIH/SWD/N IH/14-17	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	3 years (Oct. 2014 to March 2017)
New Studies			
16. NIH/SWD/N IH/16-18	Snow cover variability in the Upper Yamnotri Basin	Naresh Kumar Manohar Arora Rakesh Kumar	2 years (April 2016 to June 2018)
17. NIH/SWHD/ NIH/16-17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh	1 year (April 2016 to March 2017)
18. NIH/SWHD/ NIH/16-19	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Sushil K. Singh	3 years (April 2016 to March 2019)

S.N.	**Title of Project/Study, Study Group, Start/ Completion Dates**	**Status and Recommendations/Suggestions**
1	Application of DSS (P) for Integrated Water Resources Development & Management Study Group: A.K. Lohani Surjeet Singh Rahul Jaiswal D.K. Sonkusale Akilesh Verma DOS: April 2013 DOC: March 2016	Dr. A.K. Lohani mentioned that the DSS (P) software, which was developed under HP-II has been applied in Arpa basin of Seonath river basin to demonstrate the capabilities of the DSS (P) model. Dr. Lohani mentioned that the hydrological time series data and spatial data have been collected from Water Resources Department, Chhattisgarh for the application of DSS (P) software. Dr Lohani further mentioned that the NAM rainfall-runoff model has been setup in Mike-11 RR. ANN Rainfall-runoff model was also developed on the same set of data. Using the DSS (P) software crop planning has been carried out for (i) normal rain years, (ii) 10% above normal rain and (iii) 10% below normal rain. He further mentioned that the report writing is in progress. Dr. S.S. Grewal mentioned that the planning may be carried out for the situations beyond 10% blow or above normal rainfall criteria. Dr. Lohani agreed that the crop water planning will be attempted for suggested cases also and incorporated in the final report. Dr D.V. Reddy, NGRI suggested that the micro level DSS being developed under other projects should be merged with this DSS to extend the capabilities of the DSS. Director, NIH mentioned that the DSS (P) is a basin level DSS and it cannot be merged with the micro scale level DSS. Dr. Rakesh Kumar, Scientist G and Head Surface Water Hydrology Division also mentioned that the DSS (P) was developed under Hydrology Project-II and it is a best planning DSS in basin Scale. It has five components for (i) Surface water planning; (ii) Integrated operation of

		reservoirs; (iii) Conjunctive surface water and ground water planning; (iv) Drought monitoring, assessment and management; and (v) Management of both surface and ground water quality. As the spatial scale of a micro level and a Basin level DSS are very much different and both have their own specific purpose therefore it is not advisable to have a common DSS for both the purpose.
2	Quantitative assessment of uncertainties in river discharge estimation Study Group: Sanjay Kumar Sharad Jain DOS: April 2013 DOC: March 2016	Dr. Sanjay Kumar presented the study on "Quantitative assessment of uncertainties in river discharge estimation". He explained the background and objectives of the study and informed that study is a part of the systemic review of uncertainty clause of the ISO 9123 document. He explained the methodology based on ISO documents GUM (Guide to the expression of uncertainty in measurement), HUG (Hydrometric uncertainty guidance) and presented the progress of the study. He mentioned that, based on the discussions in the Tokyo meeting (held on 15th May 2015), all the comments and suggestions from member countries were incorporated in the Draft international standard (DIS). This DIS document was sent to BIS on 15th January 2016 for uploading on ISO site for further comments of member countries. As BIS is in the process of uploading the document, further comments on the documents are awaited. Considering above, P.I. of the study requested for the extension of six months to incorporate possible changes in the DIS documents based on the further suggestions/comments from member countries. Taking into account the progress of the study, Chairman and members agreed to extend the study for next six months.
3	Evaluation and modeling of hydrological support system for watersheds of Garhwal, Uttarakhand hills. Study Group: Avinash Agarwal, Manohar Arora R.K. Nema DOS: November 2013 DOC: October 2016	Dr. Avinash Agarwal, Scientist 'G' has presented the study, entitled "Evaluation and modeling of hydrological support system for watersheds of Garhwal, Uttarakhand hills". He informed that analysis has been completed and writing of the report is in progress. Some of the Working Group members stated that a long term and very useful data base has been created for monitoring, modeling and rejuvenation of the springs in this study. The springs are a very important source of fresh water in the hilly regions. The members expressed that not many studies are available on this important aspect of drinking water in the hilly regions. The Working Group members suggested that the research work on monitoring, modeling and rejuvenation of the springs should be continued by the Institute.
4	Estimation of Water Balance for Integrated Water Resources Management in Yerrakalva Pilot Basin, A.P. Study Group: J.V.Tyagi YRS Rao DOS: April 2014	Dr. J.V. Tyagi presented the study and informed the house that the water balance study is taken up in Yerrakalva river basin in coastal Andhra Pradesh which is selected as pilot basin by NIH for integrated water resources management. SWAT model has been employed to quantify the water balance of the basin in the present study. The model was calibrated and validated on monthly data and water balance components were computed for the basin. It was, however, informed that all files stored in the computer (including word files, excel files, pdf files, data files etc) were infected and crypted by some unknown virus. The files could not be recovered despite all efforts by experts. Therefore, entire exercise including data file preparation, SWAT model set up

	DOC: March 2016	and calibration and validation processes have to be redone. In view of the reasons beyond control, the P.I. requested for six months extension of the study period. The working Group considered the problem and granted the extension up to September 2016.
5	Hydrological modelling of Brahmani Baitarani river basin using eWater Source platform Study Group: J.P. Patra Rakesh Kumar Pankaj Mani DOS: April 2014 DOC: March 2017	Sri J.P. Patra explained the objectives of the study and stated that the eWater source is Australia's first national river basin scale water modelling system. The source modelling platform has been developed to take a holistic approach to water management including human and ecological impacts. This includes integrating policy, addressing water savings and sharing for a whole river and connected groundwater systems including cities, agricultural and environmental demands. In the India-Australia Water Science and Technology Partnership programme, Australia is collaborating with the Ministry of Water Resources to pilot the source river basin modelling platform in India. The MoWR, RD & GR is planning to develop an Integrated Water Resources Management (IWRM) plan for Brahmani Baitarani basin using the source river basin modelling platform. Hence, the present study has been taken up to develop a rainfall runoff model for Brahmani Baitarani river basin in source platform and test its applicability by generating hydrological time series. It was informed that collection of hydro meteorological data, satellite images, thematic maps etc., compilation, statistical and trend analysis of rainfall and river discharge and rainfall-runoff model set up in eWater Source platform have been completed and implications of different rainfall inputs and sub catchment size and calibration and parameter estimation are under progress. Thereafter, model performance evaluation with in various time periods would be taken up. It was explained that catchment modelling of Brahmani Baitarani river basin in eWater source platform is being carried out. The rainfall runoff model was setup with daily rainfall data of .25°×.25° obtained from IMD and ET data from Terrestrial Hydrology Group, Princeton University. The model calibration is being carried out with gauged sub catchments represented by a small proportion of the basin. Various objective functions viz. NSE Daily, NSE Monthly, NSE Monthly & Bias Penalty, NSE Daily & Flow Duration, NSE Daily & log Flow Duration, Minimise Absolute Bias, NSE Daily & Bias Penalty etc. are used for calibration of the model. Further optimization algorithm like Shuffled Complex Evolution (SCE), Uniform Random Sampling (URS), Rosenbrock, SCE then Rosenbrock etc is evaluated for their performance. In case of SCE then Rosenbrock, the variability among different simulation runs are found to be minimum. Comparison of simulated discharge obtained from various models viz. GR4J, Sacramento and SimHyd with observed discharge have been compared. It is found that the GR4J model has performed better in comparison to other model for this basin. Further it has only four parameters to calibrate, which also reduces uncertainty. Further, the exercise with available daily point rainfall data is being carried out.

6	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State Study Group: Archana Sarkar Vaibhav Garg, Sc C, IIRS, Dehradun Rakesh Kumar N.K. Bhatnagar DOS: April 2014 DOC: March 2017	Mrs Archana Sarkar, PI of the study presented the background, objectives, methodology and expected deliverables of the new study. Mrs Sarkar informed that the study area is the Uttarakhand State, often referred to as the "Land of the Gods" due to the many holy Hindu temples and pilgrimage centres found throughout the state which observed a massive flood disaster in June 2013. Mrs Sarkar informed the house that a good knowledge of local rainfall-regime is crucial for planning and management of domestic, urban as well as industrial water use, irrigation and crop practices besides forecasting and management of extreme events like floods and droughts. She further informed that in view of the recent flood disaster in the Uttarakhand state, it becomes all the more important to carry out a scientific analysis of the rainfall regime of the region. Mrs Sarkar also informed that a comparative accuracy assessment of various data sources of rainfall viz, Rain gauges, satellite sensors (TRMM), and high resolution gridded re-analysis rainfall (APHRODITE) is of prime importance as the rainfall data from these data sources are further provided to hydrological models to produce forecasts. Mrs Sarkar presented the progress of the study with results of trend analysis of historical rainfall series of number of rainfall events of various intensity (annual and monsoon) by parametric and non-parametric methods for ten rainfall stations (grid centres) five each in Kumoan and Garhwal regions using IMD gridded rainfall data of 113 years (1901 to 2013). She also informed about the processing of TRMM rainfall data being processed. Mrs Sarkar informed about the further work that will be carried out for rainfall comparison for different sources if rainfall. Working group members noted the progress of the study as well as appreciated the work.
7	Monitoring and modelling of streamflow for the Gangotri Glacier Study Group: Manohar Arora Rakesh Kumar DOS: May 2014 DOC: March 2017	Dr Arora presented the progress of the study. He informed the house that the data collected for the ablation period of 2015 was analyzed and the results were presented in the last working group. He informed the house that the future scenarios have been developed in collaboration with IIT Delhi. It is observed that the statistical downscaling has limitation in this area because of non availability of historical observed data. The Cordex experiment data can be used for the future water availability analysis. In addition the mathematical model to be used for simulation has to be tuned with the observed physical phenomena in the region. The aspect consideration with the extent of debris cover will be incorporated in the model to improve efficiency. The aspect map developed for the Gangotri glacier was presented.
8	Effect of climate change on evaporation at point scale Study Group: Digambar Singh A. R. Senthil kumar Manohar Arora DOS: June 2014	Shri Digambar Singh, PI of the study, presented the objectives, methodology and progress of the study from Jan 2016 to March 2016. The PI explained about the Turc and Thornthwaite method to calculate the evapotranspiration. The PI also explained about the yearly variability of sun shine and wind speed, temperature and humidity. Sensibility analysis was also carried out during this period. Wind speed shows sinusoidal behavior on the yearly basis. Sunshine duration decreases in the later part of the year. Sunshine analysis shows that the temperature has major control in evaporation.

	DOC: March 2017	
9	Analytical Solution for meeting of two surges or bores Study Group: S.K. Singh DOS: April 2015 DOS: March 2016	Dr. S. K. Singh informed that the study is complete and the report will be submitted by this month.
10	Generalization and parameter estimation of GEV distribution for flood analysis Study Group: S.K. Singh DOS: April 2015 DOC: April 2016	Dr. S. K. Singh informed that the study is complete and the report will be submitted by this month.
11	Flood and Sediment studies in Himalayan basin using MIKE-11 Model Study Group: A.K. Lohani Sanjay K. Jain DOS: April 2015 DOC: March 2018	Dr. A. K. Lohani, Scientist G presented the progress of the study. He mentioned that the cloudburst data of District Uttarkashi of Uttarakhand have been collected. Using the DEM slope maps, river cross section and drainage network of Assiganga river basin have been prepared. Further a cloudburst event of 2012 has been considered and it has been converted to flood event considering triangular hydrograph. This hydrograph is routed to downstream using MIKER-11 model. Further flood inundated area has been plotted. Dr. Lohani mentioned that the study of other cloud burst events is in progress. He also mentioned that the sediment modelling is also planned in the study and efforts are being made to procure sediment modelling module of MIKE-11 or MIKE HYDRO RIVER from DHI. Dr S.S. Grewal appreciated the study. Shri N.K. Sharma, IRI also appreciated the study and mentioned that the results will be useful for water resources planning purpose.
12	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin Study Group: Achana Sarkar T. Thomas Vaibhav Garg DOS: April 2015 DOC: March 2018	Mrs Archana Sarkar, PI of the study presented the background, objectives, methodology and expected deliverables of the new study. Mrs Sarkar informed that the study area is the Uttarakhand State, often referred to as the "Land of the Gods" due to the many holy Hindu temples and pilgrimage centres found throughout the state which observed a massive flood disaster in June 2013. Mrs Sarkar informed the house that a good knowledge of local rainfall-regime is crucial for planning and management of domestic, urban as well as industrial water use, irrigation and crop practices besides forecasting and management of extreme events like floods and droughts. She further informed that in view of the recent flood disaster in the Uttarakhand state, it becomes all the more important to carry out a scientific analysis of the

		rainfall regime of the region. Mrs Sarkar also informed that a comparative accuracy assessment of various data sources of rainfall viz, Rain gauges, satellite sensors (TRMM), and high resolution gridded re-analysis rainfall (APHRODITE) is of prime importance as the rainfall data from these data sources are further provided to hydrological models to produce forecasts. Mrs Sarkar presented the progress of the study with results of trend analysis of historical rainfall series of number of rainfall events of various intensity (annual and monsoon) by parametric and non-parametric methods for ten rainfall stations (grid centres) five each in Kumoan and Garhwal regions using IMD gridded rainfall data of 113 years (1901 to 2013). She also informed about the processing of TRMM rainfall data being processed. Mrs Sarkar informed about the further work that will be carried out for rainfall comparison for different sources if rainfall. Working group members noted the progress of the study as well as appreciated the work.
13	Study on effect of climate change on sediment yield to Pong reservoir Study Group: A. R. Senthil Kumar J. V. Tyagi Avinash Agarwal Suhas Khobragade Manohar Arora DOS: April 2015 DOC: March 2018	Dr. Suhas D Khobragade, Co- PI of the project presented the objectives, methodology and the progress made during January 2016 to March 2016. The sediment inflow to Pandoh reservoir located in the upstream of the Pong reservoir is not observed and it is an important input to the SWAT model. The Co-PI presented the sediment yield to Pandoh reservoir computed from the sediment observed at Mandi downstream of Pandoh reservoir using the average trap efficiency of Bhakra and Pong reservoir. The sediment volume computed to Pandoh reservoir is 3924.485 Mm^3 which is much higher than the reservoir volume of 41 Mm^3. The Co-PI informed that information of sediment yield to a reservoir similar to Pandoh would be collected and used. The Co-PI also informed that the study would be merged with the NMSHE (National Mission for Sustaining the Himalayan Eco-system) project in case the required information was not available.
14	Study of regional drought characteristics and long term changes in supplemental irrigation water requirement in Seonath Basin in Chhattisgarh Study Group: R.P. Pandey Rakesh Kumar DOS: April 2015 DOC: March 2017	The Head Surface Water Hydrology Division reported an over view about the progress of studies and subsequently invited Dr R.P. Pandey, PI of the project to make presentation and explain the details of the work done and the progress of study after the previous Working Group meeting held during 08-09 December 2015. Dr Pandey presented the complete progress on preparations of base-maps, methodology used in the analysis and results of the work done under this study. He informed that the occurrence of droughts in various parts of Seonath basin have been major concern of crop failure and acute water shortages from time to time. He informed that the Seonath river basin is the longest tributary of the Mahanadi basin draining three districts of Chhattisgarh namely Durg, Rajandgaon and Bilaspur. The drainage area of the Seonath river basin is 30,860 Sq km. which comprises nearly 25% of the upper catchment of the Mahanadi basin.In the presentation, the working group was informed that the analysis of meteorological data has progressed well. The analysis of variability and long-term trends of meteorological variables (i.e. rainfall, maximum & minimum temperature, humidity, wind speed and the evapotranspiration have been carried out for annual and seasonal time scales. Dr Pandey informed that the study will be continue for the next years to

		achieve the objectives of the study and to determine Long Term Trend in net irrigation requirement and changes in total Irrigation Water Demand (IWD). It is expected that this study will yield objective quantification of changes in irrigation water demand over past 50 years and projections for the next 50 years. He informed that the progress of the study is satisfactory.
15	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India Study Group: Ashwini Ranade DOS: Oct 2014 DOC: March 2017	Dr. Ashwini Ranade, PI of the project presented the overview of the project with objectives and progress done in last six months. She has also presented some important results of the study. The working group has well appreciated the work on onset and withdrawal of monsoon and extreme rain events.
	New Studies	
16	Snow cover variability in the Upper Yamnotri Basin Study Group: Naresh Kumar Manohar Arora Rakesh Kumar DOS: Oct 2016 DOC: March 2018	Shri Naresh Kumar proposed a new study entitled, "Snow cover variability in the Upper Yamnotri Basin". In this study, snow cover variability in the Upper Yamnotri Basin will be studied and snow depletion curves for Upper Yamnotri Basin will be developed. For this study MODIS Mod 10 A2 data will be down loaded from National Snow and Ice Data Center (NSIDC) and will be used for Snow cover analysis of the study area and preparation of snow depletion curves for the study area for different years. The study will be completed by June 2018. The beneficiaries of this study will be the stakeholders in the downstream. It will be a valuable input for the modelling studies to be undertaken for the Yamnotri Basin.
17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data Study Group: S.K. Singh DOS: April 2016 DOC: March 2017	Dr S. K. Singh proposed this new study of one year duration covering the application of developed generalization of GEV-2 and GEV-3 distribution to extensive Indian data-set (flood data at various GD sites) available/collected at NIH and CWC. In an earlier report, the practical unification of both type 2 and type 3 GEV distributions in a single GEV was taken up and a simple and an optimization methods for estimation of its parameters were considered with limited testing/application for flood frequency analysis At this stage there was no comment from the members.
18	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Dr. S. K. Singh presented the intended objectives of the study specifically utilizing/on the data collected during the Saph-Pani project completed at NIH, as (1) To apply and illustrate on the above surface-water groundwater interaction data, the developed and published analytical models by the author, a

	Study Group: S.K. Singh DOS: April 2016 DOC: March 2019	complied detail of which has earlier been submitted to our Ministry and Institute both directly and indirectly; (2) To possibly develop new analytical models if application on the data as at item 1 suggests so; (3) The items 1 and 2 are also with the aim to suggest general application of these and other methodology concerning the area of surface-water groundwater interaction in general with respective merits/demerits. It is an application study in which the developed methodologies and analyses by the author are intended to be applied on the concerning data collected at NIH as stated above. The intended development of new analytical model and methodology would be along those adopted in the development of earlier such models by the author. At this stage, there was no comment from members.

WATER RESOURCES SYSTEM DIVISION

Suggestion/comments received from members during 44th working group meeting (18-19 April, 2016)

Dr. Sharad K Jain, Scientist "G" and Head (WRS Div.), presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. He also informed about the upcoming National Hydrology project (NHP), the project on National Mission for Sustainable Himalayan Ecosystem (NMSHE), and involvement of scientists of the division in other activities. Subsequently, Dr. M. K. Goel (MKG) gave an overview of NMSHE. Following are the comments received from working group on the presentations of the various studies.

NIH_Basin – A WINDOWS based model for water resources assessment in a river basin

PI: Dr. M. K. Goel, Scientist "G"

MKG made a brief presentation of the study and informed about the various modifications that have been introduced in the modeling methodology till date. He informed that after the last working group, considerable efforts have been made in developing an excel-based procedure for preparing interactive data files, to run an executable program with the data files, and evaluate the results in MS-Excel. This procedure has been developed for an ongoing project related to Krishna basin study and the same is planned to be followed in the present case also. A brief demonstration of the procedure was demonstrated in the meeting.

MKG clarified that the procedure will help in avoiding the development of a separate code in Visual Basic for the linkage of various data files and programs. He said that because of extensive efforts in this development, the finalization of the main program for the river basin model is still in progress. He requested to extend the time frame for the present study by one year which was agreed by the members. No specific queries were raised during the presentation.

Glacier change and glacier runoff variation in the upper Satluj river basin

PI: Dr. Sanjay K. Jain (SJ), Scientist "G"

SJ informed the house that glacier change study for the upper Satluj basin have been completed and presented in the previous meeting. He informed that the data base for modeling snow/glacier melt runoff has been completed. The future projections for rainfall and temperature from IIT Bombay have been received recently. Now snow/glacier melt runoff vis a vis climate change will be studied. SJ asked for extension of six months for completion of the study. House granted the permission of extension.

Modelling of Narmada Basin using GWAVA Model (Ongoing)
PI: Dr. Sanjay K. Jain (SJ), Scientist "G"

Mr. P. K. Mishra (PKM) presented the status as well as the progress of the study. He informed that all the mandatory input files, viz., Physical Parameter files, Water Demand Files and Climate Files in the required format have been completed. The crop data file has also been done. A pre-calibrated run of the model has already been done, but with an over estimation of flows. Few bugs in the Pre-processor have been removed at CEH and a new version of PREPROCESSOR.EXE has been sent by CEH recently. There is some error in flow direction of grids based on the automated extraction in ArcGIS. Single site calibration of the model with minimum data requirements is expected to be completed by May 15, 2016. Dr. Reddy recommended to revise the Objective 1. The suggestion has been noted and will be addressed.

Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra
PI: D. S. Rathore (DSR), Scientist "F"

Work progress for the study was presented by Mr D.S. Rathore. During the period, work was carried out pertaining to drought index and water quality modelling. Standardised Precipitation Index (SPI) of 1 to 4 month scale was used to estimate probabilities of occurrence of drought and mild dry conditions for monsoon months (June- September). In case, SPI is lower than 1 in any period, the drought condition was assumed. In case of negative values, mild dry condition was assumed. SPI values estimated from cumulative rainfall values for 1 to 4 months June onwards. Drought and mild dry probabilities were 20 and 10% respectively. Probabilities for percent deficit rainfall (June-September) classes <20, 20-40, 40-60 and >60 were also estimated. Excel based procedure was developed for computed catchment wise non point and point source pollutant loading and distribution of the load based on runoff values. Maximum generated pollutant load was simulated for conservative transport and low values of decay coefficients. The values simulated were higher than observed pollutant concentration and thus it will be possible to calibrate the model using suitable coefficients. Dr D.V. Reddy pointed out that in view of ongoing large scale drought conditions in India, drought prediction aspect may be looked into. Director suggested to analyze the current data for the purpose.

Development of Ganga Information Portal
PI: D. Chalisgaonkar (DC), Scientist "F"

In absence of the PI (DC), it was informed that the study is progressing well.

Catchment scale evaluation of cold-arid cryospheric system hydrology, Ganglass catchment, Ladakh
PI: Dr. Renoj J Thayyen (RJT), Scientist "D"

This project is aimed to evaluate the catchment scale hydrologic processes of the cold-arid regime. RJT informed about the progress made after the last working group. Winter and summer mass of Phuche glacier is calculated during this period and found to be positive. Discharge at 4700m asl is derived from the AWLR data and found to be highest since the monitoring began in this catchment. RJT informed about the delay in procuring the soil thermometers for the permafrost study. No specific suggestions received for this study.

Runoff modelling of Shyok River, Karakorum Range
PI: Dr. Renoj J Thayyen (RJT), Scientist "D"

This project is being executed in coordination with Border Roads Organisation (BRO) at km 150 of Durbuk—DBO axis. Since the last working group snow cover depletion curves for the basin have been developed. It is found that the most of the basin become snow free by June itself but the discharge starts increasing significantly since July, suggesting large contributions from glacier dominant areas. RJT informed that runoff modelling is hampered due to delay in procurement of AWS for the basin and no other temperature and precipitation information is available from the basin. No specific suggestions received for this project.

RJT also informed about two newly sanctioned sponsored projects by SERB titled "Mass and Energy balance of Phuche and Khardung glaciers Ladakh range" and NMHS project , where NIH is co-lead entitled "Dynamics of Himalayan Ecosystem and its impact under changing climate scenario"

Study of hydrological changes in selected watersheds in view of climate change in India

PI: Dr. L. N. Thakural (LNT), Scientist "C"

LNT presented the objectives, methodology and the status of the ongoing study. Hydro-meteorological data namely rainfall, temperature and discharge data processed for Ramganga and Bina river basins and its preliminary analysis carried out was presented. The status of the GIS database prepared using remote sensing data (Land sat 8 imagery) and NBSS & ULIP data for Land use/Land cover and soil maps respectively in ERDAS 9.3 and ARCGIS 9.3 environment for these basins were also deliberated. The preliminary analysis rainfall data at 3 month scale prepared for the drought characterization using SPI method for these river basins was also presented in the meeting. Ground water data processing and in turn generation of fluctuation map for the Bina river basin for year 2014 was also presented. No specific suggestions were received for this project.

Hydrological Processes and Characterization of Lesser Himalayan Catchments (Ongoing)

PI: Shri M. K. Nema (MKN), Scientist "C"

While presenting the progress of the study, MKN informed that the study is experimental in nature and requires setting up variety of instruments in the proposed catchments, which is a time-taking and challenging job particularly in Himalayan conditions. He informed that the stream gauging structures at both the stream have been completed and manual monitoring is also being done since Feb, 2016. One AWS has also been installed and data is being received at NIH, Roorkee Servers. He further updated that work order for AWLR has been placed and installation is yet to be done. No major comments were made by the WG members.

Studies on Temporal Variation of Sediment Yield in a Hilly Watershed of Upper Ganga Basin, Uttarakhand

PI: Dr. P. K. Singh (PKS), Scientist "C"

PKS presented the progress report of the project. Shri C.P. Kumar asked about the initial soil moisture (V_0) proposed to be incorporated in the time distributed sediment yield model development. The PI informd that the V_0 will be incorporated in the basic proprtionality concept ($Q/P\text{-}I_a = F/S$) in volumetric terms to account for the moisture before the storm. Dr. S.K. Bartarya, WIHG, Dehradun suggested to explore the possibility of incorporating the dissolved solids loads along with suspended sediment load. A suggestion regarding sampling of bed load was also emerged during discussion. However, it was decided that the possible inclusion of both the aspects will be explored in the next monsoon season.

Assessing Climate Change Impact across KBK (Kalahandi-Bolangir-Koraput) region of Odisha (Completed)

PI: Shri P. K. Mishra (PKM), Scientist "B"

Being a completed study, PKM presented objective-wise final results of the study. Shri Mishra presented the trend for rainfall (110 years), temperature (102 years), and potential evapotranspiration (102 years) for the eight districts coming under KBK region. The year having considerable shift in rainfall and temperature pattern in the region has also been presented. PKM presented the downscaled future rainfall and temperature for the region using HadCM3 Global Climate Model (GCM) for A2 and B2 scenarios. He also presented the water availability and utilization for the Tel basin, and discussed the outputs from the Soil and Water Assessment Tool (SWAT) modeling carried out for the Tel basin.

Hydrological modeling of a part of Satluj basin using SWAT model
PI: Shri P. K. Agarwal (PKA), Scientist "B"

The progress of the study was presented by PKA before the members of the Working Group. It was informed that data processing and preparation is in progress. Spatial data have been prepared in the format required by SWAT. PI informed that the required discharge data at Harike will be collected shortly. No specific comments were received from the members of the Working Group.

WORK PROGRAMME FOR THE YEAR 2016-2017

SN	Title	Study Team	Duration	Funding (Rs. in Lakhs)
CompletedSponsored/ Internal Studies				
1.	Assessing climate change impact across KBK region of Odisha	P. K. Mishra Sharad K. Jain Sanjay K. Jain	3 Years (04/13-03/16)	NIH (28)
Ongoing Internal Studies				
1.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel Sharad K. Jain DeepaChalisgaonkar Prabhash K. Mishra	3 Years (04/13-03/16)	NIH (16)
2.	Glacier change and glacier runoff variation in the upper Satluj river basin	Sanjay K. Jain Sharad K. Jain Renoj J. Thayyen	2.5 Years (10/13-03/16)	NIH (12)
3.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Thayyen S. P. Rai Sanjay K Jain Sudhir Kumar	3 years (04/14-03/17)	NIH (48)
4.	Hydrologic Modelling of a part of Satluj Basin using SWAT Model	P. K. Agarwal Sharad K. Jain Tanvear Ahmad M. K. Goel Sanjay K. Jain M. K. Nema	2 -3/4 Years (06/14-03/17)	NIH (23)
5.	Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra	D. S. Rathore M. K. Goel, R.P. Pandey Sanjay Kumar Surjeet Singh	2 years (07/14-06/16)	NIH (34)
6.	Modeling of Narmada basin by using the GWAVA model	Sanjay K. Jain Sharad K. Jain T. Thomas (RC-Bhopal) P. K. Mishra P. K. Agarwal M. K. Nema	2.25 years Dec. 2014 – Mar 2017	NIH
7.	Runoff modeling of Shyok River, Karakorum Range	Renoj J.Thayyen Sanjay K.Jain	3 years Dec-2014 to Nov.2017	NIH (38)
8.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain Sanjay K. Jain Renoj J.Thayyen P. K. Mishra P. K. Agarwal	5 Years 12/14-12/19	NIH+
9.	Development of Ganga Information Portal	DeepaChalisgaonkar Sharad K. Jain	3 years (04/15-03/18)	MoWR (65.55)

		D. S. Rathore Sanjay K. Jain Sudhir Kumar P. K. Mishra P. K. Agarwal M. K. Nema		
10.	Study of hydrological changes in selected watersheds in view of climate change in India.	L. N. Thakural D. S. Rathore Surjeet Singh Tanvear Ahmad Sanjay K. Jain Sharad K. Jain	3 years (04/15-03/18)	MoWR (44.30)
11.	Studies on Temporal Variation of Sediment Yield in Hilly Watershed of Upper Ganga Basin, Uttarakhand	P.K. Singh Sharad K. Jain Sanjay K. Jain M. K. Nema	2 Years 01/16-12/17	NIH (8.20)
New Sponsored Study for the year 2016-2017				
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen Farooq Azam P.G. Jose A.P. Dimri	3 Years (03/16-02/19)	SERB (65.14)
2.	NMSHE SUB-PROJECTS	-	-	-

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Progress Under Work Programme For Year 2015-2016

SN	Title of Project/Study, Study Team	Status and Recommendations/Suggestions
1.	Water conservation and management in Ibrahimpur Masahi village of Haridwar district (Uttarakhand) **Team:** Omkar Singh, V.C. Goyal, Dinesh Kumar DOS: April 2013, DOC: March 2016 (extended upto Sept., 2016)	The study was presented by Shri Omkar Singh (PI). The PI requested for 6 months extension to carry out the task of preparing a water conservation plan in this study, which was agreed by the WG.
2.	WEAP Model set up for four sub-basins under Pilot Basin Studies (PBS) Programme, jointly with the RCs/CFMSs **NIH HQs:** Jyoti Patil and V C Goyal (PBS Leader) **Co-investigators from NIH RCs/CFMSs:** Chandramohan T (RC-Belgaum), Y R S Rao (RC-Kakinada), T R Nayak (RC-Bhopal), B Chakravorty (CFMS-Patna), R V Kale (RC-Jammu) DOS: Apr 2015, DOC: Mar 2017	The study was presented by Dr. Jyoti P Patil. Database development and draft WEAP model setup is under progress. Shortcomings of the study are inaccessible classified data of Mahi river and demo/ training needed by RCs. There was no specific comment from the WG members.
3.	Customization of WEAP model for application in Ur river watershed in Tikamgarh district of Bundelkhand region. **(Under TIFAC Project)** **Team:** R V Kale (PI Till Feb,2016), T Thomas-RC Bhopal, Jyoti Patil, Rajesh Agarwal, DOS: Apr 2014, DOC: March 2016 (completed).	The study was presented by Dr. Jyoti P Patil. This was completed study and efforts made by team were well appreciated by the WG members. There was no specific comment except to understand the optimization process of WEAP model.

WORK PROGRAMME FOR YEAR 2016-2017

SN	Title of Project/Study	Study Team	Duration	Funding
	Internal Studies			
1.	**Study- 1 (RMOD/2015-16/TS-1)** Water Conservation and Management in Ibrahimpur Masahi Village of Hardwar District (Uttarakhand)	Omkar Singh (PI), V C Goyal, Dinesh Kumar	DOS: Apr 2013 DOC: March 2016 (requires 6 month extenstion)	NIH
2.	**Study-2 (RMOD/2015-16/TS-3)** WEAP Model set up for four sub-basins under Pilot Basin Studies (PBS) Programme, jointly with the RCs/CFMSs	**NIH HQs:** Jyoti Patil (PI), V C Goyal **NIH RCs/CFMSs:** Chandramohan T (Belgaum), Y R S Rao (Kakinada), T R Nayak (Bhopal), B Chakravorty (Patna), R V Kale (Jammu)	DOS: Apr 2015 DOC: Mar 2017 (Ongoing study)	NIH
	Sponsored Projects			
3.	Integrating hydrology, climate change and IWRM with livelihood issues: Development of methodology and a DSS for water-scarce Bundelkhand region in India- preparation of final report	V C Goyal (PI), T Thomas, Jyoti Patil, Rajesh Agrawal	DOS: Aug 2013 DOC: Jul 2016	TIFAC (Rs 56.64 lakh)
4.	IWRM Based Development Plan for Water Security in Four Districts of Bundelkhand Region in India	V C Goyal (PI), Omkar Singh, Jyoti Patil, T R Nayak, Ravi Galkate, T Thomas, R K Jaiswal, Shashi P Indwar, Subhash Kichlu, Rajesh Agrawal, Dinesh Kumar	DOS: Apr 2016 DOC: Dec 2016	MoWR, RD & GR (Rs 299.4 lakh)
5.	Development of a DSS for Hydrology and Watershed Management in Neeranchal Project	V C Goyal (PI)	DOS: May 2016* DOC: Mar 2021	DoLR (GoI)

*Final approval from the DoLR (GoI) is awaited.

Dr. V C Goyal thanked the members for their valuable contributions during deliberations in the Working Group meeting.

The meeting ended with vote of thanks to the Chair.

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ANNEXURE-I

List of Working Group Members who attended the 44th WG meeting

1.	Er. R.D. Singh, Director, NIH	Chairman
2.	Dr. S.K. Bartarya, WIHG, Dehradun	Member
3.	Dr. D V Reddy, CSIR-NGRI, Hyderabad	Member
4.	Dr. G P Juyal, CSWCRTI, Dehradun	Member
5.	Dr. S K Mittal, CSIR-CSIO, Chandigarh	Member
6.	Er. Kireet Kumar, GBPIHED, Almora	Member
7.	Dr. S S Grewal, Chandigarh	Member
8.	Er. R K Khanna, New Delhi	Member
9.	Dr. S.K. Jain, Sc. G & Head WRS Division, NIH	Member
10.	Dr. N C Ghosh, Sc.G & Head GWH Division, NIH	Member
11.	Dr. Rakesh Kumar, Sc. G & Head SWH Division, NIH	Member
12.	Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH	Member
13.	Dr. C K Jain, Sc.G & Head EH Division, NIH	Member
14.	Dr. V C Goyal, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from National Institute of Hydrology, Roorkee

	EH Division		**SWH Division**
1	Dr. M.K. Sharma, Sc.D	17	Dr. J.V. Tyagi, Sc.G
2	Dr. Rajesh Singh, Sc.C	18	Dr. Avinash Agarwal, Sc.G
3	Dr. Pradeep Kumar, Sc.C	19	Dr. A.K. Lohani, Sc.G
	GWH Division	20	Dr. S.K. Singh, Sc.F
4	Er. C.P. Kumar, Sc.G	21	Dr. R.P. Pandey, Sc.F
5	Dr. Anupama Sharma, Sc.D	22	Dr. Sanjay Kumar, Sc.D
6	Dr. Surjeet Singh, Sc.D	23	Dr (Mrs) Archana Sarkar, Sc.D
7	Er. Sumant Kumar, Sc.C	24	Dr. Manohar Arora, Sc.D
8	Ms. Suman Gurjar, Sc.C	25	Sh. Digamber Singh, Sc.C
9	Dr. Gopal Krishan, Sc.C	26	Sh. J.P. Patra, Sc.C
	HI Division	27	Dr. Ashwini A. Ranade, Sc.C
10	Dr.Suhas Khobragade, Sc.E	28	Sh. Naresh Saini, Sc.B
11	Dr. M.S. Rao, Sc.D		**WRS Division**
12	Sh. S.K. Verma, Sc.D	29	Dr. Sanjay Jain, Sc.G
13	Sh. P.K. Garg, Sc.B	30	Dr. M.K. Goel, Sc.G
	RMO Division	31	Er. D.S. Rathore, Sc.F
14	Er. Omkar Singh, Sc.F	32	Dr. Renoj J. Thayyen, Sc.D
15	Dr. Jyoti Patil, Sc.C	33	Dr. L.N. Thakural, Sc.C
16	Dr. Hitendra Singh, Sc.C	34	Sh. Manish Nema, Sc.C
		35	Dr. P.K. Singh, Sc.C
		36	Sh. P.K. Mishra, Sc.B
		37	Sh. Tanveer Ahmad, Sc.B
		38	Sh. P.K. Agrawal, Sc.B

ANNEXURE – B

Division-wise Work Programme

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. C K Jain	Scientist G & Head
2	Dr. M K Sharma	Scientist D
3	Dr. Rajesh Singh	Scientist C
4	Sh. Pradeep Kumar	Scientist C
5	Smt. Babita Sharma	RA
6	Smt. Bina Prasad	RA

Work Programme for the year 2016-17

S.No.	Study	Study Team	Duration
	Internal Studies		
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams	Pradeep Kumar C. K. Jain	2 Years (04/16-03/18) Status: In-progress
	Sponsored Projects		
1.	Low Cost Technology for Purification of Arsenic and Microbes Contaminated Water using Nanotechnology	Vijaya Aggarwala, IITR (PI) Rama Mehta, NIH (Co-PI)	2 Years (04/14-03/16) Extended for 6 months. Sponsored by: DST Status: Completed
2.	Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier	M. K. Sharma (PI) C. K. Jain Renoj Thayyan Manohar Arora Naresh Saini Jatin Malhotra Rakesh Goyal Shyam Lal	3 Years (05/14-05/17) Sponsored by: DST Status: In progress Project Cost: 32.8 lacs Progress: In-progress
3.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI), NIH Manohar Arora, NIH M. K. Sharma, NIH Pradeep Kumar, NIH D. S. Malik, GKU	5 Years (04/16-03/21) Sponsored by: DST Project Cost: 2.25 Crore Status: In-progress
	Consultancy Projects		
1.	Petroleum Product Contamination at Akolner Village, District Ahmednagar, Maharashtra and Suggesting Remedial Measures	C. K. Jain (PI) Sudhir Kumar B. Purendra Anupma Sharma M. K. Sharma	One Year (10/15 – 09/16) Sponsored by: MPCB Amount Rs. 54.72 Lacs Status: Completed
2.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines	C. K. Jain (PI) Sudhir Kumar Y. R. S. Rao Anupma Sharma S. D. Khobragade M. K. Sharma Pradeep Kumar	15 Months (04/16 – 06/17) Sponsored by: NTPC Amount Rs. 54.96 Lacs Status: In-progress

Training Courses Organized

S.No.	Topic	Sponsored by	Venue	Period
1.	Advanced Instrumentation Techniques: Hands-on-Training	CPCB, Delhi	NIH Roorkee	19-21 Dec. 2016
2.	Hands on Advanced Instruments of Water Quality Monitoring and Testing	MoWR, RD & GR, New Delhi	NIH Roorkee	16-20 Jan. 2017
3.	Water Quality and its Management	MoWR, RD & GR, New Delhi	NIH Roorkee	20-24 Mar. 2017

Study – 1 (Internal Study)

1. **Title of the Study:** Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams

2. **Study Group:**

Project Investigator Dr. Pradeep Kumar, Sc. 'C'
Project Co-investigator Dr. C. K. Jain, Sc. 'G', EHD
Scientific/Technical Staff Nil

3. **Type of Study:** Internal

4. **Nature of Study:** Applied Work

5. **Date of start:** April 2016

6. **Scheduled date of completion:** March 2018

7. **Duration of the Study:** 2 Years

8. **Study Objectives:**

   i) To compile the data/information on biotic parameters (abundance of aquatic species) and influencing abiotic parameters (water depth & velocity and water quality parameters: water temperature, pH, DO, BOD, turbidity etc.)
   ii) To identify the significant relationships between biotic and abiotic parameter and among the biotic parameters at selected locations
   iii) To establish the habitat suitability curves for aquatic species and habitat parameters

9. **Statement of the Problem:**

A large number of water resources projects (mostly hydropower schemes) in the western Himalaya are in different stages of development. These projects are altering the flow regime either due to storage or diversion of water. The river reach is deprived of its natural flows due to water diversion at control structure. There may be critical reaches in the river where altered flows are not able to sustain the ecosystem services existing prior to implementation of these types of projects. The developmental planning process in eco-sensitive and fragile Himalayan mountainous region should ensure that the biodiversity and ecological integrity of the aquatic and terrestrial ecosystems are protected and conserved. In this view, the environmental flow assessment has become imperative for the Himalayan rivers. However, due to lack of knowledge base on the biotic and abiotic interactions, the assessment of environmental flows in India has been mostly limited to hydrological and hydraulic methods. In this connection, the present study has been envisaged for developing the habitat suitability curves (relationships between abiotic and biotic parameters) for the aquatic species of the western Himalayan streams.

10. Approved Action Plan / Methodology:

Work Element	Duration of total project work							
	1st year				2nd year			
	I	II	III	IV	I	II	III	IV
Identification of data/ information on baseline biotic and abiotic parameters of western Himalayan streams and site selection	■	■						
Compilation of biotic and abiotic data/information			■	■				
Identification of relationships between biotic and abiotic parameters					■	■		
Development of habitat suitability curves						■	■	
Synthesis and report writing								■

11. Objectives and achievement during last one year:

Objectives	Achievements
To compile the data/information on biotic parameters (abundance of aquatic species) and influencing abiotic parameters (water depth & velocity and water quality parameters: water temperature, pH, DO, BOD, turbidity etc.)	The data related with biotic (density of phytoplanktons, zooplanktons, macroinvertebrates, fish) and abiotic parameters (water temperature, pH, DO, turbidity, Nitrates, Phosphatesetc.) of western Himalayan streams have been collected through different agencies. The baseline data of biotic and abiotic parameters have been compiled for 48 western Himalayan streams. Out of these 48 streams, three tributaries of Satluj river (Gambhar, Gamrola and Seer), three tributaries of Beas river (Sainj, Tirthan and Suketi) and two tributaries of Ravi river (Panjpula and Chaner) have been selected due to availability of detailed information.
To identify the significant relationships between biotic and abiotic parameter and among the biotic parameters at selected locations	The graphs between biotic and abiotic parameters and also among biotic parameters have been prepared. Different mathematical relationships are being tried to find out the significant relationships.

12. Recommendation / Suggestion: Nil

Recommendation / Suggestion	Action Taken

13. Analysis & Results:

The graphs between biotic and abiotic parameters and also among biotic parameters have been developed to find out the significant relationships. The fish species richness has been found significant with altitude, air temp., water temp., conductivity and alkalinity. No significant relationship has been found between fish species richness and water velocity, DO, turbidity, chlorides and phosphates. The fish species richness is found to be significantly correlated with the density of vertebrates, zooplanktons and phytoplanktons in the decreasing order. No significant relationship has been found between fish species richness and macro-invertebrates density.

14. **End Users / Beneficiaries of the study:** Water Resources Development Project Proponents.

15. Deliverables: Technical Report & Research Papers

16. Major items of equipment procured: None

17. Lab facilities used during the study: None

18. Data procured or generated during the study:

Baseline information on the biotic and abiotic parameters of 48 western Himalayan streams (tributaries of Ravi, Beas, Satluj, Yamuna, Alaknanda and Bhairathi) has been procured from various sources.

19. Study Benefits / Impacts:

Measurable indicators	Achievements

20. Involvement of end users/beneficiaries: Nil

21. Specific linkage with Institution and /or end users/beneficiaries: Nil

22. Shortcoming/Difficulties: No

23. Future Plan:

i) Identification of relationships between biotic and abiotic parameters
ii) Development of habitat suitability curves
iii) Synthesis and report writing

Study - 2 (Sponsored Project)

1. Title of the Study: Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier

2. Study Group:

Project Investigator Dr. M. K. Sharma, Sc. 'D'
Co-Investigator Dr. C. K. Jain, Sc. 'G' Dr. Renoj Thayyan, Sc. 'D' Dr. Manohar Arora, Sc. 'D' Sri. Naresh Saini, Sc. 'B'
Scientific/Technical Staff Sri. Jatin Malhotra, SRA Sri. Rakesh Goyal, Tech. Gr. I Sri. Shyam Lal, JRF

3. Type of Study: Sponsored Project by DST, New Delhi, Budget: Rs 32.80 lacs

4. Nature of Study: Applied Research

5. Date of start: May 2014

6. Scheduled date of completion: May 2017

7. Duration of the Study: 3 Years

8. Study Objectives:

i) To characterize the seasonal variability of the major-ion chemistry of glacial meltwater.
ii) Chemical characterization of the suspended sediment of Gangotri glacial system
iii) To study ionic enrichment dynamics of meltwater-glacial sediment interaction
iv) To investigate open and closed system low temperature ionic enrichment process

9. Approved Action Plan/Methodology:

i) Literature survey through international publications (research papers/ reports)
ii) Reconnaissance survey of Gangotri glacier catchment for site selection.
iii) Collection Suspended sediment samples and meltwater samples from selected sites seasonally.
iv) Chemical analysis for major cations, anions and trace metals in the collected suspended sediment and meltwater.
v) Geochemical analysis of suspended sediments
vi) Study of closed system characteristics and open system dynamics
vii) Dissolution experiments of glacial meltwater-suspended sediment interaction

10. Timeline:

Activity	2014-15				2015-16				2016-17			
	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.
Literature survey												
Reconnaissance Survey												
Collection of SS and meltwater samples												
Chemical analysis of SS and meltwater samples												
Geochemical analysis of SS												
Open and close system study												
Dissolution experiments of glacial meltwater -SS interaction												
Interim Report Writing												
Final Report Writing												

11. Progress:

i) Processed suspended sediment samples collected from Gomukh, Bhojwasa and Gangotri for the ablation period of year 2016 for measurement of suspended sediment concentration.

ii) Chemical analysis of meltwater samples collected from Gomukh, Bhojwasa and Gangotri on Ion Chromatograph has been completed.

iii) Dissolution experiments of glacial meltwater-suspended/bed sediment interaction considering different operating variables viz; different months, different sediment particle sizes, different sediment dose, effect of wetting and crushing completed.

iv) XRF analysis for Geochemical study of suspended/bed sediment completed.

v) Processing of hydro-chemical data and report writing is under progress.

12. Research Outcome from the Project:

The research outcome of the project envisage the chemical enrichment processes of Gangotri glacier melt water in the pro-glacial zone and provide strong basis extending studies of solute variability and sediment and pollutant loading further downstream.

Study - 3 (Sponsored Project)

1. Title of the Study: Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin

2. Study Group:

Project Investigator/Co-Project Investigator Dr. C. K. Jain, Sc. 'G' Dr. Manohar Arora, Sc. 'D'
Co-Investigator Dr. M. K. Sharma, Sc. 'D' Dr. Pradeep Kumar, S. 'C'
Scientific/Technical Staff Sri. Rakesh Goyal, Tech. Gr. I
Collaborating Agency Prof. D. S. Malik, Professor, GKU, Haridwar

3. Type of Study: Sponsored Project by DST, New Delhi, Budget: Rs 2.24 Crore

4. Nature of Study: Applied Research

5. Date of start: April 2016

6. Scheduled date of completion: March 2021

7. Duration of the Study: 5 Years

8. Study Objectives:

i) To study ecology, biodiversity and water quality of Upper Ganga Basin
ii) To study in-stream reactions and sediment dynamics of Upper Ganga Basin
iii) To assess environmental flows in critical stretches of River Ganga

9. Approved Action Plan/Methodology:

i) Water quality assessment through comprehensive field and laboratory investigations.
ii) Monitoring point and non-point source pollution
iii) Adsorption characteristics through laboratory scale model studies.
iv) Kinetics and thermodynamics of adsorption process through experiment approaches.
v) Monitoring temporal abundance of different aquatic species at selected locations
vi) Monitoring aquatic habitat parameters (depth, velocity, slope, gradient, substrate, pH, conductance, water temperature, DO, BOD, COD, TDS, salinity, etc.) at selected locations
vii) Assessment of aquatic biodiversity: Phytoplankton, zooplankton, benthos and piscine fauna (distribution, species richness and abundance as per their habitat)
viii) Impact assessment of environmental flows in relation to productivity of River Ganga
ix) Estimating environmental flows in critical reaches

10. Timeline:

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Recruitment of Project Staff										
Equipment/software procurement										
Literature survey										
Field investigations										
Sample collection and analysis										
Adsorption characteristics										
Habitat characteristics										
Aquatic biodiversity										
Environmental flow estimations										
Report preparation										

11. Progress:

i) Water quality assessment through comprehensive field and laboratory investigations on monthly basis.
ii) Monitoring temporal abundance of different aquatic species (Phytoplanktons, Zooplanktons, Macro-Benthos) at selected locations.
iii) Monitoring aquatic habitat parameters (depth, velocity, slope, gradient, substrate, pH, EC, TDS, temperature, DO, BOD, COD, etc.) at selected locations.

12. Research Outcome from the Project:

The present investigation will help in understanding the basic hydrology and associated water quality, ecology and biodiversity in Upper Ganga Basin for sustainable development of natural resources so that ecosystem stability is maintained. As a number of water resource projects are coming up in the Ganga Basin, the values of environmental flows in the critical reaches of the river will help in environmental clearance of the water resources projects.

Proposed Work Programme 2017-18

S.No.	Study	Study Team	Duration
Internal Studies (Contd.)			
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams	Pradeep Kumar C. K. Jain	2 Years (04/16-03/18) Status: In-progress
Sponsored Projects (Contd.)			
1.	Ionic Enrichment Dynamics of Glacial Sediment and Melt water of Gangotri Glacier	M. K. Sharma (PI) C. K. Jain Renoj Thayyan Manohar Arora Naresh Saini Jatin Malhotra Rakesh Goyal Shyam Lal	3 Years (05/14-05/17) Sponsored by DST Status: In progress Project Cost: 32.8 lacs Progress: In-progress
2.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	C. K. Jain (PI), NIH Manohar Arora, NIH M. K. Sharma, NIH Pradeep Kumar, NIH D. S. Malik, GKU	5 Years (04/16-03/21) Sponsored by DST Project Cost: 2.25 Crore Status: In-progress
Consultancy Projects (Contd.)			
1.	Study on Ash Disposal from Telangana STPP into Mine Void of Medapalli Open Cast Mines	C. K. Jain (PI) Sudhir Kumar Y. R. S. Rao Anupma Sharma S. D. Khobragade M. K. Sharma Pradeep Kumar	15 Months (04/16 – 06/17) Sponsored by: NTPC Amount Rs. 54.96 Lacs Status: In-progress
Proposed PDS			
1.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) C. K. Jain Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur A. K. Shukla Ashok Verma P. C. Das	2 Years

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. N C Ghosh	Scientist G & Head
2	Er. C.P. Kumar	Scientist G
3	Dr. Anupma Sharma	Scientist E
4	Dr. Surjeet Singh	Scientist E
5	Er. Sumant Kumar	Scientist C
6	Ms. Suman Gurjar	Scientist C
7	Dr. Gopal Krishan	Scientist C
8	Mrs. Anju Choudhary	SRA
9	Sri Sanjay Mittal	SRA
10	Sri S.L. Srivastava	SRA
11	Sri Ram Chandra	RA

APPROVED WORK PROGRAMME OF THE DIVISION FOR THE YEAR 2016-17

S. No.	Project	Project Team	Duration & Status	Funding Source
1. NIH/GWD/ NIH/15-18	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.	N.C. Ghosh (Project Coord. & Lead), C.P. Kumar, B. Chakraborty, Y.R.S. Rao, Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Choudhury, Sanjay Mittal, Ram Chandar, Staff of SW Lab	21/2 year (11/15 – 4/18) **Status: In progress**. Project cost : **Rs. 375 lakh**	Sponsored by MoWR, RD & GR under Plan Fund.
2. NIH/GWD/ NIH/14-17	Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin	Anupma Sharma (PI), N.C. Ghosh, Coordinator Scientists from GWHD and EHD in association with Prof. Deepak Kashyap, IIT Ropar, as Technical Consultant	3 years (12/14 – 11/17) Status: **In progress**.	Internal Funding.
3. NIH/GWD/ NIH/15-16	Alternate water supply management strategies in arsenic affected/ vulnerable areas: Mapping of Arsenic affected zones/regions in Eastern U.P	Sumant Kumar (PI) N.C. Ghosh, Rajesh Singh, Suman Gurjar, Palash Debnath S.L. Srivastava, Anju Choudhary	1 year (04/15 – 3/17) **Status: Completed.**	Internal Funding.
4. NIH/GWD/ NIH/15-16	Web Enabled "Groundwater Recharge Estimation Model (WE-GREM) ".	Suman Gurjar (PI), N.C. Ghosh, Sumant Kumar, Surjeet Singh, Anupma Sharma	1 year (08/15 – 3/16) **Status: Completed.**	Internal Funding.
5. NIH/GWD/ NIH/16-17	Groundwater fluctuations and conductivity monitoring in Punjab.	Gopal Krishan (PI), N.C. Ghosh, Surjeet Singh, Dan Lapworth (PI from UK) Alan MacDonald (Project Coordinator)	1 year (04/16 – 03/20) **Status: In progress. Project cost : £. 11,800**	Sponsored by BGS, UK
6. NIH/GWD/ NIH/16-17	Baseline data collection and analysis of hydrological and hydrogeological data of Mewat district, Haryana.	N.C. Ghosh (Project Coordinator), Gopal Krishan (PI), Surjeet Singh, C.P. Kumar, Brijesh Yadav (IITR), Lalit Mohan Sharma (Sehgal Foundation, Gurgaon)	1 year (03/16 – 03/17) **Status: Completed.**	Internal Funding.
7. NIH/GWD/ NMSHE/16-21	Study of river - aquifer interactions and groundwater potential at selected sites in the upper Ganga basin up	Surjeet Singh (PI), N.C. Ghosh, R. J. Thayyen, S. P. Rai, Manohar Arora,	1 year (03/16 – 02/21) **Status: In progress.**	Sponsored by DST under NMSHE SP-8.

	to Dabrani.	Gopal Krishan,	**Project cost : Rs. 125 lakh**	
8. NIH/GWD/ NIH/16-16	Web Enabled "Conjunctive Use Model for Management of Surface and Ground Water using concept of MAR and ASR".	Suman Gurjar (PI), N.C. Ghosh, Sumant Kumar, Surjeet Singh Anupma Sharma	08 Months (04/16 – 11/16) **Status: In progress.**	Internal Funding.
9. NIH/GWD/ NIH/16-16	Evaluation of Saryu Nahar Pariyojna(SNP) National Project in Uttar Pradesh.	N. C. Ghosh (PI) R. P. Singh J. K. Mishra	06 Months (03/16-08/16) Status: **Completed**. **Project cost : Rs. 6 lakh**	Sponsored by MoWR, RD & GR.
10./NIH/G WD/16-17	*Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply"	N. C. Ghosh(Lead) Other Scientists of the division **Collaborators:** IIT Roorkee UCOST, Dehradun UJS, Dehradun HTWD, Germany	2 years(02/16 – 03/18) 4 training courses in two years. (2-completed) **Project cost : Rs. 38.4 lakh**	Sponsored by DST
Consultancy Projects				
11.	Hydrological and Water Quality Study of the Project sites of Rays Power Infra Pvt. Ltd. in Roorkee	N.C. Ghosh (PI), Anupma Sharma, Sumant Kumar, Anju Chaudhary, S.L. Srivastava, Mansi Tripathi, Roque Khokar, N.K. Lakhera, C.S. Chowhan, Dinesh Kumar	**06** Months (**03/16-08/16**) Status: **Completed**. **Project cost: Rs. 3 lakh**	Sponsored by Rays Power Infra Pvt. Ltd.
12.	Evaluation of Water Level Networks to identify Suitable Piezometers for Installation of Digital Water Level Recorders in Districts of North UP	N.C. Ghosh (PI), Sudhir Kumar, Anupma Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, R.P. Singh, Anju Choudhary, Sanjay Mittal, S.L. Srivastava	08 Months (11**/16-05/17**) Status: **In progress**. **Project cost : Rs. 17.7568 lakh +** 15% service tax	Sponsored by Ground Water Deptt., Govt. of UP
13.	Groundwater recharge source in deep aquifer using isotopes in Punjab		02 Months (05/17-306/17) Status: **In progress**.	Sponsored by Department of Water Supply and Sanitation, Punjab
New Studies				
14. NIH/GWD/	Grey Water to Blue Water – Natural	N.C. Ghosh (Project Leader), Anupma	3 years (11/16-10/19)	Sponsored by NWM, MoWR,

NIH/16-19	Treatment Techniques for Transforming Wastewater into Sustainable Useable Water	Sharma, Surjeet Singh, Sumant Kumar, Suman Gurjar, Anju Choudhury, Sanjy Mittal, Ram Chandar, Staff SW Lab - IIT Bombay (Partner) -UJS (Partner)	**Status: New Study.** **Project partners:** IIT Bombay UJS, Dehradun **Project cost :** **Rs. 160. 785 lakh +** service tax.	RD & GR
15.NIH/GWD/NIH/17-17	Feasibility of Managed Aquifer Recharge in NCT, Delhi	NIH-Roorkee (Lead) CGWB, New Delhi	6 months (2/17-7/17) Status : New study	Desired by Secretary, WR, RD & GR
Proposed New Studies of Year : 2017-2018				
Proposed PDS				
1.	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi	Anupma Sharma (PI)	4 years	NHP under Centre of Excellence for Hydrologic Modeling
2.	Ganges aquifer management in the context of monsoon runoff conservation for sustainable river ecosystem services – A pilot study	Surjeet Singh (PI)	4 years	Under NHP
3.	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Surmant Kumar (PI)	3 years	Under NHP
4.	Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures	Gopal Krishan (PI)	3 years	Under NHP

The detailed status of the studies is given in Annexure-I.

Forthcoming Important Activity

AGGS's 7th International Ground Water Conference **(IGWC-2017)** on **"Groundwater Vision 2030: Water Security, Challenges and Climate Change Adaptation"** in association with CGWB, AGGS and Texas A&M University,USA during 11th -13th December, 2017 at New Delhi.

Convener:

- Dr. N. C. Ghosh

Organizing Secretary from NIH

- Dr. Anupma Sharma

Joint-Org. Secretary from NIH

- Dr. Surjeet Singh,.

1. PROJECT REFERENCE CODE: NIH/GWD/NIH/15-18

Thrust Area under XII five year Plan: Drinking water supply demonstration scheme.

Title of the Project: **Peya Jal Suraksha -** Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply.
Project duration : 30 months (November, 2015 – April, 2018).
Sponsored by : MoWR, RD & GR, GoI. Under NIH's Plan Fund.

Objectives of the Project:

(i) Baseline investigations and development of pilot demonstration sites for riverbank filtration (RBF) in different hydrogeological settings;
(ii) Performance and limitations analysis of RBF schemes;
(iii) Effectiveness of RBF technique in different river-aquifer settings and river flow conditions;
(iv) Analysis of RBF under variable pollutants loads and flood situations;
(v) Development of technical elements for flood-proof water abstraction schemes; and
(vi) Scope of extending the technique in attaining drinking water security.

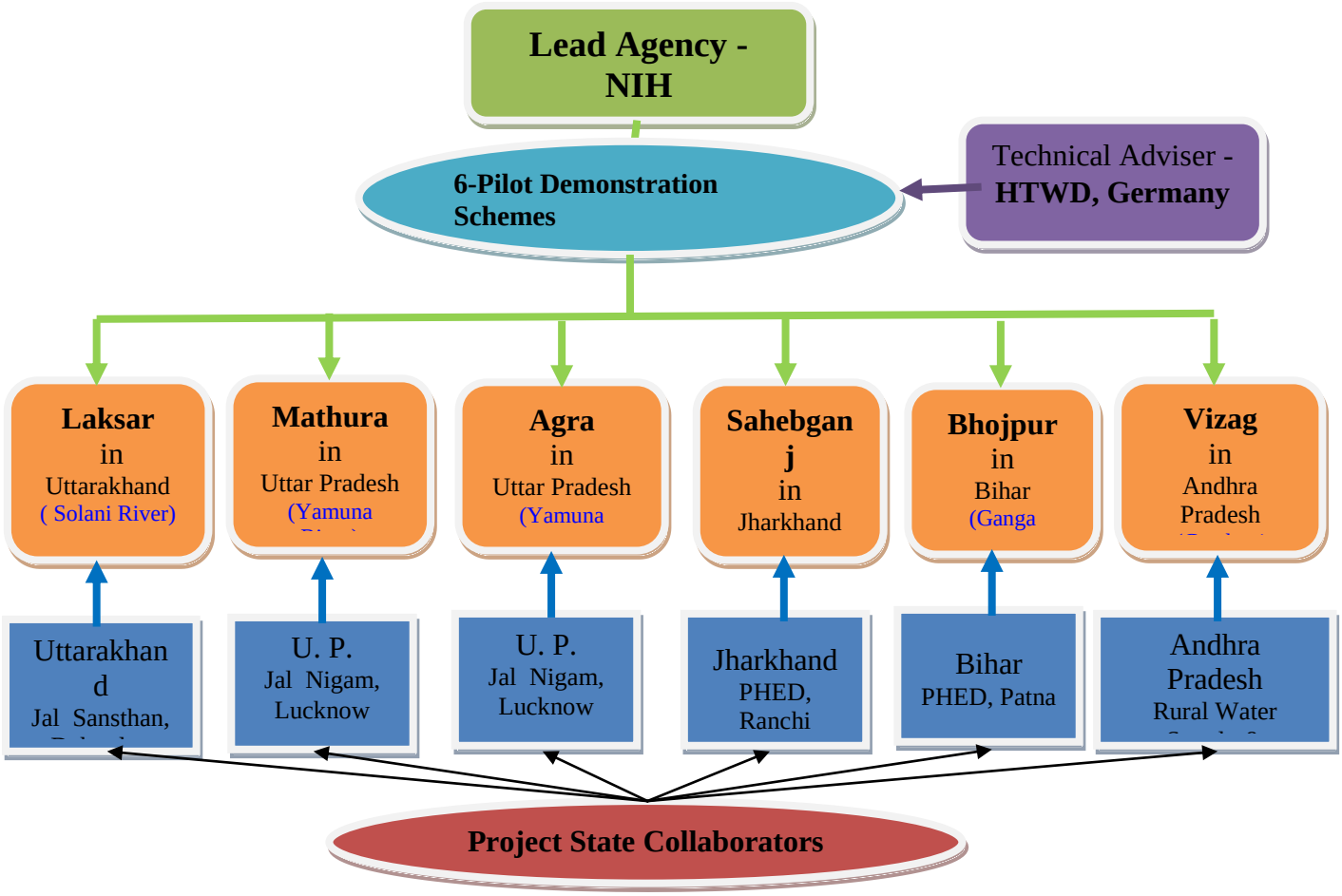


Figure 1 : Involvement of collaborators in different pilot schemes.

Methodology

Six pilot demonstration schemes in 5 states, viz. One in Uttarakhand (Laksar along Solani river), two in Uttar Pradesh (Mathura and Agra along Yamuna river); one in Jharkhand (Sahebganj along Ganga river); one in Bihar (Bhojpur area along Ganga river), and one in Andhra Pradesh (Visakhapatnam area) are to be developed. Respective State Jal Sansthan/PHED/Jal Nigam are the

collaborating partner for the schemes. HTWD, Germany is the associated partner as scientific and technical adviser.

The roles of State Jal Sansthan/PHED/Jal Nigam aree towards extending administrative and logistic supports in the field including identification of sites and providing required land for the scheme and electricity facilities for installation of tube wells and O & M of the pumps. A schematic line-diagram showing involvement of collaborating partners is given in **Figure 1.**

Project deliverables

As deliverables, six schemes demonstrating effectiveness of 'Riverbank Filtration' technique for sustainable drinking water supply in different hydrogeological settings, river hydraulic and groundwater conditions will be developed and these schemes after thorough investigations will be handed over to the respective state 'Jal Sansthan' to use them as the guiding scheme towards attaining drinking water security. Few officers from different states will also be trained on scientific and technical aspects of "Riverbank Filtration" technique. This aspect can be regarded as the capacity building on advanced tools and techniques of the state water supply department.

Progress made so far:

(i) Laksar Site, Uttarakhand:

One RBF site was developed at Kuan Khera village in Laksar UK. Drilling of bore well was done (Photograph-1) and the RBF well was developed. During heavy flood in the year 2016 in Solani river, the exploratory RBF well was damaged by bank erosion and the river bank had been shifted towards other side (Photograph-2) . On the other hand, the site featured problem of groundwater quality of geogenic origin. These trobleshoot led to ***abandoned*** the site selected at Kuan Khera village.

Photograph 1: Drilling work for RBF well RBF Development.

Photograph 2 : Dislocated riverbank of the site by erosion during 2016 flood.

(ii) Mathura and Agra Sites

Two sites; one in Mathura and the other one in Agra are to be developed. For selecting the feasible site in both the places, following activities carried:

Data collection

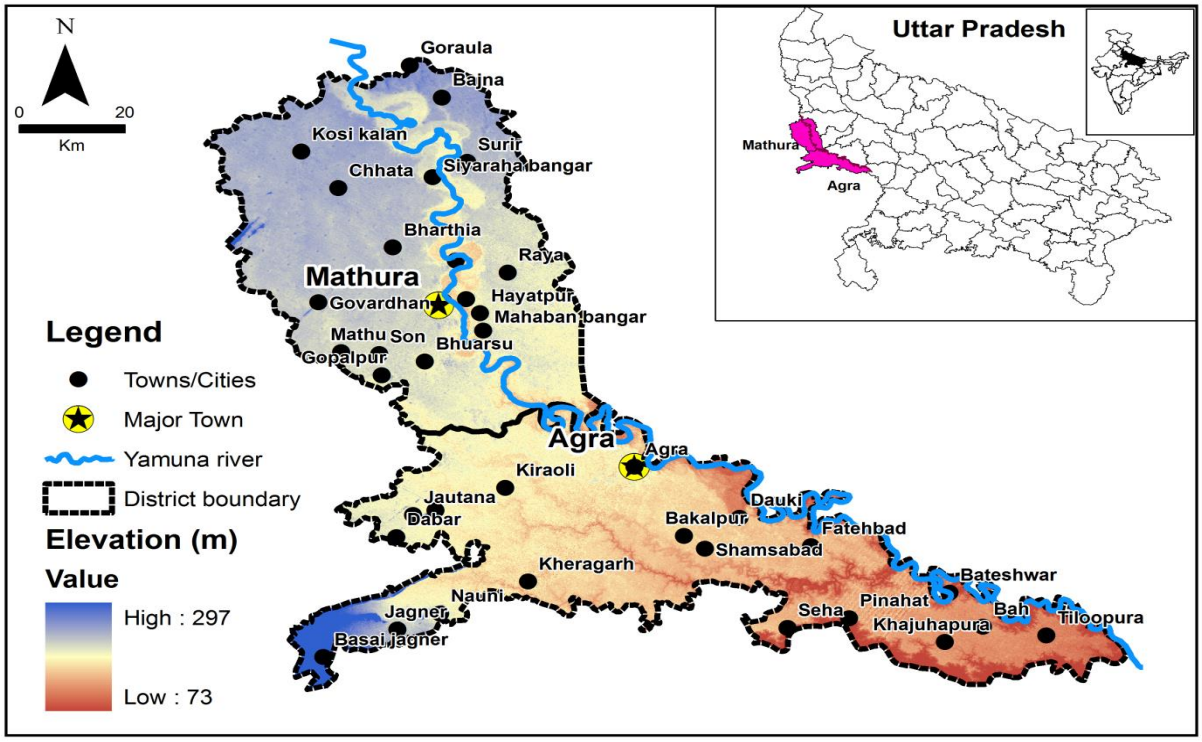
- *meteorological data*
- *river flow data at Agra & Mathura GD site*
- *soil and land use*
- *groundwater level data of Agra and Mathura districts*
- *groundwater quality data of Agra and Mathura districts*

Water sampling

- *eight times river and groundwater sampling carried out for water quality and isotopic analysis*

Analysis of temporal data

- *analysis on rainfall, temperature and river flow data.*
- *analysis of groundwater quality data collected from GW Deptt., Govt. of UP.*



Based on the analysis of baseline data, water quality of river and ground water, and isotopic data, RBF scheme at both the places are seemed feasible, subject to verification of river-aquifer connectivity by exploratory drilling. U.P. Jal Nigam has suggested developing RBF scheme at Fatehabad, in place of near to Agra city area, to provide drinking water supply in Fatehabad area. The RBF site in Fatehabad along the Yamuna has also seemed feasible. Thus, two sites in U.P. stand as: Mathura near Gakul barrage, and Fatehabad. However, the development of RBF schemes in both the places is subject to local hydraulic conditions between the river and aquifer that will be decided based on exploratory boring.

Following are under progress:

The exploratory borings and installation of tube wells shall be carried out through U.P. Jal Nigan as deposit work. Estimate (Rs. 16.52 lakh for both the sites) for the same has been obtained and a draft MoU/Agreement for undertaking the exploratory borings and installation of tube wells at Fatehabad and Mathura has been sent to U.P. Jal Nigam for consent. After signing the MoU/Agreement, the exploratory boring work and installation of wells will be taken up through U.P. Jal Nigam as deposit work for Mathura and Fatehabad site.

(iii) Arrah site in Bihar

Based on a number of field visits along with Bihar-PHED officials, Berhara village in Arrah district in Bihar has been decided for development of RBF scheme.


Photographs : Selected site in Behara village of Ara district in Bihar.

It has been decided to take up the exploratory boring and installation of tube well through Bihar-PHED as deposit work. Accordingly, estimate (Rs. 1.0057 lakh) from the Bihar-PHED was obtained and a draft MoU for taking up the task as deposit work has been sent to Bihar- PHED for consent.

(iv) **Vishakapattanam, A.P.**

For the RBF scheme in Vishakapattanam**,** the site along Varaha River at **Vishakapatnam** has been selected in consultation with A.P. RWS & S, Govt. of Andhra Pradesh. It has been decided to take up the exploratory boring and tube well installation through A.P. RWS & S, Govt. of Andhra Pradesh as deposit work. Estimate (Rs. 3.25 lakh) for the exploratory boring & development of RBF well has been obtained and a draft MoU/Agreement for undertaking the task has been sent to A.P. RWS & S for consent.


Photograph : Selected RBF site along Varaha River at Vishakapatnam.

(v) Sahebganj, Jharkhand

The RBF site in Sahebganj (Jharkhand) is yet to decide in consultation with Jharkhand-PHED.

2. PROJECT REFERENCE CODE: NIH/GWD/INT/14-17

Title of the study: **Management of Water Resources for Quantity and Quality in Yamuna-Hindon Inter-basin**

Type of study (sponsored/consultancy/referred/internal): Internal

Date of start: December 2014

Duration of study: Three years

Study objectives:

- *Numerical modeling for optimal management of surface water and groundwater in Yamuna-Hindon inter-basin*
- *Strategies for groundwater management associated with climate variability events*
- *Assessment of surface water and groundwater quality degradation due to disposal of municipal and industrial effluents and impact on groundwater pumpage*

Need for study and Specific linkages with Institutions and/or end-users/beneficiaries: Severe water quality degradation issues have affected domestic and irrigation water supply in the fertile Yamuna-Hindon inter-basin. Need to develop strategies for conjunctive management of water resources in the region.

Index map of the study area.

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Data collection	Historical groundwater level data from State and Central Ground Water Depts., crop cultivation, relevant reports and maps, meteorological data, data collection during field visits including soil moisture, depth to water levels, TDS, etc.
Field experiments and Laboratory investigations	- Collection of soil samples and water samples from Hindon river and groundwater - Soil sample analyses in laboratory for texture analysis, soil moisture characteristics - Chemical analyses of water samples (river water and groundwater) for trace metals during pre- and post-monsoon season
Database preparation	DEM, land use, soil texture, drainage, groundwater levels (pre & post monsoon), water quality
Data analysis and Groundwater modeling	- Analysis of water table and water quality data, satellite data, land use; analysis of soil samples and data for infiltration rates and saturated hydraulic conductivity. - Groundwater modeling in Yamuna-Hindon interbasin

Adopters of the results of the study and their feedback: Study yet to be completed

List of deliverables (e.g. equipment, papers, reports, softwares, manuals, brochures, flyers, training programs, users interaction workshops)

- Reports
- Research Papers

Lab facilities used during the study:

- Soil and Water Lab, NIH
- Water Quality Lab, NIH
- Institute Instrumentation Centre, IIT Roorkee

Future plan:

- Numerical simulations

3. PROJECT REFERENCE CODE: NIH/GWD/INT/15-16

Title of the study: Alternate water supply management strategies in arsenic fected/vulnerable areas: Mapping of Arsenic affected zones/regions in Eastern U.P

Type of study : Internal
Date of Start : 1st April, 2015
Scheduled Date of Completion : 31st March, 2016 (1 year extension)
Location Map : Study area is Ballia district in eastern U.P.

Objectives

(i) Baseline data collection & diagnosis survey of the area affected by and vulnerable to arsenic contamination.
(ii) Arsenic (As) risk zone mapping for Ballia district.

End users/beneficiaries of the study:

The proposed study is undertaken in light of the recommendation given by Inter-Ministerial Group (IMG) on "Arsenic Mitigation" constituted by Ministry of Water Resources, River development & Ganga Rejuvenation and Public Accounts Committee (PAC, eighth report, 16th Lok Sabha) on 'Water Pollution in India'. PAC recommended under Groundwater Pollution: "Alternate sustainable programmes be launched for ensuring supply of arsenic-free water through conjunctive use of surface water and in situ groundwater after thorough scientific studies". The proposed study will be a step forward in understanding the root causes and magnitude of arsenic contamination in eastern U.P. and for attaining sustainable supply of arsenic safe groundwater to affected areas.

Approved action plan

- Literature Review
- Field Investigations & Data Collection
- Sample Collection, analysis & interpretation
- Risk zone mapping

Objectives & Achievements

Baseline data collection & diagnosis survey of the area affected by and vulnerable to arsenic contamination	Baseline data have been collected from U.P Jal Nigam and CGWB, Lucknow (Allahabad unit). Literature review and field investigations have been done to identify the location or area affected by arsenic in Ballia.
Arsenic risk zone mapping for Ballia district	WQ sampling, chemical analyses and interpretation has been done for the water samples. The data are fed to Arc-GIS to prepare the Arsenic distribution map.

Analysis and Results: Literature survey has been done to understand the causes for occurrence of As in GW. Areas affected by arsenic in Ballia district have been identified through literature. Water Quality sampling was done in pre- monsoon (year 2016) for all the seventeen blocks of Ballia district. The chemical analyses results revealed that out of 17 blocks 12 blocks are contaminated by As(As> 50 ppb). As concentration in the studied samples was found to be in the range of 0- 461 µg/L, the enrichment was encountered in the

sampling sites that were close to the convergences of Ghagra and Ganges river. Furthermore, the results revealed that major portion mainly in the newer alluvium plain shallow depth groundwater of Ballia District are contaminated by As. Based on the geo-chemical analyses, an As distribution map have been developed for the study area.

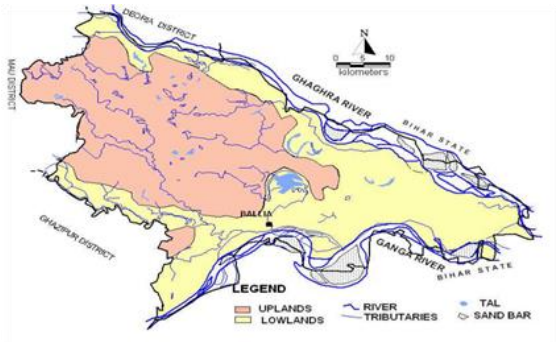


Figure : Map showing hydro-geological Setup and river routes in Balia district.

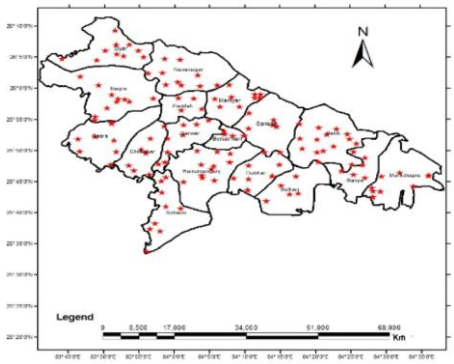
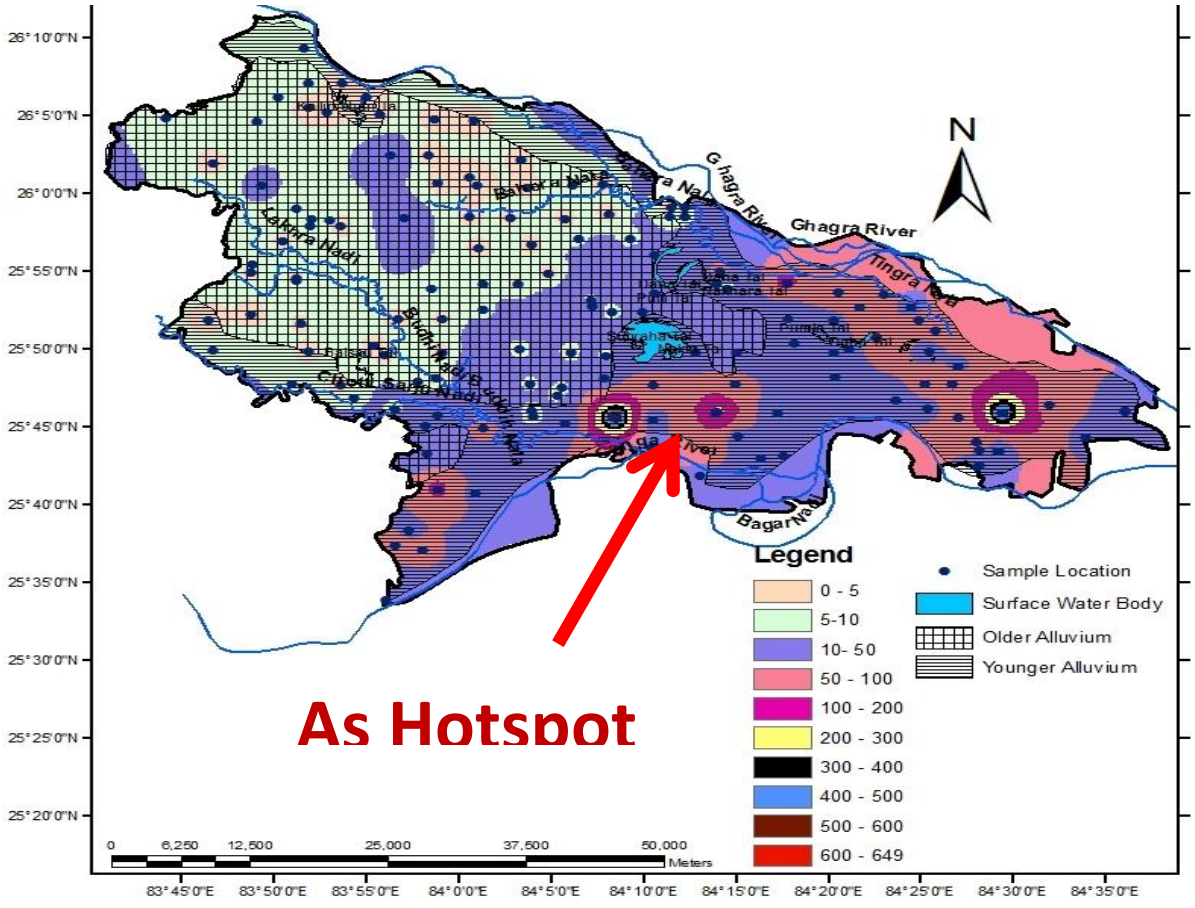


Figure : Distribution of 148 sampling locations in Balia district



Map showing spatial distribution of Arsenic concentration in Balia district

4. PROJECT REFERENCE CODE: NIH/GWD/INT/15-16

Title of the Project: Web Enabled "Groundwater Recharge Estimation Model (WE-GREM) "

Type of study: Internal

Nature of study: Outreach Services.

Duration: August 2015-March 2016

Objectives:

- To develop a comprehensive user friendly web-enabled time-varying "*Groundwater Recharge Estimation Model*".
- To provide a platform to users and professionals for calculating time-varying depth of water in, and groundwater recharge from, a surface water body without using any third party software.
- To facilitate users and professionals in estimation of groundwater recharge from a large surface water body and depth of water in it and to visualize the output in graphical as well as tabular format.
- To host the module in the public domain for its large uses by stakeholders and groundwater professionals.

Methodology:

- A semi-analytical mathematical model to estimate unsteady groundwater recharge resulting from variable depth of water in a large waterbody, influenced by time variant inflows and outflows has been developed.
- The model has been derived by integrating Hantush's (1967) analytical expression for water table rise due to recharge from rectangular basin into water balance equation of waterbody.
- The model has provision of direct inputs and to calculate of various hydrological components of the water balance equation. These components include evaporation rate, inflow rate, outflow rate, rainfall etc.
- The module has the platform to provide direct values of input variables and also to calculate the variable using mathematical equations. For example, to calculate inflow rate from rainfall, SCS-CN method is used, and to calculate evaporation rate Pan Evaporation Method, Mass Transfer Method and combination of Penman and Priestley-Taylor Method are used.
- The results will be in the form of graphical format, interactive charts and tables.

Progress made so far:

- Development of Web-enabled Groundwater Recharge Estimation Model (WE-GREM) has been completed and the working version of the model together with a comprehensive help module and the technical document have been uploaded in NIH's website (www.nihr@gov.in) .
- As of now, more than 2000 people visited the uploaded model.

5. PROJECT REFERENCE CODE: NIH/GWHD/NIH/2015-16

Title of the study : Groundwater fluctuations and conductivity monitoring in Punjab

Type of study : Sponsored, BGS, UK.

Date of start (DOS) : April, 2017

Scheduled date of completion : March, 2020

Location : Bist- Doab Punjab

Study objectives:

- To characterize multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers,
- To prepare a status report on groundwater issues in Punjab

Whether Study is a New Study/Extension of Previous Studies: Presented in 43rd WG meeting

Methodology:

In this study, groundwater level and conductivity data are monitored and high resolution field based observations are collected. For this the loggers for water level and conductivity have been installed in 4 shallow piezometers of PWRED, Chandigarh at Saroya (Kandi region), Bhogpur, Kapurthala and Sultanpur Lodhi in 2014.

From the water level data for the 4 sites: Saroya, Bhogpur, Kapurthala, Sultanpur Lodhi, It has been observed that the groundwater level depth at Saroya, Bhogpur and Kapurthala increased during the Kharif season (June to October) perhaps as a result of excessive abstraction for irrigation during this period (Krishan et al., 2014b). The groundwater level at Sultanpur Lodhi was almost constant. The results for conductivity show at:

Saroya: The conductivity starts rising abruptly in the month of March, 2015

Bhogpur: A continuous decline in the conductivity was observed from October, 2014 onwards

Kapurthala: There was a slight decline in conductivity during the period October, 2014 to March, 2015 but it again started increasing slightly after March, 2015

Sultanpur Lodhi: During September-October, 2014, some fluctuations were observed but after that the conductivity was almost constant.

Action plan:

Year	**Mar. 2017 to Mar., 2020** (Annexure 1)	Remark
March, 2016 to Mar. 2017	Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects in Punjab Monitoring of water level and conductivity fluctuations in Bist-Doab, Punjab Prepare a status report on groundwater issues in Punjab Presentation of work progress in a workshop/review meeting under the project	Report preparation as per Annexure 1

Study Benefits /Impact:

An overview report on groundwater status in Punjab

- Research publication in high impact journals.
- Upload of results on Websites.

Specific linkages with Institutions: BGS, UK

Progress

- Fund from BGS, UK has been received.
- The field work for downloading the data will be conducted in few days and results will be shown in coming working group meeting.

Future plan

- Field work for downloading conductivity and water level data
- The hydro-meteorological data will be collected from state departments
- Data analysis work will be carried out with respect to various parameters like rainfall, land use etc. to observe the seasonal and spatial variation
- Field work for data downloading will be planned in pre-monsoon season

6. PROJECT REFERENCE CODE: NIH/GWHD/NIH/2016-17

Title of the study	**:**	Baseline data collection and analysis of hydrological and hydrogeological data of Mewat district, Haryana
Type of study	**:**	Applied Research
Date of start (DOS)	**:**	April, 2016
Scheduled date of completion	**:**	March, 2017
Location	**:**	Mewat district, Haryana

Study objectives:

- To collect baseline hydrological, hydrogeological and water quality data of Mewat district
- To analyze and identify the problems and groundwater recharge sources using isotopes

Methodology

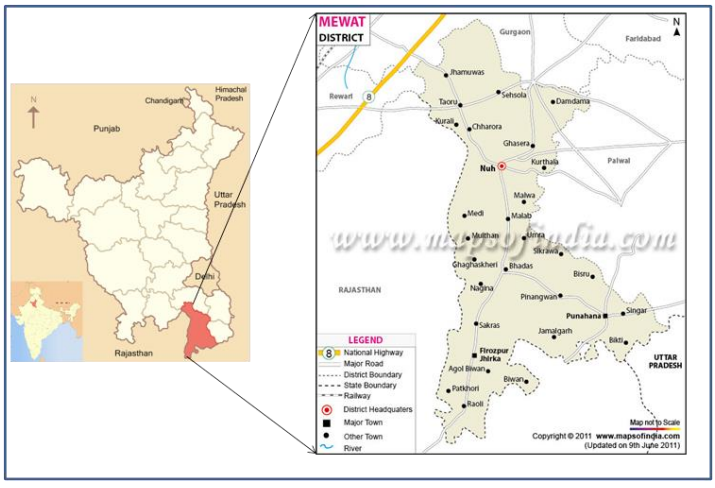
In order to investigate the changing groundwater conditions (quality and quantity), water and soil samples were collected and analysed for salinity, alkalinity and major anions F, Cl, NO_3 & SO_4 and cations Ca, Mg, Na. K. Analysis of stable isotopes of groundwater was also carried out to investigate the groundwater dynamics.

Soil analysis

Soil analysis show that the sandy loam and loamy sand are the major soil types prevailing in the area. The moisture content ranged from 6 to 36%. Bulk density found to range from 1.49 g/cm^3 to 1.84 g/cm^3. Nitrogen and potassium were found low, phosphorus was in medium range. In most of soil samples- Arsenic, cadmium and nickel were found above permissible limits and very high copper, iron, zinc and manganese content.

Field Survey

The survey was carried out in the entire district and which has helped in understanding the water related issues from the perspective of inhabitants of Mewat more critically and holistically. From the survey, in Mewat district it has been observed that the main occupation is farming and majority of farmers have small land holdings (0-3 acre). Groundwater is the main source of irrigation. Mewat district faces mainly 2 water related issues: (i) high groundwater salinity and (ii) declining groundwater levels. The survey results were found matching with the field based observations for TDS and water level for the period 2011-2015.



Map of Mewat district

TDS and Water level data (2011-15)

Taking into account this scenario, we have collected groundwater level and Total dissolved solids (TDS) data for 40 monitoring wells developed by Sehgal Foundation, Gurgaon. The data was taken and analyzed for pre-monsoon and post-monsoon season during the time period of 2011 – 2015. The results shows that groundwater level is decreasing as the decline in minimum, maximum and average groundwater level is 47.5%, 26.26% and 29.03% respectively. For post-monsoon season, the decline in groundwater level is 84.61%, 53.63% and 35.23% for minimum, maximum and average values respectively. Monsoon rains are the only recharging source for the aquifers. Also, TDS decreases with increase in solubility at most of the wells except few. The study is helpful in providing the basic information about the quantity and quality of the groundwater reservoir at Mewat which will further help in facilitating the researches and finding out applicable solutions for the development related to water problems.

Analysis results of water samples

In order to investigate the changing groundwater conditions (quality and quantity), water samples were collected randomly from different sites in the months of March, May, August and November, 2016 using the standard procedures. These samples were analysed for salinity, alkalinity and major anions F, Cl, NO_3 & SO_4 and cations Ca, Mg, Na, K. Analysis of stable isotopes of groundwater carried out to investigate the groundwater dynamics.

The groundwater in many wells which previously contained freshwater has now salinized. Electrical conductivity (EC) ranged from 759 to 32300 µS/cm at 25oC. Around 73% of the district area has been found to have EC value more than 1000 µS/cm at 25oC out of which 86% of the district area is having EC value more than 2000 µS/cm at 25oC. A strong positive correlation (R = 0.9975) is observed between EC and Chloride concentration. The P-Value is < 0.00001. The result is significant at $p < 0.01$; $p < 0.05$; $p < 0.10$. The anion chemistry of the analysed samples shows that the abundance order of $Cl^- > SO_4^{2-} > HCO_3^- > NO_3^- > F^-$ in all the samples. The major cations include Ca, Mg, Na and K, the cations follow dominance order as Na=Mg>Ca>K water type.

Whether Study is a New Study/Extension of Previous Studies: New Study

Action plan:

Year	**Mar. 2016 to Mar., 2017** (Annexure 1)	**Remark**
Apr. 2016 to Mar. 2017	Data collection on available groundwater studies including water table, water quality and other hydro-geological aspects in Mewat district Collection of water and soil samples to assess the salinity conditions Dissemination of outputs in a workshop/review meeting under the project	Report preparation as per Annexure 1

Study Benefits /Impact:

- Problems to be identified
- Continuing the present work in PDS

Specific linkages with Institutions: IIT-Roorkee, Sehgal Foundation-Gurgaon

Data requirement & Expected source: Hydro-meteorological data collected from the Sehgal Foundation, Gurgaon.

7. PROJECT REFERENCE CODE: NIH/GWHD/NMSHE/2016-21

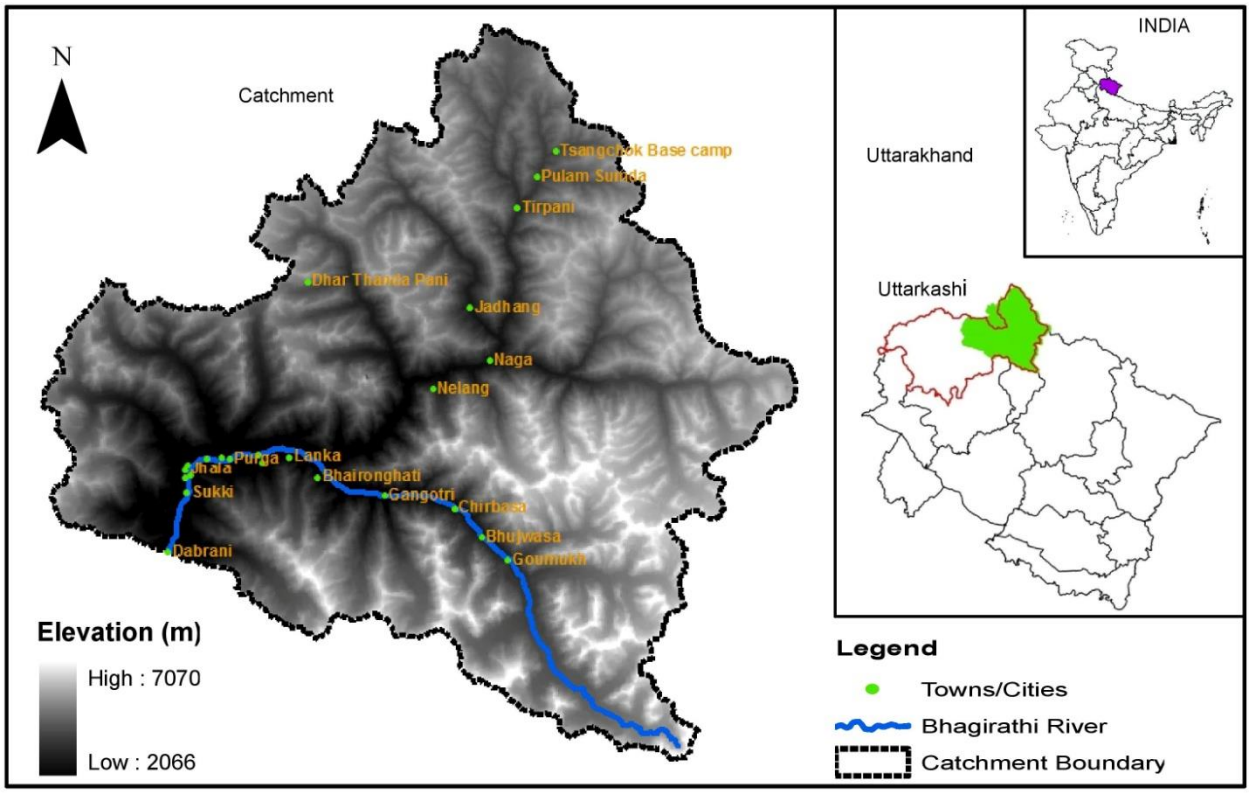
Title of the study : Study of river - aquifer interactions and groundwater potential at selected sites in the upper Ganga basin up to Dabrani

Type of study : Sponsored by DST under NMSHE SP-8

Date of start (DOS) : March, 2016

Scheduled date of completion: January, 2021

Location : Bhagirathi Basin up to Dabrani (Uttarkashi)



Study objectives:

1. Understanding of river-aquifer interaction and dynamics processes in Himalayan environment,
2. Groundwater potential assessment and availability prospects resulting from snow and glacier melt recharge.

Approved Action Plan:

- Collection/procurement of available long-term hydro-meteorological and hydro-geological data for the study area.
- Preparation of various thematic layers (sub-basins, geology, soils, wells, snow cover, drainage, monitoring network, water use, etc.).
- Selection of suitable sites for piezometer development.
- Development of piezometers for monitoring of groundwater.
- Developments of lithologs & aquifer characterization.
- Collection of water samples & monitoring of groundwater levels.
- Analysis on the stream-aquifer interactions and dynamics processes.
- Estimation of groundwater recharge & water potential.

Timeline and Justification for time over runs:

For the development of piezometers, open bids were invited but only single bid was received and hence re-bidding is being done.

Objectives vis-à-vis Achievements:

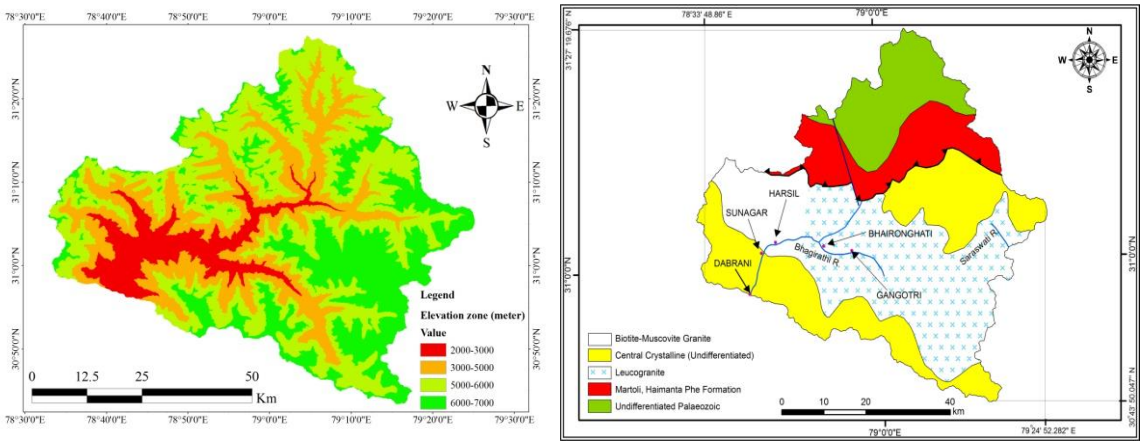
Part of Objectives	Achievements
Literature review	Completed till date.
Database preparation	DEM, drainage, sub-basins, 3D map, slope map, land use, sampling location, geology.
Selection of sites for piezometer development	- Sites were selected. - Map for selected sites also prepared.
Data collection	Geological map, ground surface contour, litho logs of five locations, water quality and isotopic data from water sampling.

Recommendations/ Suggestions in previous meetings of Working Group/ TAC/ GB

Nil.

Analysis of Results:

During various field visits to the study area, work on reconnaissance survey, sampling from surface and ground water for water quality and isotopic analysis and identification of sites for the piezometer development was carried out. Geological traversing was also done to define the geology from Dabrani to Gangotri along the river course and valleys. Following maps show the elevation and geology of the study area.



The landforms were traversed from Dabrani to Gangotri. Bhagirathi River originates from the Gangotri glacier and is the 5th ordered stream which traverses through all major litho-tectonic domains of Himalaya that are neo-tectonically active. The combined effect of rainfall and tectonic instability in area causes excessive land sliding in the region. There are number of recent and old landslides, which have been traced in the traversed area**.** Highest and lowest elevation points of the catchment are 7,070 m and 2,066 m, respectively. Drainage pattern of the Bhagirathi catchment up to the Dabrani is trellis to sub-trellis type. In this type of drainage pattern, all tributaries join main stream at right angle. Trellis drainage pattern is the characteristic of folded mountains. Tributary rivers are flowing through the steep valleys whereas Main River, Bhagirathi, through the less steep but 'V' shaped valleys. Gorges are present at many places such as near the Lanka and Bhaironghati. These gorges are developed in highly jointed granitic rocks having two sets of joints cutting each other at right angles. Glacial deposit e.g. moraine was traced near Gangotri and Lanka and at several places in between. Same trend i.e. NW-SE of the each moraine, indicates about the similar origin. Thickness of the glacial deposit is ranging from 13 to 15 m. Sediments ranging from boulder to cobble size present in the glacier which are sub-angular to sub-rounded and inter-bedded

within the granule size matrix. These glacial deposits are fluvio-glacial in origin as indicated by the mutual arrangement of the sediment and presence of erratic boulders. The collection and testing of water samples for water quality and isotopic analysis is in progress. The sites for piezometer development have been selected at Dabrani, Jhala, Harsil, Dharali and Gangotri.

Adopters of the Results of the Study and their Feedback: Study yet to be completed.

List of Deliverables:

- Reports; Research papers; Training Workshops.

Major Item of Equipment Procured: GPS, pH Meter and EC Meter.

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research.
- Nuclear Hydrology Laboratory.

Data Procured/ Generated during the Study:

- Geological map; Water quality data; Isotopic data; Surface contours.

Study Benefits /Impact:

- Process understanding of groundwater recharge due to glacier and snow melt recharge.
- Understanding dynamics and behavior of soil-snow interface in the snowmelt Himalayan region.

Specific linkages with Institutions: DST, UJS.

Major Items of equipment needed: GPS, Portable WL Indicator, pH and EC meter.

Future Plan:

- Development of piezometers.
- Monitoring of groundwater levels.
- Collection and testing of samples from surface and ground water for quality and isotopic analysis.

8. PROJECT REFERENCE CODE: NIH/GWHD/NIH/2016-16

Title of the study : Web Enabled "Conjunctive Use Model for Management of Surfaceand Ground Water using concept of MAR and ASR"

Type of study : Internal

Nature of study : Outreach Services.

Duration : April 2016 - November 2017

Objectives:

- To develop a comprehensive user friendly web-enabled "*Conjunctive Use Model for Management of Surface and Ground Water in a recharge basin using concept of MAR and ASR*".
- To provide a platform to users and professionals for calculating time-varying depth of water in , and groundwater recharge from, a recharge basin consequent to the pumping in the vicinity of the basin for recovery of recharged water .
- To provide a platform to users to simulate the contaminant transport process in the basin and through saturated soil column before mixing with the groundwater.
- To visualize the output in graphical as well as tabular format.
- To host the module in the public domain as an extension of WE-GREM for its large uses by stakeholders and groundwater professionals.

Methodology:

- An analytical model to determine the recharge rate due to interaction of different hydrological components in a recharge basin including pumping in the vicinity of the basin has been developed.
- The model has been developed based on water balance of recharge basin that includes inflow to the basin, outflow from the basin, and rainfall over the basin, evaporation from the basin and groundwater recharge from the basin. For estimation of different hydrological components processed based equation have been used for example SCS-CN method is used for inflow, Standard models like Pan Evaporation, Mass Transfer, combination of Priestley-Taylor and Penman are used for Evaporation, analytical method Hantush (1967) is used for groundwater recharge and for pumping Thesis(1935) well response function is used.
- To simulate the in-basin transport processes and fate of contaminants through saturated soil column before mixing with the groundwater, the conservation equation with decay for the in-basin mass transport, and the analytical solution of 1-Dimensional advection-dispersion equation (ADE) given by Ogata and Banks (1961) together with the decay and Freundlich linear adsorption isotherm equation for contaminant transport through saturated soil column is used.
- The developed model will be converted into a web-enabled and user friendly interface.
- The interface will be an extension to the WE-GREM.

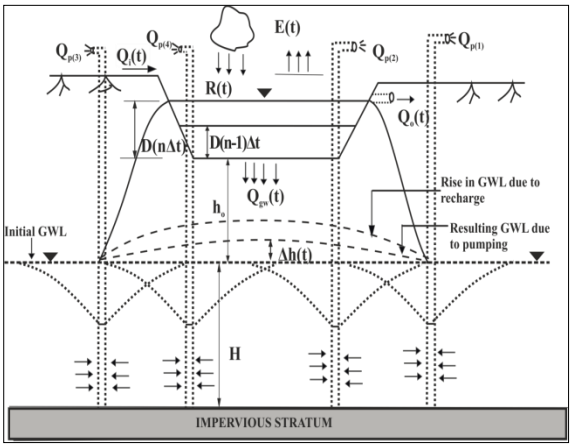


Figure: Schematized MAR & ASR scheme.

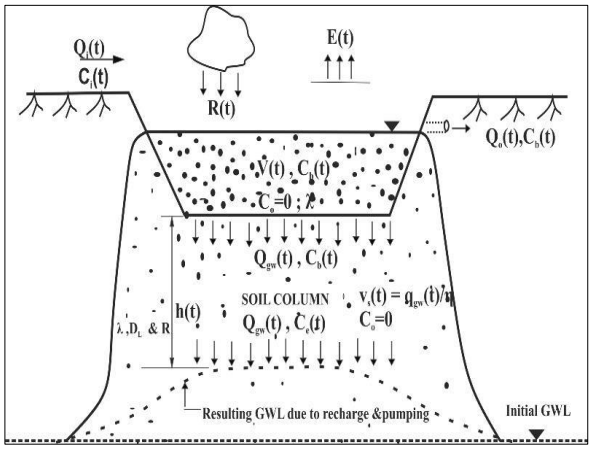


Figure: Schematized contaminant transport processes.

Progress made so far:

- The code of the model is developed and tested, the result have been analyzed on the sample data.
- The Web-enabled interface is under development.

Deliverables:

- Web-enabled system for calculating time-varying depth of water in , and groundwater recharge from, a recharge basin consequent to the pumping in the vicinity of the basin for recovery of recharged water. In addition with the module for calculation of the contaminant's transport in the basin and through saturated soil column before mixing with the groundwater.
- Results will be in the form of charts, tables and graphs.

9. PROJECT REFERENCE CODE: NIH/GWD/INT/16-16

Title of the Project: Evaluation of Saryu Nahar Pariyojna(SNP) National Project in Uttar Pradesh.

Type of study: Sponsored by MoWR, RD & GR

Nature of study: R&D

Duration: March 2016 - August 2016

Progress :

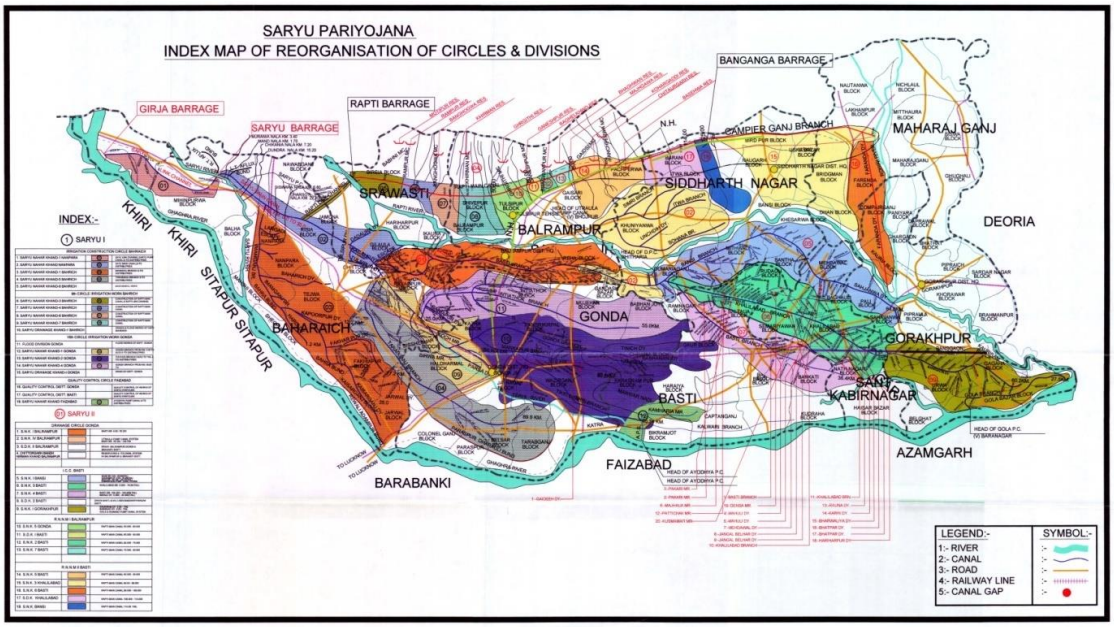
The Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India has entrusted the task to carry out a comprehensive study on the following aspects:

(i) The areas under the SNP command, which were earlier devoid of organized irrigation facilities and were governed by monsoon crops and groundwater based agricultural activities, on its full scale canal based irrigation facilities with limited attention to use of groundwater whether would cause any long term harm to the land-water development practices.

(ii) Whether irrigation return flows and canal seepage together with rainfall recharge during monsoon period would cause any waterlogging condition in the canal command areas?

(iii) Whether scope exist to have conjunctive management of canal water and groundwater to counter possible risks. If feasible, what are the expected regulations and measures?

(iv) Whether there is any futuristic risk/vulnerability to soil salinity because of changing condition of land-water practices.



Index map of the Saryu Nahar Pariyojna showing its command areas, districts, and location of diversion structures.

To evaluate the providence of the above concerns, a comprehensive analysis of hydrological and hydrogeological features of the SNP catchment viz. drainage systems, topography, soils, geomorphology, canal networks, rainfall, lithology, aquifer formations,

groundwater levels & direction, infiltration rate, canal seepage, groundwater quality, etc. was carried out under the GIS framework. All spatial data and related maps were analyzed as per the geographical coordinate systems. The analyzed results were based on the data acquired from IMD-Pune for rainfall, CGWB-Lucknow and UP-GWD for borelongs and groundwater levels, Survey of India maps for topography, etc. The soils textures and soils types classification and infiltration rate estimation were based on the field and laboratory experiments carried out by the NIH.

Based on the extensive analysis of different hydrological and hydrogeological components, results obtained and sulitable recommendations had been proposed to counteract the probable problems. The report had been submitted in the Ministry in October, 2016.

The following conclusions were drawn from the study:

(a) The SNP canal command has widespread susceptibility to waterlogging in few districts. In the long run, the situation may aggravate further, if suitable groundwater management strategy to restrain rise of groundwater table is not adopted.

(b) Areas assessing about 5,783 sq. km (23.4% of the SNP catchment) has been identified as vulnerable to waterlogging for the pre-monsoon period. These areas have been found mainly along Ghaghra River towards eastern land side of Bahraich district, and in some parts of Gonda, Balrampur, Shravasti, Sidharthanagar and Basti district. The vulnerable waterlogging areas are more pronounced and widespread in Bahraich and Gonda district particularly, along the routes of main and branch canals.

(c) During the post-monsoon period, about 90% area of the SNP catchment, nearly 22, 278 sq. km, has shown rise in groundwater table depth $\leq$ 3 m bgl. The fluctuation of groundwater tables between the pre- and post monsoon period varied from 1 m to 2.5 m.

(d) The waterlogging areas of the pre-monsoon period in Bahraich district have been found along and around Imamganj, Tarabganj and Gonda branch canals; in Gonda district along Tarabganj and Manakapur branch canal; and in Balarampur and Sidharthanagar district along Rapti main canal.

(e) It is apprehended that after the full scale development of the canal networks, both the pre- and post monsoon groundwater table may further rise and may aggravate the problem of waterlogging. Thus, to avoid future risk of waterlogging, there is a need to restrain the groundwater table rise mainly, in the vulnerable waterlogging areas by evolving suitable surface and ground water management plan.

(f) The SNP catchment has good feasibility of using solar energy for groundwater pumping. A detailed investigation to that regard is strongly recommended before its large scale endorsement and implementation.

The following recommendations were made:

(i) The SNP has provision to install 3600 tube wells, of which 100 has already been installed. The locations of installing forthcoming 3500 tube wells could be such that they can help contain rise of groundwater table and the extracted groundwater can be fed to the nearby canal system for facilitating irrigation needs in the downstream water demand areas. It is thus recommended that a series of tube wells, one in every 2 km on both sides of the canal at a distance of about 400 m to 450 m away from the canal, can be installed along Imamganj branch canal network in Bahraich district and Tarabganj branch canal in both Bahraich and Gonda district. Few tube wells can be installed along Tikri branch canal in Basti district, and few along Rapti main canal in Balrampur and Sidharthnagar district.

(ii) Currently, canals are operated 8 months (July-February) in a year. To restrain the rise of groundwater table and waterlogging particularly in Bahraich district, it is recommended to pursue both surface and ground water based conjunctive canal water supply during the months November through February; after February until July only groundwater based irrigation water supply can be encouraged. In all other vulnerable areas namely, in Gonda, Basti, Balrampur and Sidharthnagar district, groundwater based irrigation water supply can be adopted during the months February through June.

(iii) To rationalize the conflict of interest on share of groundwater amongst water users, it is recommended to adopt groundwater based canal water supply rather than localized tube well based irrigation water supply to facilitate: (i) transfer of surplus groundwater from the areas vulnerable to waterlogging to the areas that have no threat to waterlogging, and (ii) harmony amongst the users on uses of groundwater.

10. PROJECT REFERENCE CODE: NIH/GWD/INT/16-17

Title of the Project: *Country-wide Capacity Building Program on* "Bank Filtration for Sustainable Drinking Water Supply".

Type of study: Sponsored by DST, Govt. of India (Rs.36.4 lakhs for four training courses)

Nature of study: Outreach Activity

Duration: February 2016 - March 2018

Objectives:

(i) To develop, strengthen and upscale competence on bank filtration technique and its allied aspects in the Country for attaining drinking water security;

(ii) To create a platform of knowledge repositories on bank filtration in the Country, and develop a network to connect & interact with trained personnel for exchanging knowledge.

Methodology:

A total of 4 training courses, each of 5-day duration, are to be organized in two years. In each year, two training courses; one for the states representing Indo-Gangetic and Brahmaputra & Barrack basin covering all eight north-eastern states, West Bengal, Bihar, Jharkhand, Uttar Pradesh, Uttarakhand, Himachal Pradesh, and Delhi and the other one for the all other states namely peninsular states, Odisha, Maharastra, Goa, Gujarat, M.P., Chhattisgarh, Punjab, Haryana, Rajasthan and Jammu & Kashmir are to be organized and same will be repeated for the second year to increase more competent persons in each state.

Deliverables:

- Upscale Process for competence building on "Bank Filtration"
- Services for knowledge dissemination and up-gradation on "Bank Filtration"
- Compiled report on conducted training courses including feedback analysis.

Progress:

As of now, two training courses, the first one for the states representing Indo-Gangetic and Brahmaputra & Barrack basin covering all eight north-eastern states, West Bengal, Bihar, Jharkhand, Uttar Pradesh, Uttarkhand, Himachal Pradesh, and Delhi was organized at NIH, Roorkee during 12^{th} - 16^{th} September, 2016; in which, thirty (30) participants had attended the training course; the second training course for the states of Tamil Nadu, Karnataka, Kerala, Pudicherry, Andhra Pradesh, Telengana, Odisha, Maharastra, Goa, Gujarat, Madha Pradesh, Chhatisgarh, Punjab, Haryana, Rajasthan, Jammu & Kashmir and UTs of Andaman & Nicober was organized at Goa during 6^{th} -10^{th} February, 2017, in which twenty eight (28) participants had attended.

The third training course is planning to hold at Shillong during August/September, 2017 together with RC-Guwahati.

NEW STUDIES

11. PROJECT REFERENCE CODE: NIH/GWD/INT/16-17

Title of the Project: *Grey Water to Blue Water* – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water.

Type of study: Sponsored by: MoWR, RD & GR, GoI under National Water Mission.

Nature of study: Demonstration

Duration: November 2016 - October 2019

Objectives:

The objectives are to develop a cost effective and non-hazardous wastewaters treatment technique for re-use and recycling of treated water to attain urban and peri-urban water supply security by studying the following aspects:

(i) Potential of natural treatment techniques namely, Constructed Wetlands (CW), Managed Aquifer Recharge (MAR) and Riverbank Filtration (RBF) in treatment of municipal and domestic wastewaters to bring in conformity with the usable water, when applied in series,
(ii) Response and performance evaluation of natural treatment techniques to variable inflows and outflows rate and variable water quality constituents,
(iii) Response of aquifer to variable input loadings, and determination of migration pathways of residual traces in the aquifer under different hydrologic and hydrogeologic conditions,
(iv) Assessment of wastewater and improvisation of water constituents from one treatment unit to another, and
(v) Risk evaluation of hydro-geologic regime due to induced recharge.

Methodology:

- Pilot field experimentation,
- Sampling campaign at regular intervals and analysis of samples at laboratory,
- Field experimental setup establishment,
- Rigorous analysis of hydrological, hydrologeological, borelogs and water chemistry data using advanced tools and techniques,
- Space-time analysis of data and developing thematic maps in Arc-GIS framework,
- Groundwater flow and contaminant transport modeling,
- Risk assessment using conventional techniques, and
- Application of non-conventional source of energy.

Deliverables:

(i) Document on design criteria of natural treatment techniques for varying input and output conditions, hydrogeological setups and river flow conditions,
(ii) 'Hand book' on performance of 'Natural Treatment Techniques' for treatment and re-use of wastewaters,
(iii) Scientific publications,
(iv) Training and dissemination.

Progress

- IIT Bombay and UJS, Dehradun are the partners of the project.
- 40% of the project cost (Rs. 64,31,400/-) was received from NWM, MoWR, RD & GR.
- After constant persuasion with SDM-Roorkee since November, 2016, we have received the land allotment letter from SDM-Roorkee on 23rd March, 2017. Delay from the civil administration side was mainly because of implementation of "Election Code of Conduct".
- Possession of land is yet to handover.

- Sampling campaigns and analyses of water quality constituents of waster water, river and ground water are being carried out in each month.
- To implement the proposed experimental setups comprising of civil/mechanical/electrical works , Rural Engineering Department , Government of Uttarakhand has requested to submit the cost estimate to take up the task as deposit work.
- The matter related to procurement of equipment under the project is yet to get finalized.
- The progress of the different activities was not satisfactory mainly because of administrative shortfalls of NIH. However, the progress is likely to gear up in future.

12. ROJECT REFERENCE CODE: NIH/GWD/NIH/17-17

Title of the Project: Feasibility of Managed Aquifer Recharge in NCT, Delhi.
Type of study: Assigned by MoWR, RD & GR, GoI.

Nature of study: **Applied research**

Duration: February, 2017 – July, 2017

Executing organizations : NIH & CGWB

Objectives:

The study was assigned by Secretary, WR, RD & GR, GoI with the following objectives:

(i) To study of aquifer configuration, aquifer-river linkage, aquifer characterization, groundwater resources availability and utilization in NCT, Delhi.
(ii) To investigate feasibility of MAR, in different locations inside NCT Delhi by conservation of monsoon runoffs, and by moderation of monsoon flood water;
(iii) To study the possibility of using treated wastewaters from different STPs by MAR,
(iv) To investigate the scope of Well Fields development at potential sites, on similar lines as that of the Palla area, for drinking water security in NCT, Delhi

Progress:

- GIS mapping of water bodies, STP locations, drainage networks, DEM, geological map, groundwater contour maps, water quality maps, etc. have been completed,
- One time sampling campaign of STPs' (influent & effluent quality) and analysis was done; second sampling campaign and ground-truthing of few feasible MAR locations shall take place very soon,
- Other analyses, such as, aquifer storage capacity estimation, strategy for capturing surface water and firming up feasible MAR locations, etc are in progress.

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sudhir Kumar	Scientist G & Head
2	Dr. S D Khobragade	Scientist E
3	Dr. S P Rai	Scientist E
4	Dr. M S Rao	Scientist D
5	Sri S K Verma	Scientist D
6	Sri P K Garg	Scientist B
7	Sri Rajeev Gupta	SRA
8	Sri U K Singh	SRA
9	Sri V K Agarwal	SRA
10	Sri. Raju Juyal	RA
11	Sri Vishal Gupta	RA

APPROVED WORK PROGRAMME FOR 2016-2017

S. No.	Study	Team	Duration/ Status
	INTERNAL STUDIES		
1.	Interaction between groundwater and seawater along the northern part of east coast of India	M. S. Rao (PI), Sudhir Kumar Pankaj Garg	2 years (08/15 - 07/17) Continuing Study
2.	Status Report on Rewalsar Lake, Himachal Pradesh	SD Khobragade (PI) Sudhir Kumar, C. K. Jain	1 year (04/15 – 07/16) Continuing Study
3.	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	S.D Khobragade (PI); Sudhir Kumar; S. P. Rai, Senthil Kumar; Pankaj Garg	3 years (04/15 – 03/18) Continuing Study
4.	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	M. S. Rao (PI) Sudhir Kumar	3 years (04/16 – 03/19 New Study
5.	Isotopic Investigations in parts of Upper Yamuna River Basin	S. K. Verma (PI), Sudhir Kumar, S P Rai, Mohar Singh, Vishal Gupta	2 years (04/16 – 03/18) New Study
	SPONSORED PROJECTS		
6	The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates	S. P. Rai (PI); M. S. Rao; Surjeet Singh; S. K. Verma; C. P. Kumar; Sudhir Kumar	3 years (06/12-07/16) Continuing Study
7	Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques	S. P. Rai (PI) R. V. Kale M. S. Rao C. P. Kumar Sudhir Kumar	3 years (10/12-07/16) Continuing Study
8	Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains	Sudhir Kumar (PI); S. P. Rai; S. D. Khobragade; C. K. Jain; P. K. Garg	2 years (05/13-06/16) Continuing Study
9.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	S. P. Rai (PI); Sudhir Kumar; Rajesh Singh; S. D. Khobragade; M. Arora; Dr. R. J. Thayyen; Sh. P. K. Garg	*5 Years 04/16-03/21 New Study*
	CONSULTANCY PROJECTS		
1.	Hydrogeological Study for Dewatering of Jhamarkotra Mines, Distt. Udaipur	Sudhir Kumar	05/13-04/16 Continuing Study
2	Hydro-geological study for Gadarwara super thermal power project, Madhya Pradesh	SD Khobragade	07/15-06/16 Continuing Study
3	Hydro-geological study for Katwa super thermal power project, West Bengal	Sudhir Kumar	07/15 – 4/16 Continuing Study
4	Hydro-geological study for Darlipali super thermal power project, Odisha	Sudhir Kumar	9/15 – 8/16 Continuing Study

S. No.	Study	Team	Duration/ Status
5	Hydro-geological study for Khargone super thermal power project, Madhya Pradesh	SD Khobragade	07/15 – 4/16 Continuing Study
6	Hydro-geological and isotopic study for 1x660 MW Harduaganj thermal power project, UP	Sudhir Kumar	11/15 – 10/16 Continuing Study
7.	Hydro-geological and isotopic study for 1x660 MW Panki thermal power project, UP	Sudhir Kumar	12/15 – 11/16 Continuing Study
8.	Hydro-geological study for Kudgi super thermal power project, Karnataka	Sudhir Kumar	11/15 – 10/16 Continuing Study
9.	Hydro-geological study for Jawaharpur thermal power project, Etah, UP	Sudhir Kumar	12/15 – 11/16 Continuing Study

R & D STUDIES:

1. PROJECT REFERENCE CODE: NIH/HID/INT/2015-16/1

Title of the Study : Interaction between groundwater and seawater along the northern part of east coast of India

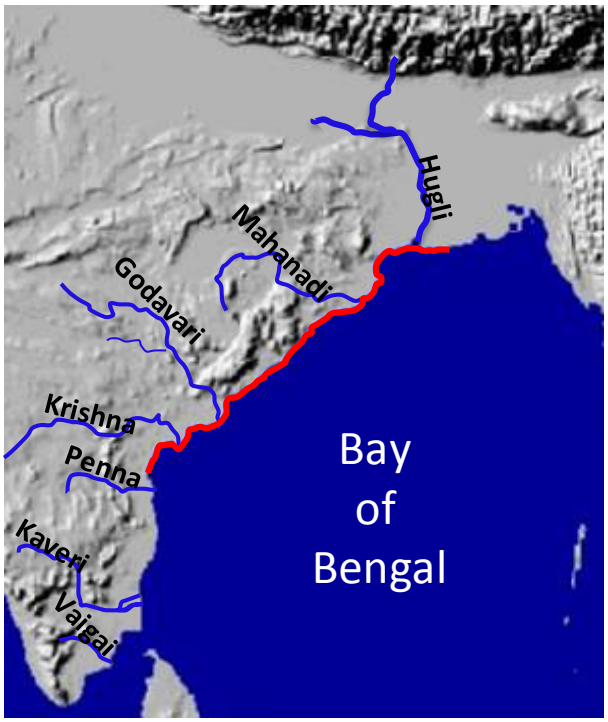
Study Team: : Dr M. Someshwar Rao (PI), Dr Sudhir Kumar and Pankaj Garg

Technical Collaborators **:** Sh. Niladri Naha, Additional Director, SWID, Kolkata
Dr. Abhijit Chakraborty, Asstt. Prof., IIT, Kharagpur

Funding Agency : Internally Funded
Budget : Rs. 26.82 Lakh
Date of Start :November, 2015
Date of Completion : : October, 2017

Study Area

The study area covers the Coastal region of West Bengal, Odisha and Andhra Pradesh. Major hydrological problem in the area is seawater intrusion & excess loss of fresh groundwater water to marine environment.



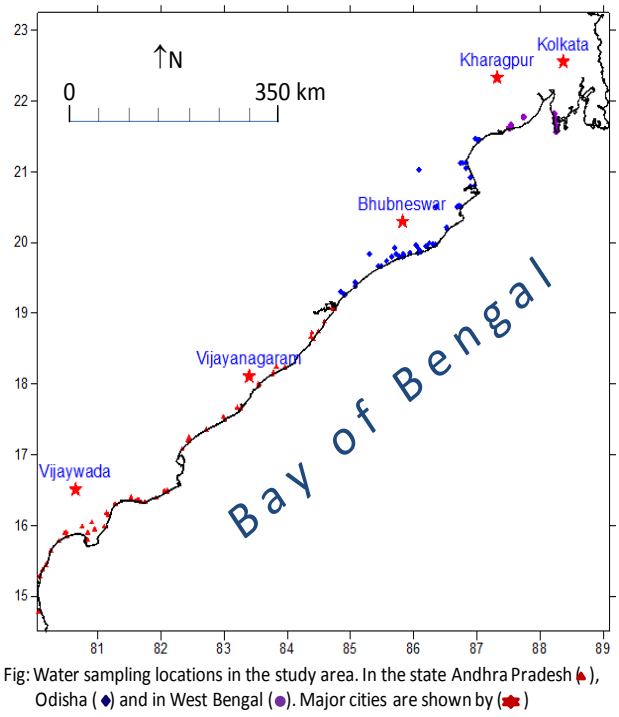


Fig: Water sampling locations in the study area. In the state Andhra Pradesh (▲), Odisha (♦) and in West Bengal (●). Major cities are shown by (★)

Fig: Topographic features of eastern coastline of India and study area (shown in red-line)

Study Objectives:

The objectives of the study are:

i. Mapping the zones of fresh groundwater and saline groundwater zones in the coastal areas of WB, Odisha and AP.
ii. Investigating the groundwater seawater exchange process using water quality and isotope (stable, tritium, dissolved radon) analysis of groundwater
iii. (ii) Measures for augmentation and management of coastal groundwater resource

Statement of the Problem

India has over 8000 km length of shore line with people living over 250 million within 50 km width of the coast and groundwater is an important resource in this region. Increasing population density, industrial growth, irrigation expansion, falling water levels is causing continuous depletion of freshwater resource whereas, factors like monsoon variability, climate change, sea-level change, episodic cyclones etc., are causing short & long term variability in the freshwater availability and thereby variability in the seawater-groundwater interface zone in the coastal zone of India. Mapping of fresh and saline groundwater zones and the operative processes along this zone help to protect the groundwater resource from getting it salinized. The present project is intended to provide a regional map of seawater-groundwater interaction zone of coastal West Bengal and Odisha using salinity and isotopic mapping.

Objectives vis-à-vis Achievements

<table>
<tr><th>Work elements/ Objectives</th><th>Achievements</th></tr>
<tr><td>Sample collection and analysis</td><td>Samples collection & analyses
<table>
<tr><th>State</th><th>Field work Period</th><th>No of Samples collected</th></tr>
<tr><td rowspan="2">WB</td><td>Nov 2015</td><td>7 GW</td></tr>
<tr><td>Dec 2016</td><td>7 GW+2SW+12 GW from Bakhali on monthly interval</td></tr>
<tr><td rowspan="3">Odisha</td><td>Nov 2015</td><td>37 GW +1 SW</td></tr>
<tr><td>May 2016</td><td>3 GW</td></tr>
<tr><td>Dec 2016</td><td>33 GW +2 SW+72 GW from 7 locations on monthly intervals</td></tr>
<tr><td>AP</td><td>May 2016</td><td>53 GW</td></tr>
<tr><td></td><td>Nov 2017</td><td>To be done</td></tr>
</table>
(Abrev for samples: GW- Groundwater, SW- Sea water)
Index map prepared. 2 sets of samples collected from WB & Odisha and 1 set from AP during Nov 2015- Dec 2016.

Most of the sample got analyzed in the last one quarter and few samples are in the process of analysis.</td></tr>
<tr><td>Mapping the groundwater-seawater interaction regions vis-à-vis the operating hydrological process (SGD/Seawater intrusion)</td><td>1st order interpretation based on one set of pre &post monsoon data set is being completed.

After collecting the last set of water samples in the post monsoon of 2017 (from WB, Odisha and AP), the coastal zone groundwater process will be interpreted and the final report will be prepared.</td></tr>
</table>

Analysis: Water sample brought from field are submitted to the laboratory for isotopic & chemical analysis and the analyses are expected to get completed shortly.

Initially, in the project the Andhra Pradesh coastal zone was not there. Recently, MoWRRD&GR has invited research proposals (PDS) for NHP programme. Considering the interest of DRC, Kakinada in the ongoing work, coastal part oof AP is also included and, accordingly, an inventory to Andhra Pradesh coast was taken up in 2016-17. Further, during 2016-17, sample analysis got delayed due to instrumental problems and sample overload from other projects of the Division & institute. Due to these added parameters, the targeted completion period (Oct, 2017) will be required to be extended to April 2018. In the final

report, the data from Andhra Pradesh coast will also be included. If the PDS get approved the present project will be culminated and continued under NHP programme.

Constraints observed in execution of the research: During the field survey it is found that getting groundwater samples from saline coastal aquifers is non-trivial as the wells are always drilled selectively to a depth to tap fresh groundwater for potable or irrigation use. The problem of getting saline aquifer water samples may get reduced to large extent under NHP as the states are planning to install piezometers to monitor aquifer specific groundwater from multiple depths. Therefore, it is planned to continue the project objectives under NHP programme jointly with the State Department and accordingly, PDS with West Bengal and Andhra Pradesh have been prepared and submitted.

Work Elements for 2017-18:

- Post monsoon water sampling from WB, Odisha and Andhra coast
- Analysis of final set of water samples
- conducting a training programme
- Writing of final Project Report & publications

Expected date of completion of project: April 2018 (required 6 months additional. The work will be completed with the remaining funds).

2. PROJECT REFERENCE CODE: NIH/HID/INT/2015-16/1

Title of the Study:	**Hydrological Aspects of Rewalsar Lake, Himachal Pradesh (Status Report)**
Project Team:	Suhas Khobragade (PI), Sudhir Kumar, C. K. Jain, V. K. Agrawal, and Satya Prakash
Type of Study:	Internal Study
Budget:	3.27 Lakh
Date of start:	**April, 2015**
Duration:	**1 year, Extended by Four months**
Date of completion:	**July, 2016**

Study Objectives:

1. To determine the environmental status of the lake
2. To identify major problems of the lake
3. To identify major management issues of the lake
4. To review current research status and research needs for lake
5. To review the data availability scenario and identify data gaps vis-a-vis identified research needs
6.

Statement of Problem:

Water quality degradation has been reported for the lake. Due to pollution the nature of water has turned acidic (Tribune India, May 11, 2010). The poor sewerage system of Rewalsar town is further increasing the problem as contaminated water directly flows into the lake (Tribune India, May 11, 2010). According to the news published in the Tribune (May 14, 2014), more than 700 fish died during May 2014 at Rewalsar Lake. The death of fish is a regular feature of the lake but no systematic studies have been reported for the lake. No hydrological studies have been reported for the lake so far.

Study Area:

Rewalsar Lake, or Tso Pema Lotus Lake, is a mid-altitude lake located in Rewalsar town in Mandi District in Himachal Pradesh, 22.5 km south-west from Mandi. It lies between 31º37’30" N and 76º49’15" E at an altitude of 1360 meters above sea level. It is a small natural lake with a shoreline of about 735 meter and 175 hectare catchment area. The shallow lake has the maximum depth of 6.5 m. The lake is significant from religious, cultural and tourism purposes. It is held as a sacred spot for Hindus, Sikhs and Buddhists alike.

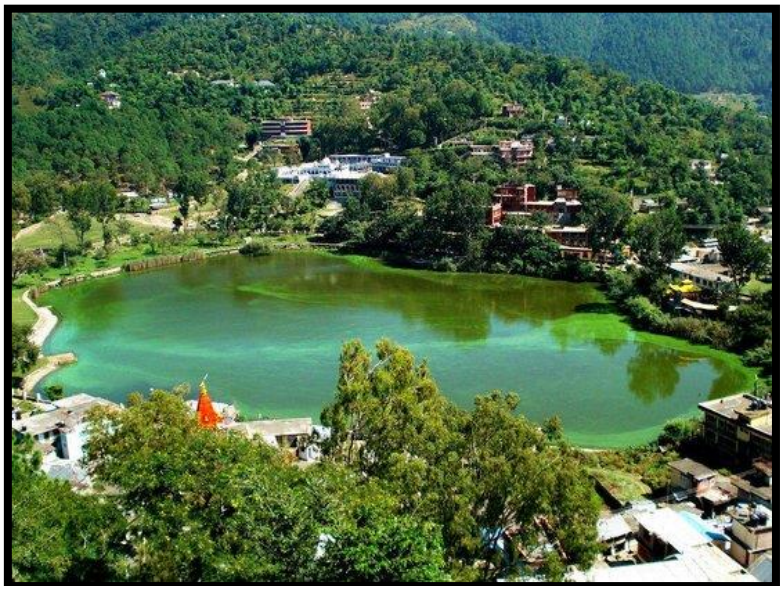


Fig. 1: A view of Rewalsar Lake, Mandi (H.P.)

Brief Methodology:

The envisaged objectives will be achieved through:

a) Collection, processing and analysis of the available data
b) Review of literature
c) Field survey
d) Interaction with management authorities and local people
e) Collection and laboratory analysis for water sample/sediment samples for water quality and isotopic characteristics

Objectives vis-à-vis Achievements

Sr. No.	Objective	Achievement
1.	To determine the environmental status of the lake	Water quality assessment has been carried out for monsoon and post monsoon seasons. Pre-monsoon sampling is proposed in May, 2016.
2.	To identify major problems of the lake	Done
3.	To identify major management issues of the lake	Done
4.	To review current research status and research needs for lake	Have been done based on the present understanding of the problems
5.	To review the data availability scenario and identify data gaps vis-a-vis identified research needs	Completed

Results and Analysis:

Water quality sampling was carried out during the month of July 2105 and the analysis has been completed. It has been observed that in general the lake water quality of Rewalsar Lake is good. The concentration of most of the parameters is generally low. This could be the dilution effect caused by the water received from the rain as direct fall over the lake.

High DO (average value of 12.21 mg/l) along with very low value of BOD (average value of 0.73 mg/l) clearly indicates absence of organic pollution in the lake. The results of the bacteriological parameters for the lake indicate that Total coliform value ranged between 240 and 2400 per 100 ml at the three locations. As far as faecal coliform is concerned, it was in the range of 210-280 MPN/100 ml at the three locations.

Isotopic analysis of the lake and surrounding ground water has also been carried out. The values of $\delta^{18}O$ for the lake are observed to vary in the range of -1.79 ‰ to -1.53 ‰ while corresponding δD values range between -12.65 ‰ and -10.85 ‰. The surrounding groundwater shows different isotopic characteristics than the lake water. The values observed in the lake are highly enriched compared to the surrounding groundwater due to evaporation effect.

Sedimentation in the lake has been determined using Cs-137 technique. Sediment core was collected from the lake and was analysed for Cs-137 activity. The results are shown in Fig. 2. Based on the analysis, rate of sedimentation for the Rewalsar lake comes out to be 0.82 cm/year.

However, analysis of water quality data particularly the high DO values, fail to explain dying of fish during summer. Further analysis of water quality was suggested including analysis of heavy metals for analysis of seasonal variation and particularly the summer water quality. Accordingly, sampling was carried out again for winter season during January, 2016 and the detailed results, including analysis of the heavy metals, shall be presented in the working group meeting.

The study has been completed

3. PROJECT REFERENCE CODE: NIH/HID/INT/2015-18/1

Title of the study: **Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh**
Study Team: **Suhas Khobragade (PI),** Sudhir Kumar, Senthil Kumar, P Garg, Sh. V. K. Agrawal and Satya Prakash
Type of Study: **Internal**
Duration: **3 years**

Date of Start: **April, 2015**
Date of Completion: **March, 2018**

Statement of Problem:

Sukhna Lake in Chandigarh faces water scarcity problems especially during the deficit rainfall years. No studies on the interaction of the lake with surrounding groundwater have been reported so far except for the preliminary investigations carried out by NIH. Preliminary studies on water balance carried out by NIH do indicate that seepage may be a significant factor determining the water availability in the lake. A careful and detailed studies on this aspect is however needed to understand and establish the seepage losses from the lake. Hence the present study has been undertaken.

Study Objectives:

(i) To determine seepage losses from the lake
(ii) To determine the relative significance of seepage losses in overall water balance of the lake

Brief Methodology:

i) Collection, processing and analysis of the lake water level data
ii) Collection, processing and analysis of the U/s and D/s piezometer data
iii) Sample collection and laboratory analysis for isotopic investigations
iv) Analysis of relationship between lake and piezometer for isotopes and other parameters such as temperature, WQ etc
v) Water balance of lake

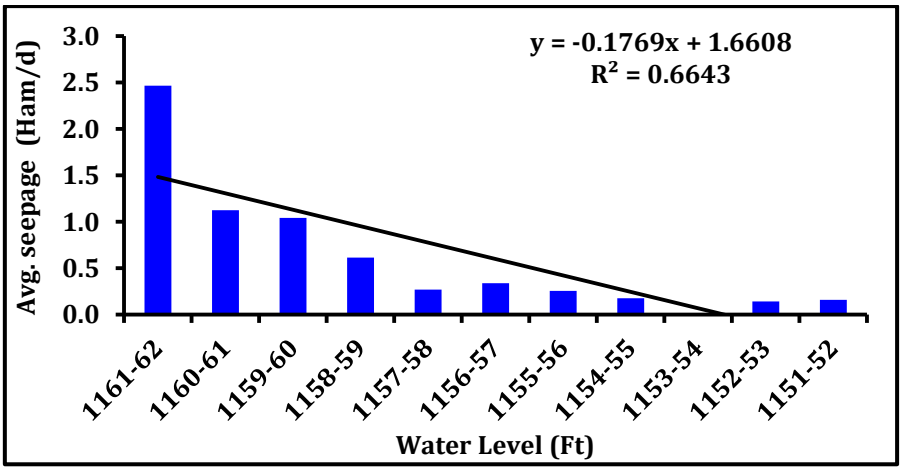
Objectives vis-à-vis Achievements

Sr. No.	Objective	Achievement
1.	To determine seepage losses from the lake	It has been done based on water balance
2.	To determine the relative significance of seepage losses in overall water balance of the lake	Determined based on water balance

Results and Analysis:

Water balance of the post monsoon period for three years period from 2011 to 2014 has been done, for intervals during which water levels have varied by 0.25 ft, 0.59 ft and 1 ft. The seepage rates have been determined for this all these three intervals and average seepage has been obtained (Fig. 1) It can be seen that the average seepage loss is more when the water level of the lake is more. At higher elevations of 1161-62 ft amsl the average seepage rate is as high as 2.46 ham/d and they decline exponentially with decrease in lake water

level. The rates decrease significantly below the 1158 ft amsl level and at lower elevations of 1153 ft amsl and below, the seepage rates are almost negligible at 0.1 ham/d. Interestingly a zero value of seepage was obtained for elevations between 1153-54 ft amsl. This could be due to error of water balance or may be due to lining of the dam at this level.



Relative losses of seepage volumes during monsoon and post monsoon months in the total losses from the lake have been compared and are presented in Figures 2 and 2 respectively. It can be seen that seepage losses were in the range of 10-15 % during monsoon of 2011 and 2012 where as during the monsoon of 2013 the losses were almost 50% of the total losses from the lake. The relatively lower higher contribution of seepage losses in total losses during the year 2011 and 2012 compared to the year 2013 can be explained based on the lower water levels reached by the lake during the monsoon seasons of these years, as seepage losses are higher if the at higher water levels.

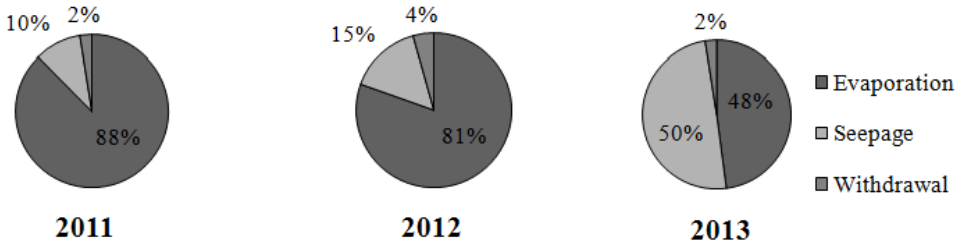


Fig.: Relative contribution of seepage during monsoon months

As far as post monsoon season is concerned, the total seepage losses were 10% of the total losses during 2011-12 and they were about 41% of the total losses during 2012-13. This is because at the end of monsoon 2011 i.e. on 1st October 2011, the lake water level reached was 352.46 m amsl. At this level the seepage rates are lower so the amount of water lost through seepage is also lower. The losses during the post monsoon season of 2011-12 were dominated by evaporation with little share of 10 % from seepage. As far as 2012-13 is concerned, the water level reached at the end of monsoon was much higher compared to 2011-12. It was 354.04 m amsl on 1st October, 2012. At this level the seepage rates are higher so the amount of water lost through seepage are also higher (41%) compared to 2011-12, reducing the relative contribution of evaporation in the total losses from the lake to about 55%.

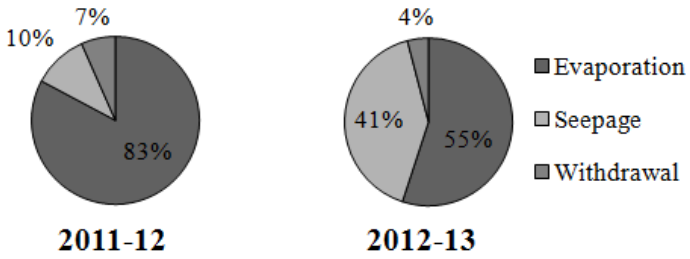


Fig. : Relative contribution of various losses during post-monsoon months

Other results shall be presented in the working group meeting

Future Plan:

(i) Monitoring of water level data of lake vis-a-vis piezometers.
(ii) Analysis of relationship between isotope data & WQ data of peizometers wth that of lake water
(iii) Publication of research paper related to seepage analysis

4. PROJECT REFERENCE CODE: NIH/HID/INT/2015-18/1

Title of the study: **Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin**

Study Team: : Dr M. Someshwar Rao Sc. 'E'(PI)
Dr Sudhir Kumar, Sc G

Funding Agency : Internally Funded
Budget : Rs. 15.95 Lakh
Duration : $2^1/_2$
Date of Start : May, 2016
Date of Completion : Oct, 2018

Study Objectives :

The objectives of the study are:

i) Development of ^{14}C dating system
ii) Preparing manual of 'Procedure of Radiocarbon dating analysis in NIH'
ii) Dating old groundwater as inferred from tritium dating using ^{14}C dating technique and re-interpretation of the data.

Work elements:

- Fabrication of ^{14}C glass line
- Purchase of imported items (reference standards, chemicals and glassware)
- Purchase of items from Delhi/Roorkee and fabrication of items in-house
- System calibration
- Sample collection
- Analysis
- Preparation of Manual & SOP

Work Accomplished:

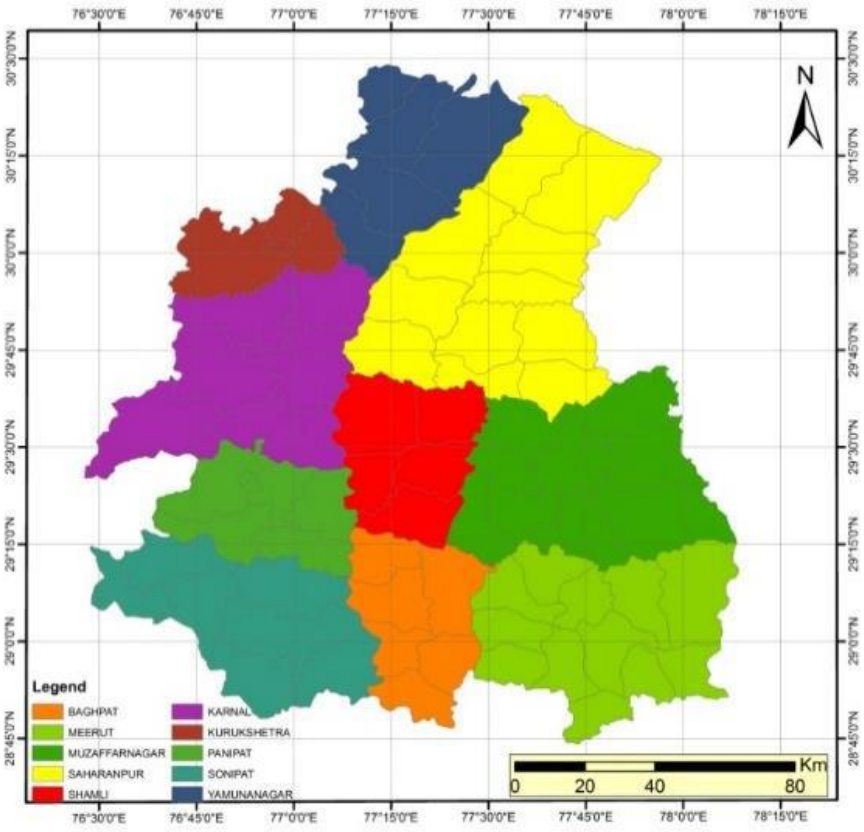
- Purchased imported glassware
- Identified old groundwater samples from Ganga basin
- Purchase of other items & fabrication work are in process.

Work Elements for 2017-18:

- Procurement of international standards
- System installation and calibration
- Sample collection and analysis

5. PROJECT REFERENCE CODE: NIH/HID/INT/2015-18/1

Title of the Study	:	**Isotopic Investigations in parts of Upper Yamuna River Basin**
Study Team	:	S. K. Verma (PI), Sudhir Kumar, S. P. Rai, Mohar Singh, Vishal Gupta
Type of Study	:	Internal
Duration of study	:	Two years
Date of Start	:	April 2016
Date of Completion	:	March 2018
Study Area	:	Parts of Upper Yamuna river basin



Study Objectives:

1. To assess radon concentration in groundwater
2. Isotopic (δ^2H & δ^{18}O) characterization of groundwater
3. To indentify the geothermal zones and its impact on isotopic composition

Present state-of-art:

During the last 40 years large scale groundwater abstraction, particularly in the north western states of Punjab, Haryana & Uttar Pradesh has taken place due to increase in irrigation requirements. As a result of this, groundwater depletion of this region has become under the vulnerable condition and a hot spot for groundwater management. The groundwater depletion rates in the states of northwestern India are reported highest in comparison to other parts of world. There is a major task to replenish the groundwater depletion through rainfall recharge. In this connection, NIH has initiated an isotopic investigation in parts of upper Yamuna river basin through a project entitled “Integration of

Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains" funded by IAEA. The preliminary investigations carried out under this project indicated that the temperature is more than 30^0 C in some parts of Upper Yamuna river basin. Therefore, the detailed isotopic investigations are required to investigate the source and cause of this thermal groundwater occurring in parts of Upper Yamuna river basin.

Brief Methodology:

In order to study the radon concentration in the study area at different locations, groundwater samples from shallow as well as deeper aquifers will be collected for in-situ radon measurement. Spatial variation of radon concentration in groundwater will be studied. The groundwater samples from shallow/deeper aquifers for existing hand pumps, open wells and tube wells will also be collected for stable isotopes & strontium analysis to study their variations. The hydro-geological data will also be collected for the study area in order to study the hydro geological features to be linked with the radon concentration in groundwater.

Action Plan

Sr. No	Activity	April 2016 to March 2018							
		1st Q	2nd Q	3rd Q	4th Q	1st Q	2nd Q	3rd Q	4th Q
1.	Review of literature, Collection of hydro-geological data/information for the study area etc.	♦	♦						
2.	Preparation of index map of study area, selection of locations/sites for experimental works etc.	♦	♦						
3.	Collection of groundwater samples for radon measurement, stable isotopes analysis & analysis of radon concentration		♦	♦	♦	♦			
4.	Lab. analysis of groundwater samples for stable isotopes and Strontium		♦	♦	♦	♦	♦	♦	
5.	Interpretation of isotopic data						♦	♦	
6.	Preparation of interim report/Part-1				♦				
7.	Final report								♦

Analysis and Results

- The analysis of radon concentration has been carried out for a total of 18 groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the districts of Ambala, Yamunanagar & Saharanpur. The values of radon concentration obtained fall well below the safe limit recommended by the World Health Organization (WHO) for drinking water purpose.
- The electrical conductivity has been measured at 18 locations for the groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the study area. The electrical conductivity varies from 440 µS/cm to 860 µS/cm in the study area.
- The stable isotopes analysis ($\delta^{18}O$, δD) has been carried out for all the 18 groundwater samples collected from intermediate/deep aquifers using tube wells for drinking water supply from different locations in the study area. The variation of stable isotopes ($\delta^{18}O$, δD) with radon concentration for groundwater samples as

collected above has been studied.

- In addition to above, a total of 18 groundwater samples from intermediate/deep aquifers have been collected for environmental tritium analysis in Nuclear Hydrology laborator**y**. The analysis of 18 groundwater samples for environmental tritium is in progress in the laboratory.

Future Plan:

- Monitoring of radon concentration in rest of the study area
- Stable isotope analysis ($\delta^{18}O$, δD) for rest of the area
- Environmental Tritium analysis

SPONSORED PROJECTS

1. PROJECT REFERENCE CODE: NIH/HID/MOES/2012-15

Title of the Study : **The Structure and Dynamics of Groundwater Systems in Northwestern India under Past, Present and Future Climates**

Study Team : S. P. Rai (PI), S. K. Verma, S. Khobragade, Surjeet Singh, Sudhir Kumar, V. K. Agarwal, Rajeev Gupta, S. L. Srivastava, Vishal Gupta, Mohar Singh

Type of Study : Sponsored

Funding Agency : MoES, Government of India

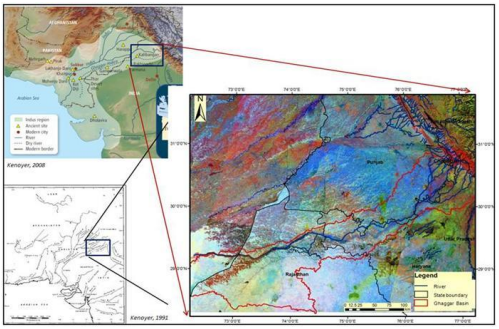
Budget : Rs. 210 Lakh (NIH component Rs. 35 lacs)

Date of Start : June 2012

Date of Completion : July 2016

Location Map

The study area covers the North Western India. However, Ghaghar basin has been selected to carry out detailed investigations, which covers the states of Himachal Pradesh, Punjab, Haryana and Rajasthan.



Land use: Agriculture dominated

Major problem of the area is declining of groundwater levels at a very fast rate, but at few places groundwater level is raising also.

Study Objectives

- Isotopic characterization ($\delta^{18}O$ and $\delta^{2}H$) of groundwater, stream and rain water
- Groundwater dating
- Delineation of flow direction and recharge zones
- Identification of recharge source and zones of groundwater in the study area

Statement of the Problem

India is largest agricultural user of groundwater in the world. The last 40 years have seen a revolutionary shift from large scale surface water management to widespread groundwater abstraction, particularly in the northwestern states of Punjab, Haryana and Rajasthan. As a result of this, groundwater depletion of this region has become under the vulnerable condition and a hotspot for groundwater management. The groundwater depletion rates in the states of northwestern India are reported highest in the world. This unmanaged use of groundwater becomes more challenging due to increasing demands from population and industrial developments under the climate change scenario. There is a major task to replenish the groundwater depletion through rainfall recharge. Therefore, this study is proposed to study groundwater dynamics in the region.

Objectives vis-à-vis Achievements

Objectives	Achievements
Isotopic characterization ($\delta^{18}O$ and $\delta^{2}H$) of groundwater, stream and rain water	Isotopic composition and meteoric water Line for rain, groundwater, stream and canal developed
Groundwater dating	Carried out Using Tritium Technique
Delineation of flow direction and recharge zones	Groundwater level data of 1974 to 2010 was analysed and trend analysis was carried out
Identification of recharge source and zones of groundwater in the study area.	Isotopic signature reveals that local precipitation and canal are the main source of recharge

Analysis and Results:

Variation of Groundwater Level Data

Groundwater level data of last 30 years of Ghaghar basin were analysed to study the groundwater fluctuation. Water level data show dramatic decline in groundwater level by 12-18 meters during this period. Initial water level decline trend show that water declines at slower rate between 1974 and 1998 comparison to that of between 1998 and 2010. After 1998, there is steep decline in groundwater level of the study area. However, southwest part of the study area show rising trend in groundwater level.

Isotopic Composition of Rainfall, River and Canal Water

The stable isotope data of precipitation of study area and surrounding are used to characterize the isotopic composition of precipitation. The $\delta^{18}O$ varies from -19.4‰ (minimum) to 9.8‰ (maximum) and $\delta^{2}H$ from -150.1‰ (minimum) to 59.1‰ (maximum). The local meteoric water line is

$\delta^{2}H = 7.9 * \delta^{18}O + 5.4$, $r^2 = 0.98$, n = 148

Ghaggar river samples have been collected from its origin near to Nahan in Himachal Pradesh to downstream upto Siras in Haryana. The $\delta^{18}O$ of river varies from -7.3‰ to -5.3‰ and $\delta^{2}H$ vary between -50.6‰ to -43.8‰. The $\delta^{18}O$ in origin area (between Nahan to Panchkula) varies between -7.3‰ and -6.7‰ and between -50.6‰ and -46.4‰ for $\delta^{2}H$. Near Patiala and Sirsa isotopic composition of river is found -6.1‰ and -5.3‰ for $\delta^{18}O$ and -49.8‰ to -43.8‰ for $\delta^{2}H$ respectively. The canal water samples were collected from various sites in the catchment. The isotopic variation of canal water are found between -12.1‰ and -11.5‰ for $\delta^{18}O$ and -80.9‰ and -74.9‰ for $\delta^{2}H$. The isotopic composition of canal water is depleted in comparison to Ghaggar river and local precipitation. Since, the source of canal water is Bhakara reservoir, which is Satluj river.

The spatial variation of $\delta^{18}O$ values of groundwater of shallow depth show that $\delta^{18}O$ varying between -4‰ and -12‰. The enriched $\delta^{18}O$ values are found in the upper part of the catchment while depleted values in the middle and lower part of the catchment. The depleted isotopic signature of groundwater in the middle and lower part indicates recharge to groundwater through canal water. The environmental tritium activity has been measured for groundwater at different locations and it is found to vary between 0.3 TU and 8 TU. Tritium results reveals that groundwater at the most of site is submodern to modern age. The groundwater at deep tubewell sites are older than 50 yrs.

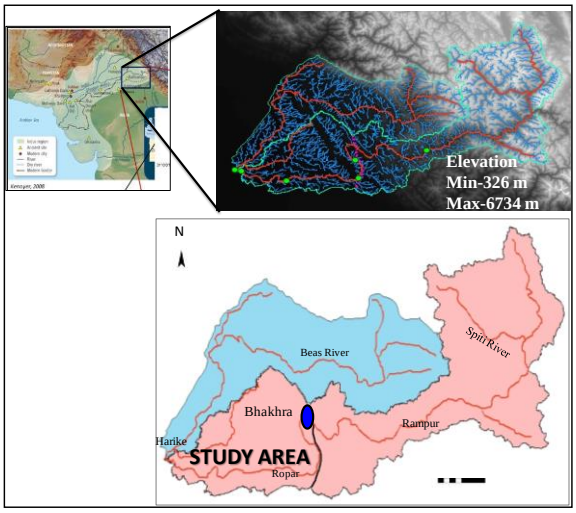
The electrical conductivity (EC) of Ghaghar river and canal water is found in the range of 400 µS/cm to 450 µS/cm and 200 µS/cm to 220 µS/cm, respectively. The canal and river water samples show low salt values than the desirable value of Indian & WHO Standards (782 µS/cm). EC of groundwater ranges between 230 µS/cm and 10500 µS/cm in shallow aquifer, 260 µS/cm to 3900 µS/cm in middle aquifer and 420 µS/cm to 9500 µS/cm in deep aquifer, respectively. In shallow aquifer, EC ranges 250 µS/cm to 2000 µS/cm in upper reaches of study area, 500 µS/cm to 1000 µS/cm in middle part of study area and 1000 µS/cm to 10500 µS/cm in lower part of study area. The southern part of the basin is more saline. This is reason that groundwater level is raising upwards in southern part of the study area. The hydrochemical analysis of groundwater of study area has been analysed and details results will be present in working group meeting.

There is marked variation in isotopic and chemical composition of groundwater which indicates complex system of recharge. At several places significant recharge from canal has been observed. Details of the findings will be presented in working group meeting.

2. PROJECT REFERENCE CODE: NIH/HID/IAEA-2/2012-15

Title of the Study	:	**Assessment of Baseflow and its Impact on Water Quality in the Part of Satluj River in India using Environmental Isotopes and Age Dating Techniques**
Study Team	**:**	S. P. Rai (PI), R. V. Kale, M. S. Rao, C. P. Kumar, Sudhir Kumar, V. K. Agarwal, Vishal Gupta, Mohar Singh
Type of Study	:	Sponsored
Funding Agency	:	IAEA, Vienna
Budget	:	5000 Euro per year
Date of Start	:	October 2012
Date of Completion	:	July 2016

Location Map



The study area falls in the Punjab state of India. Groundwater levels in Punjab have reached to most critical condition. As per report of Central Ground Water Board, Government of India (2009), 80% area of Punjab state falls under over-exploited zone. With onset of Green Revolution during 1960s, the state rapidly adopted the green revolution technology and resulted in increased demand for irrigation water. The requirement of irrigation was met through development of irrigation canal network and development of tube wells. Between 1960 and 1999, the food grain production of Punjab increased from 3.16 to 22.22 million tones. During this period, number of tube wells increased from 0.60 million to 1.1 million, leading to over-exploitation of groundwater in most parts of the state. The concentrated pumping has affected the natural groundwater conditions and flow regime.

Study Objectives

- To develop thematic maps based on isotope and related information
- Identification of groundwater recharge sources and zones of Groundwater and its dynamics in study area.
- Estimation of baseflow component using isotopic techniques and baseflow modelling approach
- To assess the potential and limitations of the tracer techniques for routine application in hydrological studies

Statement of the Problem

The importance of Satluj river in Indian context is better understood from the fact that it continues to play a major role in the socio-economic development of north-western part of the country. The dependency of the states of Himachal Pradesh, Punjab, Haryana and Rajasthan on the resources of Satluj river for the sustenance and growth of agricultural and

hydroelectric power sector is ever growing. In addition to several micro and mini projects, several mega projects are under way, particularly in the upper part of Satluj Basin has modified the hydrology of the river. The Satluj River runoff consist contribution from snow/glacier, rainfall derived runoff and groundwater/baseflow. The assessment of rainfall derived runoff and snow and glacier melt runoff have been carried out by previous workers. However, contribution of the baseflow to river flow was overlooked. Therefore, this study will be a first approach to understand the groundwater and river interaction in this part of the Satluj catchment.

Objectives vis-à-vis Achievements

Objectives	Achievements
• To develop thematic maps based on isotope and related information • Identification of groundwater recharge sources and zones of Groundwater and its dynamics in study area.	○ Isotopic characterization ($\delta^{18}O$ and $\delta^{2}H$) of groundwater, stream and rain water ○ Carried out groundwater dating using tritium ○ Delineation of flow direction and recharge zones ○ Hydro-chemical analysis of groundwater ○ Isotopic technique has been used to separate out baseflow component of river
• Estimation of baseflow component using isotopic techniques and baseflow modelling approach	○ Modelling approach has been attempted to separate out the baseflow component of stream discharge
• To assess the potential and limitations of the tracer techniques for routine application in hydrological studies	○ Assessment of potential of tracer techniques are under progress

Analysis and Results

Isotopic Composition of Precipitation

The isotopic composition of precipitation in study are varies from -19.4‰ to 9.8‰ for $\delta^{18}O$ and -150.1‰ to 59.1‰ for $\delta^{2}H$. The $\delta^{18}O$- $\delta^{2}H$ bi plot of precipitation in the study area shows similarity with GMWL (Rozanski *et al.* 1993) and Indian Meteoric Water Line for the north region (IMWL- North) (Kumar *et al.* 2010).

Isotopic Composition of River

The $\delta^{18}O$ of Satluj River varied between -12.7‰ to -6.8‰ and $\delta^{2}H$ from -87.9‰ to -48.5‰. The isotopic composition of river gets enriched as water move from Ropar to Harike (downstream). The depleted isotopic composition of Satluj River at Ropar is due to major contribution from the higher Himalayas. As river move downstream, enrichment of $\delta^{18}O$ of river water is observed which may be due to the contribution from groundwater.

Isotopic and Chemical Composition of Groundwater

The groundwater samples were collected from existing dug well, hand pump and tube wells. The depth of dug well, handpumps and tube wells represents to different depth of water level. The depth of open well, dugwell, hand-pumps and tubewells were collected from the

sampling sites. The overall depth data indicate that handpumps are bored up to depth of 80 m and tubwells below the 80 m depth.

Open well and Handpump = <80 m
Tubewell of private farmers and Government = > 100 m

The oxygen isotope ratio ($\delta^{18}O$) of groundwater up to depth of 80 m varied from -12.4‰ (minimum) to -4.7‰ (maximum) and hydrogen isotopic ratio ($\delta^{2}H$) from -85.1‰ (minimum) to -32.4‰ (maximum). The $\delta^{18}O$ of groundwater below the depth of 100 m varied from -11.3‰ (minimum) to -5.4‰ (maximum) and $\delta^{2}H$ -81.6‰ (minimum) to -35.2‰ (maximum).

Generally, shallow groundwater show enriched $\delta^{18}O$ and $\delta^{2}H$ values in the study area. However at few locations depleted value (more than -9‰) are also found due to possible recharge through river/canal. In contrast, the stable isotopic composition of groundwater below 80 m bgl, show a close affinity with Annual Weighted Average of Precipitation (AWAP), indicating that the dominant recharge source is modern local meteoric water. However, low tritium concentrations indicate relatively long residence times particularly in the lower reaches of the basin.

The groundwater mainly belongs to Ca-Mg- HCO_3 type. The Na^+/Cl^- vs Cl^- plot shows increasing Na concentration without any significant change in Cl^- indicates increase in Na^+ mainly due to dissolution of plagioclase as the major source for groundwater chemistry in the study area. The results of water chemistry support the finding of the isotope.

The partitioning of stream flow has been carried out using the isotopic modeling techniques and non tracer techniques i.e., (i) Local Minimum Method, (ii) One Parameter Digital Filter, (iii) Eckhardt Digital, and (iv) Modified Eckhardt Digital Filter. The results of these studies are corroborating to each other.
The results of this study reveal that isotope technique can be used to validate a groundwater model of a particular area. It is very difficult to generate the isotope data for estimation of base flow of a river under different climatic conditions. To solve this issue a validated model can be used to estimate the baseflow component under varied rainfall conditions

4. ***PROJECT REFERENCE CODE:*** **NIH/HID/IAEA-3/2013-15**

Title of the Study	**:**	**Integration of Isotope Hydrology in Aquifer Mapping Efforts in India: A Pilot Study of Upper Yamuna Plains**
Study Team	**:**	Sudhir Kumar (PI), S. P. Rai, Suhas Khobragade, C. K. Jain, P. K. Garg
Funding Agency	:	IAEA, Vienna
Budget	:	€28,500
Duration	**:**	May 2013 to April, 2015

Study Objectives:

i. To identify the various aquifers present in alluvial tract of the Upper Yamuna Plains.
ii. To identify the source of recharge of different aquifers, and the interaction between various aquifers.
iii. To investigate the continuity of aquifers on both the sides of the river Yamuna,
iv. To determine the groundwater dynamics in different identified aquifers, and
v. To estimate the groundwater velocity and replenishment potential of the deeper aquifers.

Statement of the Problem:

Alluvial aquifers are primarily composed of thick unconsolidated Quaternary deposits made up of alternating sequences of sand, silt and clay in various proportions. The major part of water demand in these areas is catered from groundwater which is by and large copiously available because of potential nature of aquifers as well as adequate recharge from rainfall. Western part of the Upper Yamuna Plains has a good irrigation canal network of Western Yamuna Canal, which originates from Hathnikund Barrage in Yamunanagar District of Haryana. The unconfined aquifers in the study area are expected to be recharged by the seepage from canal network and irrigation return flow apart from the rainfall, which is the major source of recharge. The canal water originates at higher altitudes in the Himalayas has different isotopic composition ($\delta^{18}O$ and δD) as compared to the groundwater locally generated in the Upper Yamuna Plains.

Deeper aquifers in the area are supposed to be recharged from the Bhabhar zone, the coarse material deposited as alluvial fans on the margin of Himalayas. Groundwater velocity in the deeper aquifers is expected to be very slow, thus groundwater dating (^{14}C) should give an idea about the groundwater flow direction as well as groundwater velocity in the deeper Aquifers. If there is vertical recharge through the semi-confining layers, the same should be easily detected by Tritium dating.

Thus, isotope based investigations can help understanding the surface water and groundwater interactions, aquifer-aquifer interactions, groundwater dynamics and identification of recharge sources and recharge areas of deeper aquifers for taking better management strategies**.**

Objectives vis-à-vis Achievements:

S. No.	Objective	Achievement
1	To identify the various aquifers present in alluvial tract of the Upper Yamuna Plains.	Achieved
2	To identify the source of recharge of different aquifers, and the interaction between various aquifers.	Achieved

3	To investigate the continuity of aquifers on both the sides of the river Yamuna,	Established
4	To determine the groundwater dynamics in different identified aquifers, and	Achieved
5	To estimate the groundwater velocity and replenishment potential of the deeper aquifers.	Achieved

Results:

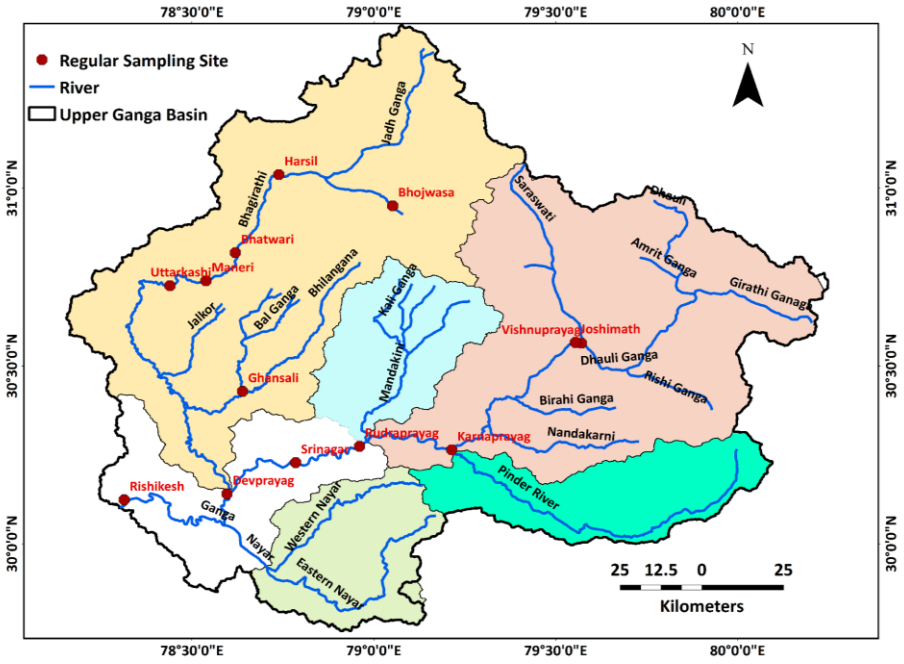
1. Deeper groundwater (Aquifer-III) in the south western part of UP side is the not being vertically recharged.
2. Good correlation between Terrigenic Helium and age of groundwater
3. Oldest ground water in the area estimated to be more than 1,00,000 years based on Helium dating.
4. There is a high temperature zone in the south and south western part of UP side study area
5. Final draft report has been submitted to IAEA. The project has been completed.

4. PROJECT REFERENCE CODE: NIH/HID/SPON/12-15

Title of the Study:	**Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques**
Study Team:	Dr. S. P. Rai (P.I.), Sc. 'F', Dr. Sudhir Kumar, Sc. 'G', Rajesh Singh, Sc. 'C', Dr. M. Arora, Sc. 'D', Dr. R. J. Thayyen, Sc. 'D' and Er. S. K. Verma Sc. 'D'
Type of Study	Sponsored
Funding Agency	DST, Govt. of India
Budget	Rs. 177.228 lakh
Date of Start:	April 2016
Date of Completion	March 2021

Study Area

Study area encompasses Ganga River Basin upto Rishikesh. The two main tributary joins together at Devprayag and combined flow is known as River Ganga. River Ganga and tributaries are fed by snow/glacier Melt during the lean flow period of summer months.



Study Objectives:

a) Isotopic characterisation of precipitation and identification of sources of vapour
b) Runoff generation processes in headwater region of Ganga using isotope and modeling
c) Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries.
d) Contribution of transient groundwater and its role in sustainable flow of Ganga.
e) Groundwater dynamics in mountainous area including identification of recharge sources and zones of major springs

Statement of the Problem:

The Himalayan mountain system is the source of one of the world's largest supplies of fresh water which is under threat due to serious environmental degradation and climate change. Continuing climate change is predicted to lead to major changes in the strength and timing of the Asian monsoon, inner Asian high pressure systems, and winter westerlies – the main systems affecting the climate of the Himalayan region. The impacts on river flows, groundwater recharge, natural hazards, and the ecosystem, as well as on people and their livelihoods, could be dramatic affected, although not the same in terms of rate, intensity, or direction in all parts of the region. Therefore, a thorough understanding of hydrological processes operating Ganga River Basin is a fundamental requirement.

Action Plan: (2016-2021)

Activities	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Appointment of Project staff	√									
Procurement of instruments	√	√								
Literature Collection	√	√	√							
Sample collection and analysis of sample for stable and radio isotope		√	√	√	√	√	√	√		
Compilation of data, interpretation and analysis					√	√	√	√	√	
Organisation of training course and workshop				√		√		√		
Preparation of final report										√

Objectives vis-à-vis Achievements

Objectives	Achievements
Isotopic characterisation of precipitation and identification of sources of vapor	Sampling of precipitation from different altitude has been started for isotopic analysis.
Runoff generation processes in headwater region of Ganga using isotope and modeling	Water samples from river, springs, snow and glacier melt has been collected for isotopic analysis. Input file for SNOWMOD model is under preparation
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	To cover the spatial and temporal variability, 9 sites from upstream to downstream have been developed for regular sampling from both Bhagirathi and Alaknanda.
Contribution of transient groundwater and its role in sustainable flow of Ganga	Samples collected for tritium analysis of GW, river and precipitation under laboratory analysis
Groundwater dynamics in mountainous area including identification of recharge sources and zones of major springs	Few springs have been selected for detailed isotopic investigation in order to in order to determine the recharge zone.

Progress of Work/Results and Analysis

- MoUs with Wadia Institute of Himalayan Geology (WIHG), Dehradun and Hemwanti Nandan Bahuguda University (HNBU), Srinagar, Garhwal have been signed with the objective of defining the scope of works among collaborative institutes.
- Three field visits have been made to collect river and spring water sample in the catchment.
- A total number of 671 water samples including 578 stream/spring, 42 groundwater and 51 rainfall have so far been collected
- Samples have been analysed for physio-chemical properties (EC and pH) and stable isotopes (δ^2H and δ^{18}O), the analysis of tritium is in process.
- The daily sampling River water and rainfall has been started at nine sites along Bhagirathi and Alaknanda Rivers for the isotopic characterisation of stream and precipitation.
- 200 hundred MODIS satellite images (January 2013 to June 2016) have been downloaded for the classification of snow cover area

The results of isotope (δ^{18}O, δ^2H and ^{3}H) will be presented during the working group meeting.

Future Plan

- Regular sampling of river, groundwater, precipitation for stable and radio isotope
- Preparation of detailed geomorphological map
- Measurement of Radon isotope
- Estimation of contribution of different tributaries in Alaknanda and Bhagirathi River
- Estimation of snow and glacier melt contribution in Alaknanda and Bhagirathi river
- Estimation of Recharge zones of springs.

ITEM NO. 45.4 PROPOSED WORK PROGRAM OF THE H.I DIVISION FOR THE YEAR 2017-18

As per the approved work program of the Hydrological Investigations Division for the FY 2016-17, 4 Internal studied, 1 sponsored projects shall continue during the FY 2017-18. Moreover, it is proposed to start three new studies (2 internal and 1 sponsored,) w.e.f 01.04.2016.The proposed work program of the division during FY 2016-17 is given at Annexure-II.

Type of study/Project	***Continuing Studies***	***New studies proposed***	***Total***
Internal Studies	4	0	4
Sponsored Projects	1	6	7
Consultancy Projects	7	2	9
Total	12	8	20

The details of the proposed new studies and the sponsored projects to be undertaken during the FY 2017-18 are given below:

Title of the Study : ***Integrated Study on Groundwater Dynamics in the Coastal Aquifers of West Bengal for Sustainable Groundwater Management***

Study Team: : Dr M. Someshwar Rao Sc. 'D'(PI)
Dr Sudhir Kumar, Sc. 'G'& Head, H. I. Division and
Budget : Rs. 46.0 Lakh
Duration : $3^1/_2$
Study Team : Dr Sudhir Kumar, Sc. G
Dr M Someshwar Rao, Sc. E (PI)
External Institution: Er. Subrata Halder, Exec. Eng., State Water Investigation Directorate (SWID), Government of West Bengal

Statement of the Problem

The structure of the saline–freshwater interface is important in the assessment of (i) diminishing rate of fresh groundwater reserve (ii) fresh groundwater discharge to sea (iii) salt enrichment in the inland aquifers and (iv) pollution discharge into the marine environment. Isotopic & chemical tracer techniques are field based methods extensively used for investigating the dynamic state of the freshwater - saline water interface. In the present study, seasonal variation in the seawater groundwater interface and the responsible factors affecting this dynamic condition in the coastal zone of West Bengal will be assessed using isotopic and chemical techniques. The results from field based data and modeling exercise will be attempted to develop management strategies (protocol for groundwater withdrawal, artificial recharge measures etc) for long term groundwater sustainability.

Study Objectives: The specific objectives of the project are:

i. Assessment of spatio-temporal variables (sea level change, variation in groundwater levels, rainfall trend etc) influencing dynamics between seawater & groundwater interface using archival data
ii. Spatio-temporal variation map of fresh water – saline water interface from the present observations.
iii. Identification of source of salinity in groundwater
iv. Identification of groundwater recharges sources & flow pattern and temporal and spatial pattern of excess surface water available in the coastal zone for artificial recharge measures
v. Management measures for safe & sustainable coastal groundwater use

Methodology

To meet the project objectives the study will be conducted along the following lines:

i) **Literature Survey:** Literature on state of art knowledge on Seawater Intrusion & Submarine Groundwater Discharge will be compiled and, the present state of fresh groundwater availability in the coastal West Bengal will be prepared.

ii) Data collection & Analysis: The archival data on hydrological details of the study area (sea-level change, groundwater level, rainfall data, river stage etc.), will be collected and will be analyzed to get hydro-meteorological trends, groundwater flow pattern, groundwater fluctuation etc.

iii) Field work: Water samples from production wells (hand-pumps, bore wells etc) will be collected in pre & post monsoon seasons and will be analyzed for major ion concentration, EC, $\delta^{18}O$ & δD and radon concentration to investigate seasonal variation in hydrological exchange pattern between land and sea in response. A few samples will also be dated by measuring their environmental tritium activity. The groundwater age can be used to assign the time scales of groundwater-seawater exchange process.

iv)Analysis: EC, $\delta^{18}O$ and δD, dissolved radon, major ion concentration, environmental tritium activity etc measured in the collected samples will be interpreted in integration with the archival data to explain, source of salinity in groundwater, recharge sources to

groundwater and coastal contamination process. Various thematic maps will be prepared.

vi) End use: The results will be interpreted in terms of identification of recharge areas, adoptive management strategies to improve the groundwater conditions through suitable artificial recharge measures or by groundwater withdrawal strategies.

vii) Knowledge dissemination: Annual/ interim reports, publications, knowledge dissemination through training programme, mass awareness programme etc.

Work Plan & Activity Chart

(Describe various work elements of study and give a 3-monthly activity chart)

Sl. No.	Work Element	1st Yr				2nd Yr				3rd Yr				4th Yr	
		1	2	3	4	1	2	3	4	1	2	3	4	1	2
1	Appointment of project staff	✓													
2	Procurement of items	✓			✓										
3	Preparation of various index maps		✓	✓											
4	Field survey for water sampling, sample & data collection and monitoring of hydro-meterological data		✓		✓	✓		✓	✓		✓	✓	✓		
5	Literature survey and writing of Status report, review report & interim report		✓	✓	✓	✓	✓	✓		✓					
7	Stable isotope, water quality, radon measurement and tritium analysis				✓	✓	✓	✓	✓	✓	✓	✓	✓		
8	Preparing of thematic maps, data analysis & modeling, identification of recharge areas, drawing inferences on coastal hydrological processes and suggesting adoptive measures to improve the groundwater conditions							✓	✓	✓	✓	✓	✓	✓	
9	publications									✓	✓	✓	✓		
10	Trainings and mass awareness programme					✓			✓		✓		✓	✓	
11	Final report													✓	✓

Head-wise budget details

S. No.	Head	1st Year	2nd Year	3rd Year	4th Yr	Total Amount (Rs.)
1	Remuneration/Emoluments for Manpower (1 JRF +2 High skilled persons)	4.8	4.8	4.8	1.8	14.4
2	Travelling Expenditure	2.7	2.7	2.7	0.65	9.11
3	Infrastructure/Equipment	0.5	6.,00	0.5	-	7.00
4	Experimental Charges/Field work/Consumables	3.0	4.0	3.5	-	10.50
5	Capacity building/Technology transfer	--	3.0	3.0	2.0	8.00
6	Contingency (miscellaneous charges)	0.2	0.3	0.3	0.1	0.9
	Total	51.50 lakhs (NIH: Rs 46lakhs + WB: Rs. 5.5 = 51.5)				

2) Title of the Study ***Development of management strategies for the rejuvenation of Rispana and Bindal rivers in Dehradun district of Uttarakhand***

Study Team:

NIH, Roorkee:

Dr. Sudhir Kumar, Sc. G
Dr. M. Someshwar Rao, Sc. E (PI)
Dr. A. R. Senthil Kuamr, Sc. E
Dr. Gopal Krishan, Sc. C
Sh. Jagdish Prasad Patra, Sc. C
Sh. Digambar Singh, Sc. c

Partner Organization (IRI, Roorkee)

Shri B. K. Pandey, Superintending Engineer (PI)
Sh. M. K. Khare, Executive Engineer,
Sh. Anubhav Nautiyal, Assistant Engineer,
Sh. Manish Shankar Sant, Assistant Engineer,

Budget (NIH, Roorkee) : 33 lakhs
Duration $3^1/_2$

Statement of the Problem:

Since the ancient times, many of the cities have been developed on the banks of rivers. However, with the passage of time, the cities expanded and encompassed these rivers. As a result, the rivers started getting polluted, their discharge reduced and they started getting used as city drains. Further, the global climate change is also affecting hydrological cycle, crop productivity and water demand. The combined effect of natural and anthropogenic factors is seen affecting rivers & springs worldwide including that in Himalayan region.

Dehradun, the capital of Uttarakhand is one of the fastest growing city of the state Uttarakhand. Rispana and Bindal are the tribuatries of the river Suswa which is a tributary of the river Song. Suswa and its tributaries drain central part of Dehradun city whereas, the river Song drains eastern part of Dehradun. River Suswa after its traverse along the foothills of Siwalik hills joins the river Song which then further after traverse of about 15 km joins to the the River Ganga. The river Suswa and its tributaries Rispana and Bindal which once were the source of fresh water to Dehardun city and to the wildlife of the reserve forest are presently in dying condition and are getting loaded by the city waste. The pollution load in the river is polluting the city environment, contaminating the local groundwater, providing polluted drinking water to the wildlife and, finally, contaminating the river Ganges on discharge into it.

The objective of the present project is to put all kinds of scientific efforts to rejuvenate this river system to their natural aesthetic condition to benefit city environment, wild-life and adding value to the Clean Ganga Mission.

Study Objectives: The specific objectives of the project are:

1. Investigation of the factors responsible for the change in the river hydrological conditions
2. Assessment of river discharge components (inflow from springs, catchment run-off, base flow; outflow as recharge to groundwater, direct withdrawal etc) using field observations, watershed modeling and isotopic analysis
3. Mapping the source of pollution to the streams and assessment of seasonal variation in water quality of river system
4. Preparation of base-line report on (i) seasonal variation in stream discharge and stream water quality and (ii) stream response to climate change

5. Preparation of various thematic maps and proposing ways to revive the streams

Methodology:

To meet the project objectives the study will be conducted along the following lines:

Hydrological inflow & outflow components will be monitored by installing hydro-meteorological instruments at suitable locations. The monitored data will be used for generating springs and stream hydrographs. These hydrographs will be inter-compared to identify inter-relation between streams & springs and the time delay between rain event and its appearance in the discharge points. The discharge characteristic of the springs will be inter-compared to interprete about their source of origin. Stream hydrographs will be resolved for separation of base flow component. Variation in sediment load in streams will be analyzed to identify the correlation between run-off and soil erosion.

SWAT and ANN procedures will be applied to compute the run-off and water storage at sub-watershed scale.

Isotopic and chemical data will be analyzed to investigate interrelation between hydrological components (rainfall, groundwater, river water and spring water).

A few samples will be analyzed for environmental tritium and dissolved radon to examine the groundwater recharge zones and groundwater flow rates.

Groundwater flow pattern, vulnerability of water resource to climate change, cost-effective structures for revival of rivers, possibility of interlinking of surface water structures or any such suitable measures will be suggested.

Work Plan & Activity Chart

Sl. No.	Work Element	1st Yr				2nd Yr				3rd Yr				4th Yr	
		1	2	3	4	1	2	3	4	1	2	3	4	1	2
1	Selection of site. Identification of camp office. Construction/ renovation of v-notch gauging site.	✓	✓	✓											
2	Inevntry and mapping of spring, canal, rivers, drains		✓	✓	✓	✓	✓	✓							
3	Land use map of different seasons and year		✓	✓	✓	✓	✓	✓							
4	Mappiing of spring sheds and sub-watersheds		✓	✓	✓	✓	✓	✓							
5	Purchase of Equipments/instruments	✓	✓	✓	✓										
7	Installation of Equipment	✓	✓	✓	✓										
8	Appointment of project staff	✓	✓	✓	✓										
9	Electronic & manual data collection			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
10	Collection of water samples for water quality and isotopic analysis			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
11	Lab Analysis					✓	✓	✓	✓	✓	✓	✓	✓		
12	Model development, calibration & validation					✓	✓	✓	✓	✓	✓	✓	✓		
13	Data Interpretation for water quality and water availability in different seasons in the sub-watershed			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
14	Mapping of hotspots contaminating water resource and zones with excess water availability								✓	✓	✓	✓	✓		
15	Development of field based scenario for river rejuvenation using the model results										✓	✓	✓	✓	✓
16	Knowledge dissemination through									✓	✓	✓	✓		

	interactive training programmes														
17	Interim annual report/ Final report & publication			✓	✓			✓	✓				✓	✓	✓

budget details *(NIH component)*

S. No.	Head	Amount (Rs. in lakhs)
1	Remuneration/Emoluments for Manpower (JRF/SRF, Sr Proj Officer, Lab Assitt, Field Assitt: 1 no each)	22.0
2	Travelling Expenditure	4.0
3	Infrastructure/Equipment	--
4	Experimental Charges/Field work/Consumables	5.0
5	Capacity building/Technology transfer	2.0
6	**Total**	33.0

3) Project Title: ***Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin***

Study Team

Dr Sudhir Kumar, Sc. G (PI)
Dr. C. K. Jain, Sc. G
Dr M Someshwar Rao, Sc. E

Partner Organization: Er. Y. B. Kaushik, R. Dir., CGWB, Northern Region, Lucknow

Budget (NIH) : Rs. 50.6 Lakhs

Duration : $3^1/_2$

Statement of the Problem:
Groundwater in India is depleting at shocking rate. About half a century back, the dug wells which were providing sufficient water to serve the country have got replaced by over 50 lakhs tube wells drawing over 245 BCM of groundwater. Growing demand of food grain, speedy economic growth, agricultural drought, climate change etc are accelerating the water demand and, the advancement in technology is providing ease to draw water from deeper and deeper depth. Today, in most part of the country the shallow aquifers are either dried up or nearly became un-usable for economic use. Even the Ganga basin, one of the largest groundwater multi-aquifer systems in the world is witnessing the groundwater problem. The basin is covered by alluvium of varying thickness with a depth ranging up to 8km (Sastri et al., 1971). Recent studies carried out by National Institute of Hydrology in support with IAEA, Vienna has revealed that deep groundwater of Ganga basin are older than 1,00,000 years, meaning that groundwater in deeper aquifer is quasi-static in nature. With the progressive water demand as the wells are getting sunk to deeper depths the deeper aquifers will become active (depletion and contamination). As on date it is not known the depth below which groundwater exist in quasi-static condition, what is the age, quality and source of this groundwater. The objective of the present project is to investigate and answer some of these unknown details.

Study Objectives: The specific objectives of the project are:
i. To identify the various aquifers present in Upper / Middle Ganga Plains.
ii. To identify the source of recharge of deep aquifers
ii) To assess interaction of deep aquifer with overlying aquifers.
iii. Water quality of deep aquifer
iv. Sustainability of deep aquifer for its exploration and future use

Methodology:
Water sampling: In the study region, tube-wells of CGWB/ State owned wells will be examined and the selected deep aquifer groundwater (which tap water form depth more than the wells presently getting tapped for any purpose (irrigation/industrial/domestic). Water samples from surface water sources (rain, river canal etc) will also be sampled to fingerprint the recharging groundwater source.
Measurements: Physico-chemical parameters, major ions & trace metals concentration, bacteriological analysis, stable isotopes ($\delta^{18}O$, δD), tritium (^3H) content & ^{222}Rn concentration will be measured using the experimental facility available at NIH, Roorkee. For dating old samples, radiocarbon measurement facility will be developed in NIH.
Support of IAEA, Vienna will be taken for measurement of noble gas and for dating using $^3H/^3He$ and ^{36}Cl techniques.
Interpretation:
Data will be interpreted in terms of formation (leakage from overlying aquifer, distant recharge areas, flow dynamics, turn over time (i.e, how old is the groundwater) etc
Noble gas data will be used to estimate the recharging source water temperature.

Knowledge dissemination: Annual/ interim reports, publications, thematic maps etc., will be prepared. The knowledge gained will be disseminated through organizing training programme, mass awareness programme etc.

Work Plan & Activity Chart

Sl. No.	Work Element	1st Yr				2nd Yr				3rd Yr				4th Yr
		1	2	3	4	1	2	3	4	1	2	3	4	1
1	Appointment of project staff	✓												
2	Procurement of items	✓			✓									
3	Collection of available literature, data from CGWB and State Groundwater Departments and identification of wells and aquifers to be tapped for groundwater sampling		✓	✓	✓									
4	Water sampling for chemical, stable isotope analysis, ^{222}Rn, radiometric dating (^{3}H, ^{14}C, $^{3}H/^{3}He$) and noble gas analysis					✓	✓	✓	✓					
5	Development of radiocarbon dating line, procurement of standards from IAEA, Vienna, calibration of the system		✓	✓	✓	✓	✓	✓						
7	Chemical, bacteriological and isotopic analysis of water samples at NIH, Roorkee and transport of samples to IAEA, Vienna for analysis at IAEA, Vienna					✓	✓	✓	✓	✓	✓			
8	Noble gas & $^{3}H/^{3}He$ analysis at IAEA, Vienna							✓	✓	✓	✓			
9	Data analysis & interpretation									✓	✓	✓	✓	
10	Trainings and mass awareness programme								✓		✓		✓	✓
11	Interim reports & Final report				✓				✓					✓

Budget details (in lakhs)*:*

S. No.	Head	1st Year	2nd Year	3rd Year	4th Year	Total Amount (Rs.)
1	Remuneration/Emoluments for Manpower	4.08	4.56	3.38	1.5	13.98
2	Travelling Expenditure	3.2	3.2	3.2	1.0	10.6
3	Infrastructure/Equipment	5.0	9.0	1.5	0.1	14.6
4	Experimental Charges/Field work/Consumables	3.0	3.0	3.0	-	9.0
5	Capacity building/Technology transfer	--	--	3.0	2.0	5.00
6	Contingency (miscellaneous charges)	0.2	0.2	0.3	0.1	0.9
	Total					53.98 (NIH: Rs 50.6 lakhs + CGWB: Rs. 3.38 lakhs = 53.98 lakhs)

Isotope investigation of contemporary and past hydro-meteorological processes across Indian Himalaya

The Indian Himalayan Region (IHR) has tremendous hydrological significance because of the presence of numerous glaciers, high altitude lakes, karst springs, thermal springs and wetlands which directly or indirectly decide water availability for agricultural and human consumption, not only for the 40 million people living in the Himalayan region but also for the 500 million people in the Indo-Gangetic plains. Hydrological variations in terms of fluctuations in snow and ice cover and amount and time of precipitation in IHR can significantly affect socio-economy of people in the Indo Gangetic Plains (IGP), which produces about 50% of the total food grains in India and feed about 40% of the Indian population. It is, therefore, important to improve the understanding about the hydrometeorological, geo-hydrological and cryological processes affecting the dynamics of water reserves in Indian Himalayan Region.

The timely availability of water decides the agricultural productivity and hence profoundly affects socio-economic status of people in this region. In this context, change in the pattern of onset and withdrawal of monsoon and extent and intensity of western disturbances may have more profound impact on agriculture, forestry, fisheries, and livestock, as well as the urban and industrial water requirements. Therefore, understanding the hydrometeorological processes operating in the entire Himalayan region should be viewed as an essential necessity of a knowledge base to sustain socio-economic growth of India and not just as an academic quest.

In this connection a multi-institutional and multi-expertise research proposal has been developed by Physical Research Laboratory, Ahmadabad. The aims of the project are to address specific questions that have been identified based on the current scientific understanding and in cognizance of the perceived knowledge gaps. The Hydrological Investigations Division, National Institute of Hydrology, Roorkee is part of the proposed study.

ANNEXURE-II

HYDROLOGICAL INVESTIGATIONS DIVISION

PROPOSED WORK PROGRAMME FOR 2017-2018

S. No.	Study	Team	Duration/ Status
		INTERNAL STUDIES	
1.	Interaction between groundwater and seawater along the northern part of east coast of India	M. S. Rao (PI), Sudhir Kumar Pankaj Garg	2 years (08/15 - 03/18) Continuing Study
2.	Lake-Groundwater Interaction Studies for Sukhna Lake, Chandigarh	S.D Khobragade (PI); Sudhir Kumar; S. P. Rai, Senthil Kumar; Pankaj Garg	3 years (04/15 – 03/18) Continuing Study
3.	Radiocarbon dating of deeper groundwater of Indo-Gangetic Basin	M. S. Rao (PI) Sudhir Kumar	3 years (04/16 – 03/19 Continuing Study
4.	Isotopic Investigations in parts of Upper Yamuna River Basin	S. K. Verma (PI), Sudhir Kumar, S P Rai, Mohar Singh, Vishal Gupta	2 years (04/16 – 03/18) Continuing Study
		SPONSORED PROJECTS	
5	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	S. P. Rai (PI); Sudhir Kumar; Rajesh Singh; S. D. Khobragade; M. Arora; Dr. R. J. Thayyen; Sh. P. K. Garg	*5 Years 04/16-03/21*
6	Isotope investigation of contemporary and past hydro-meteorological processes across Indian Himalaya	S. P. Rai (PI);	*07/17 to 06/20 New Study*
7	Development of an action plan for conservation and sustainable management of Renuka Lake	SD Khobragade (PI)	*04/17 to 03/20 New Study*
8	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar CK Jain MS Rao	*04/17 to 03/20 New Study*
9	Development of management strategies for the rejuvenation of Rispana and Bindal rivers in Dehradun district of Uttarakhand	MS Rao	*04/17 to 03/20 New Study*
10	Dating vary old groundwaters of deeper aquifers in Ganga Plains, India	MS Rao, Sudhir Kumar	*10/16 to 09/20 New Study*
11	Stable isotope analysis of groundwaters of India	Sudhir Kumar	*04/17 to 03/18 New Study*
		CONSULTANCY PROJECTS	
1.	Hydrogeological Study for Dewatering of Jhamarkotra Mines, Distt. Udaipur	Sudhir Kumar	11/16-10/21 New Study
2	Hydro-geological study for Gadarwara super thermal power project, Madhya Pradesh	SD Khobragade	07/15-06/16 Continuing Study

S. No.	Study	Team	Duration/ Status
3	Detail Hydro-geological study of ash pond area, Talcher Super Thermal Power Station (TSTPS), Angul, Orissa	SP Rai	7/16 to 6/17 Continuing study
4	Hydro-geological study for Darlipali super thermal power project, Odisha	Sudhir Kumar	9/15 – 8/16 Continuing Study
5	Hydro-geological study for Khargone super thermal power project, Madhya Pradesh	SD Khobragade	07/15 – 4/16 Continuing Study
6	Hydro-geological and isotopic study for 1x660 MW Harduaganj thermal power project, UP	Sudhir Kumar	11/15 – 10/16 Continuing Study
7.	Hydro-geological and isotopic study for 1x660 MW Panki thermal power project, UP	Sudhir Kumar	12/15 – 11/16 Continuing Study
8.	Identification of source of seepage in the villages surrounding the Ash Dykes of Barh STPP	Sudhir Kumar	3/17 to 6/17 New
9.	Hydro-geological study for Jawaharpur thermal power project, Etah, UP	Sudhir Kumar	12/15 – 11/16 Continuing Study

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Rakesh Kumar	Scientist G & Head
2	Dr. J V Tyagi	Scientist G
3	Dr. A K Lohani	Scientist G
4	Dr. R P Pandey	Scientist F
5	Dr. S K Singh	Scientist F
6	Dr. A R Senthil Kumar	Scientist E
7	Dr. Sanjay Kumar	Scientist D
8	Dr. Archana Sarkar	Scientist D
9	Dr. Manohar Arora	Scientist D
10	Sri Digambar Singh	Scientist C
11	Sri J P Patra	Scientist C
12	Dr. Ashwini A. Ranade	Scientist C
13	Sri Naresh Kumar	Scientist B
14	Sri N K Bhatnagar	Scientist B
15	Sri R K Neema	PRA
16	Sri Hukum Singh	PRA
17	Sri Om Prakash	SRA
18	Sri Jatin Malhotra	SRA
19	Sri T R Sapra	RA

Work Program of for the Year 2016-17

S.No. & Ref. Code	Title	Study Team	Duration
COMPLETED STUDIES			
1. NIH/SWHD/NIH/14-16	Estimation of Water Balance for Integrated Water Resources Management in Yerrakalva Pilot Basin, A.P.	J.V. Tyagi YRS Rao	2.5 years (April 2014 to Sept. 2016)
2. NIH/SWHD/NIH/13-16	Application of DSS (P) for Integrated Water Resources Development & Management	A.K. Lohani Surjeet Singh Rahul Jaiswal D K Sonkusale Akilesh Verma	3 years (April 2013 to May, 2016)
3. NIH/SWHD/NIH/15-17	Study of regional drought characteristics and long term changes in supplemental irrigation water requirement in Seonath Basin in Chhattisgarh	R.P. Pandey Rakesh Kumar	2 years (April 2015 to March 2017)
4. NIH/SWHD/NIH/13-16	Quantitative assessment of uncertainties in river discharge estimation	Sanjay Kumar Sharad Jain	3.5 Years (April 2013 to December 2016)
5. NIH/SWHD/NIH/14-17	Hydrological modelling of Brahmani Baitarani river basin using eWater Source platform	J.P. Patra Rakesh Kumar Pankaj Mani	3years (April 2014 to March 2017)
ONGOING STUDIES			
6. NIH/SWHD/NIH/16-17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh	1 year (April 2016 to September 2017)
7. NIH/SWHD/NIH/16-19	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Sushil K. Singh	3 years (April 2016 to March 2019)
8. NIH/SWHD/NIH/14-17	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar Vaibhav Garg Rakesh Kumar N.K. Bhatnagar	3 years (April 2014 to Sept. 2017)
9. NIH/SWHD/NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Achana Sarkar T. Thomas Vaibhav Garg	3 years (April 2015 to March 2018)
10. NIH/SWHD/NIH/14-17	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora Rakesh Kumar	4years (May 2014 to March 2018)
11. NIH/SWD/NIH/14-17	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	3 years (Oct. 2014 to Oct 2017)

12. NIH/SWHD/NIH/15-18	Study on effect of climate change on sediment yield to Pong reservoir	A. R. Senthil Kumar J. V. Tyagi Avinash Agarwal Suhas Khobragade Manohar Arora	3 years (April 2015 to March 2018)
13. NIH/SWHD/NIH/14-17	Effect of climate change on evaporation at point scale	Digambar Singh A. R. Senthil kumar Manohar Arora	3years (June 2014 to Oct 2017)
14. NIH/SWHD/NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani	3 years (April 2015 to March 2018)
15. NIH/SWD/NIH/16-18	Snow cover variability in the Upper Yamnotri Basin	Naresh Kumar Manohar Arora Rakesh Kumar	2 years (April 2016 to June 2018)

1. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-16

1. Title of the Project: **Estimation of Water Balance for Integrated Water Resources Management in Yerrakalva Pilot Basin, A.P.**

2. Thrust Area under XII five year Plan: Integrated Water Resources Development & Management

3. Project Team: Dr. J.V.Tyagi, Sc 'G', SWH Div. (PI)
Dr. YRS Rao, Sc 'F', DRC, Kakinada (Co-PI)

4. Objectives of the study:

(i) To calibrate and validate SWAT model on Yerrakalva pilot river basin
(ii) To estimate water balance components and water yield in the basin

5. Statement of the problem:

Under 12th five-year plan program, NIH has taken up Pilot Basin Studies (PBS) for Integrated Water Resources Management (IWRM) in Yerrakalva river basin in coastal Andhra Pradesh. The program involves detailed studies on various components of the hydrologic cycle including water balance study of the basin. A water balance study quantifies the components of the hydrologic cycle at the catchment scale. The components of water balance of a basin are influenced by climate, the physical characteristics of the watershed such as morphology, land use and soil. Therefore, understanding the relationship between these physical parameters and hydrological components are very essential for integrated water resources management. This provides the most fundamental information about the hydrology of a watershed and is necessary to assess the importance of climate and land cover in determining water availability. In addition to providing a baseline understanding of the hydrologic processes occurring within a catchment, the water balance components can be compared over long periods of time to track the hydrologic response of a catchment to climatic and land cover variability. Therefore, the present study has been taken up for estimation of water balance and water yield in Yerrakalva river basin which is critical to long term sustainable management of water resources in the basin.

6. Study area:

The Yerrakalva river rises in the eastern slopes of the eastern ghats at the boarder of West Godavari and Khammam districts. It enters into West Godavari district after 6.4 km run in Khammam district and runs in West Godavari district for about 180 km and joins the Upputeru river, which takes off from the Kolleru lake and falls into Bay of Bengal. Yerrakalva enters the Godavari western delta near Nandamuru aquiduct of Tadepalligudem Mandal. The catchment area of the river is 2725.03 Sq km of which 2330.10 Sq km spreads in upland and 394.93 Sq km in delta (Fig. 1). The study area gets rain during both Southwest and Northeast monsoons. The annual normal rainfall in the basin is around 1078mm.

7. Present state of art:

Major hydrological processes can be quantified with the help of water balance equations. Since the hydrologic processes are very complex, watershed models are widely used for proper comprehension of water balance components. The models based on explicit catchment water balance modelling are numbered in the hundreds and new models are still being presented. The watershed models partition rainfall into various hydrological processes such as surface runoff, evapotranspiration, percolation, lateral flow and base flow etc. with the constraint to account for all water entering, leaving and being stored in a catchment. This adaptation of the principle of conservation of mass constrains the potential for error.

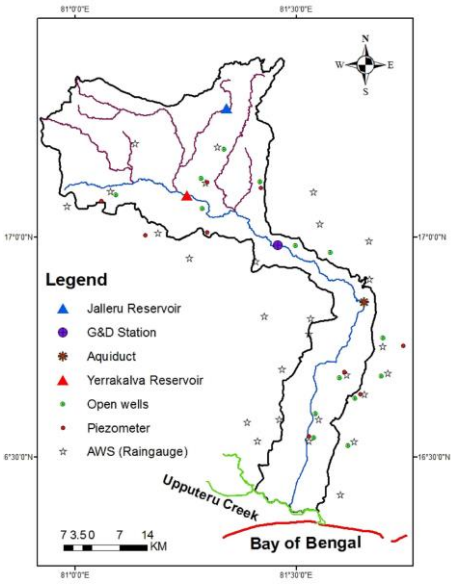


Fig. 1: study area

8. Methodology

SWAT, one of the most recent models developed by the USDA, is used to analyse and quantify the water balance of the Yerrakalva river basin. SWAT has been chosen as it is an integrated river basin scale, physically based, continuous-time, distributed watershed model. Also, its suitability to different parts of the world has been well established. The SWAT model uses physically based inputs such as weather variables, soil properties, topography, land use characteristics and land-management practices occurring in the catchment. The hydrologic cycle as simulated by SWAT is based on the water balance equation. Model outputs all water balance components (surface runoff, evaporation, lateral flow, recharge, percolation, sediment yield, etc.) at the level of each watershed and are available at daily, monthly or annual time steps.

9. Work schedule

(a) Date of commencement of the project: April 2014
(b) Duration of the project: Three years

10. Status of the study: Completed

11. Results

SWAT model was setup and calibrated for daily river discharges of 2009-12 at Ananathapalli G-D site (1662 sq km) which is located downstream of Yerrakalva reservoir. Since discharges at G-D site are regulated by the reservoir, the reservoir is also incorporated in the model to take into account the effect of reservoir regulation on flows at G-D site. The discharge data of four years from 2005 to 2008 were used for validation of the model. The results exhibited fairly good agreement between observed and simulated daily values, with coefficient of determination (R^2) of 0.65 and Nash–Sutcliffe simulation efficiency (E_{NS}) of 0.64 for calibration and 0.62 and 0.62 respectively for validation. The monthly values, aggregated from daily values, however, indicated a very high performance with R^2 and E_{NS} of 0.98 and 0.95 for calibration and 0.87 and 0.87 respectively for validation. The model also computed various water balance components and it was found that surface runoff amounted to 16.6%, lateral flow 3.1%, base flow 22.4% and ET 55.7% of average annual rainfall during calibration and 16.2%, 2.8%, 19.5% and 56.9% respectively during validation. The annual water yield was computed as 580 mm (41.8%) and 536 mm (38.3%)

during calibration and validation respectively. Overall, the model demonstrated good performance in capturing the patterns and trend of the observed flow series, which confirmed the appropriateness of the model for future scenario simulation. The study suggests that SWAT model could be a promising tool to predict water balance and water yield in sustainable management of water resources.

12. Research Outcome from the project:

(i) Quantification of water balance components of the catchment
(ii) Long term average estimates of catchment water yield
(iii) Technical publications in the form of report and research paper

2. PROJECT REFERENCE CODE: NIH/SWD/NIH/13-16

Title of the Project: Application of DSS(P) for Integrated Water Resources Development and Management

1. Study Group: Dr. A.K. Lohani, Scientist 'G'Surface Water Hydrology Division, PI
Data Collection, Data Processing, Data Analysis, Simulation, Interpretation of results etc.
Dr. Surjeet, Scientist 'D',Ground Water Hydrology Division, Co-PI
Data Collection, Data Processing, Simulation
Rahul Jaiswal, Scientist 'C' &Ganga Plains Regional Centre, Bhopal, Co-PI
Data Collection, Data Processing,Simulation
Officers from Water Resources Department, Chhattisgarh
***D. K. Sonkusale,** Water Resiurces Department, Raipur-Data Collection*
***AkileshVerma**, Water Resiurces Department, Raipur-Data Collection*

2. Type of study: Internal
3. Date of Start: April 1, 2013
4. Date of Completion: May 30, 2016
5. Type of Study: Internal
6. Statement of Problem

The management of water resources requires integration of large volumes of disparate information from diverse sources. An efficient and easy to use framework is required to couple this information with hydrological modelling tools for assessment and evaluation that allow broad, interactive participation in water resources planning and decision making process and effective methods of communicating results to a broader audience. Better and useful information needs to be made available to a larger number of participants in more open and participatory decision making and this information is to be effectively integrated into decision making processes. It is a challenge to integrate new information technologies with traditional methods of analysis and to put these tools to work in practice. A Decision Support System (DSS) helps in attaining this objective. DSS (planning) developed under Hydrology Project-II pertains to a decision support system for integrated water resources development and management. The proposed study will demonstrate the implementation steps and applicability of the DSS(P) for a selected basin.

7. Objectives:

To collect and process hydrological time series data and spatial data
To carry out rainfall-runoff modelling using NAM
To implement Mike basin in the study area
To generate scenarios for integrated water resources management

8. **The Study Area**

The Seonath River Originates near village Panabaras in the Rajnandgaon District. The Basin is located between latitude 20^0 16' N to 22^0 41' N and Longitude 80^0 25' E to $82^0$35' E. The Basin area of river up to confluence with the Mahanadi River is 30,860 Sq Km .The river traverses a length of 380 Km. The main tributaries of Seonath river are Tandula, Kharun, Arpa, Hamp, Agar and Maniyari Rivers. The mean annual rainfall in the basin varies from 1005 mm to 1255 mm.

9. Deliverables

The study was presented in the 69th TAC meeting of NIH held on 21.07.2016 and the final report of the study has been submitted.

3. PROJECT REFERENCE CODE: NIH/SWD/NIH/15-17

Title of the study: STUDY OF REGIONAL DROUGHT CHARACTERISTICS AND LONG TERM CHANGES IN SUPPLEMENTAL IRRIGATION WATER REQUIREMENT IN SEONATH BASIN IN CHATTISGARH

Project team:

Name of PI: **Dr. R.P. Pandey, Scientist G**; Surface Water Div., NIH Roorkee
Name of Co-PI: Dr. Rakesh Kumar, Scientist G, Surface Water Div., NIH Roorkee

Type of study: **Internally Funded**

Project Duration: **2-years**

Date of start: **April 2015**

Scheduled Date of Completion: **March. 2017**

OBJECTIVES OF THE STUDY:

The primary objectives in this study are as follows:

(1) To analyse long-term rainfall and streamflow data for assessment of regional drought characteristics
(2) To assess the climatic variability in terms of long term trend in climatic variables.
(3) To assess long-term changes in evapotranspiration and sensitivity analysis of ET to different climatic variables.
(4) Estimation of Crop Water Requirement (CWR) and net irrigation requirement (NIR) using suitable method.
(5) To analysis Long Term Trend in NIR
(6) To estimate the change in total Irrigation Water Demand (IWD).

Study Area: <u>Seonath Basin in the Chhattisgarh State</u>

The study selected for this study is Seonath River Basin in the state of Chattisgarh. The Seonath River is the longest tributary of the Mahanadi River basin draining three districts of Chhattisgarh namely Durg, Rajandgaon and Bilaspur. The Basin is located between latitude $20^0$16' N to 22^0 41' N and Longitude $80^0$25' E to $82^0$35' E. The drainage area of the Seonath river basin is 30,860 Sq km. The mean annual rainfall in the basin varies from 1005 mm to 1255 mm. Seonath river basin comprises 25% of the upper catchment of the Mahanadi basin

The study area (Seonath river basin) falling in Chhattisgarh State faces frequent droughts. Most of the tributaries of Seonath River get dried by mid-winter season and both rural and urban areas are subjected to severe water crisis during the summer season due to erratic and skewed nature of rainfall. Multipurpose water demand has increased with growth in population and the pattern of water availability and utilization has also changed with time. Sustainability has become a challenging issue in water resources development and management.

Proposed Methodology

For determination in variability of climatic factors and the long term changes in IWD, the methodology would include the following:

- The determination the monotonic linear trends in metrological time series (Temperature, Rainfall, Relative Humidity, Wind Speed and Sunshine Hours) using the Mann Kendall's test.
- Estimation of the slopes of trend lines of metrological variables using the Theil–Sen's slope estimator.

- Determination of the step change/ detect the abrupt changes in the time series using cumulative deviation test and distribution free CUSUM test.
- Determination of the percentage variability of metrological series by Coefficient of Variation (CV) over entire Seonath river basin.
- Estimation of ET using suitable method and the application of the Partial Relative Correlation Method to investigate the correlation between ETo and meteorological variables.
- Estimation of CWR and NIR and subsequently assessment of changes in the total Irrigation Water Demand in different seasons.
- Long term Trend Analysis of Net Irrigation Requirement and determination of trend in ET and NIR using Mann Kendall's test and Thiel's Sen's Slope Estimator will be use to estimate the trend magnitude.
- Thus the study will lead to assess changes in irrigation water demand over past 50-years in the context of long term changes in climatic variables.

Progress of Work

(i) **Collection of information and Hydro-meteorological Data**

a. The daily meteorological data [Rainfall, Temperature (maximum, minimum and mean)] of 24 stations have been collected from IMD, Pune for 51 years (1960-2010). Observed data on wind speed and relative humidity is available only for eight stations. The pan evaporation data is available only for one station viz., Raipur. The location of the stations and digital elevation model (DEM) of basin are shown in Figure 1a &1b.

b. The discharge data for the same period at the single outlet namely Nandghat, has been obtained from State Data Centre, Department of Water Resources, Raipur (Chhattisgarh).

(ii) **Preparation of Base maps *(Digital Elevation Model (DEM), Soil Map, Land Use Map and District Map etc*. has been completed:**

The composite maps have been prepared to illustrate the location of different meteorological stations located within Seonath River Basin and DEM. The maps of land use and soil type (Figure 2a & 2b) have been prepared. . The major land use of the basin is for agriculture except in Raipur district which shows major settlement; therefore the basin is described as an agriculture basin (Figure 2a) The main soil types found in the basin are sandy clay covering 72.28% of the basin area followed by silt loam 17.29% of the basin area (Figure 2b).

Agriculture is the main occupation of people in this sub-basin. About 76% of the basin area is under cultivation. There are two cropping seasons namely, monsoon (kharif) season from mid-June to October and post-monsoon (rabi) season from November to middle of April. Rice is the major crop of monsoon season covering 94% of the cultivated basin area (Figure 3a). During rabi season, wheat, summer paddy, pulses and oilseed are grown. The kharif rice, wheat and summer paddy are the main crops covering an area of about 22679 sq. km i.e., 98% of the basin cultivated area (Figure 3b).

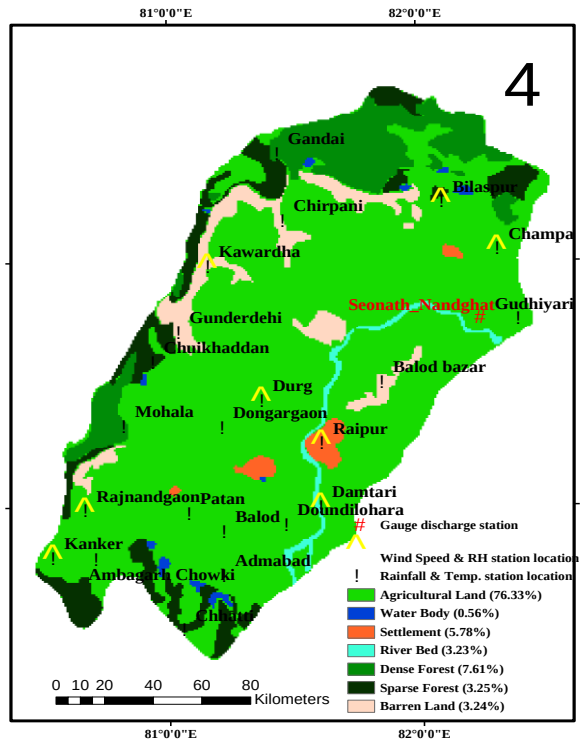


Figure 2a: Land Use/Cover Map

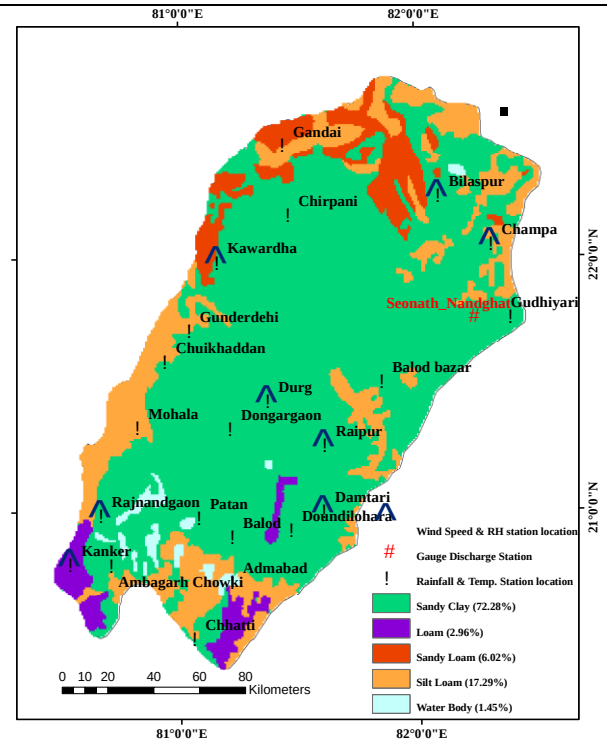


Figure 2b: Soil Type Map

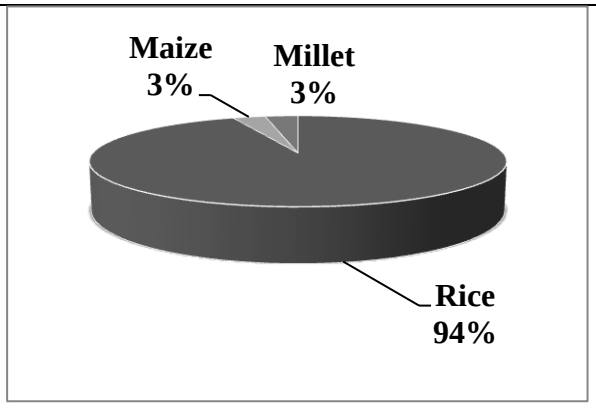


Figure 3a: Kharif season crops in Seonath river basin. *(Source: Directorate of Economics and Statistics, Chhattisgarh)*

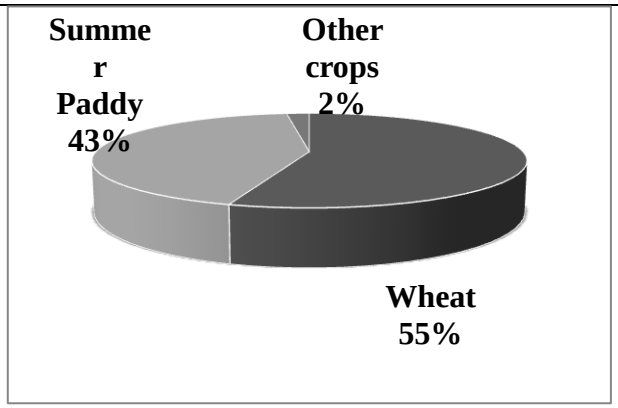


Figure 3b : Rabi season crops in Seonath river basin. *(Source: Directorate of Economics and Statistics, Chhattisgarh)*

(iii). Assessment of trends in climatic variable:

The daily data of rainfall, maximum and minimum temperature, relative humidity and wind speed have been collected from India Meteorological Department (IMD), Pune, and State Data Centre, Department of Water Resources, Raipur (Chhattisgarh) from 1960-2010 (51 years). For rainfall, maximum temperature and minimum temperature data is available for 24 stations whereas for wind speed and relative humidity, data is only available for eight stations. The detail information about the stations has been presented in Chapter 3. These data has been used to check the trend and variability on annual and seasonal time scale viz. summer (March-May), winter (November to January) and monsoon (late June to October) for Seonath River Basin falls in Chhattisgarh State.

A: Homogeneity Test: Double Mass Curve analysis has been carried out to check the homogeneity/consistency in the annual and monthly rainfall data series.

B: Dependency Test (Autocorrelation coefficient): The dependency of different meteorological parameters has been computed using lag-1 serial correlation coefficient. In this study, almost all the series are found to be non-correlated except few of the series are correlated (Figure 4).

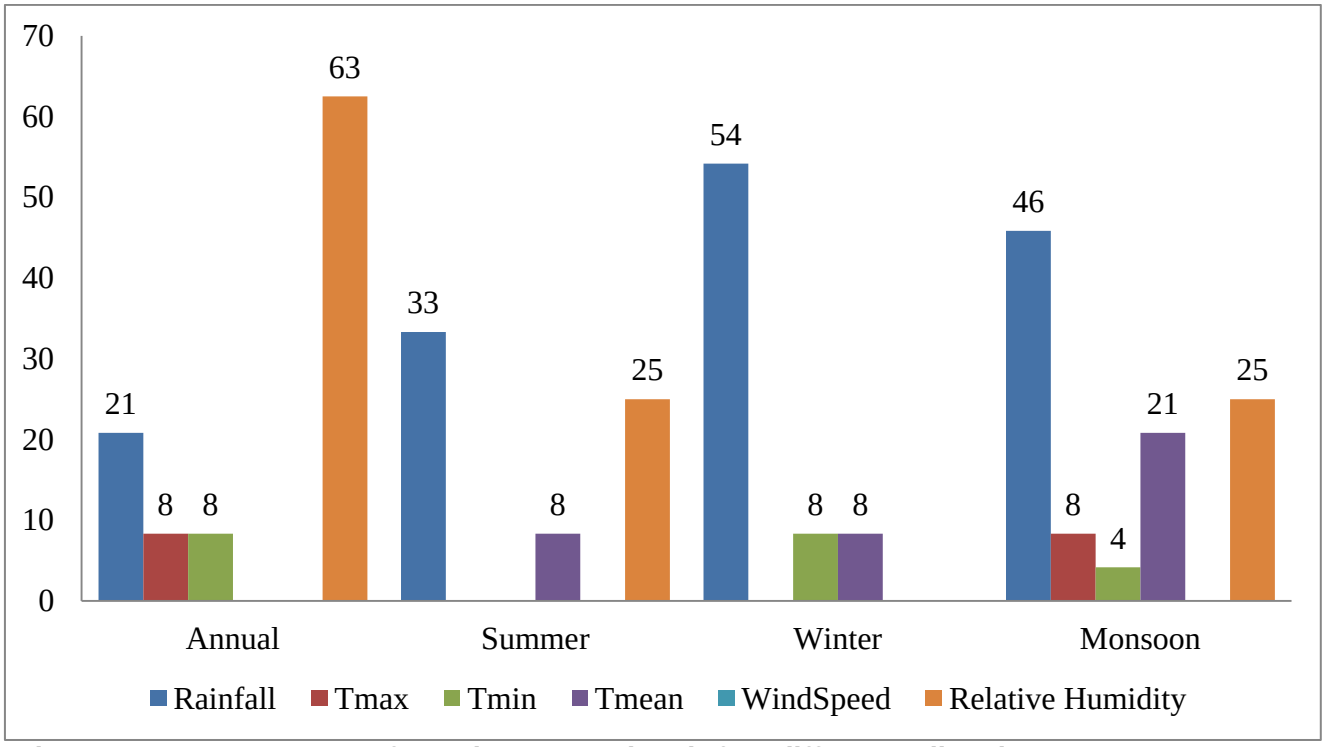


Figure 4a: Percentage of Stations correlated for different climatic parameters (Annual and Seasonal)

(iv). Statistical Test for Trend and Variability Analysis

The Mann-Kendall test **(Non-parametric)** (Yu and Neil, 1993; Douglas et al., 2000; Yue et al., 2003; Burn et al., 2004, Singh et al., 2008a, b) is used to detect monotonic (increasing or decreasing) trend in rainfall data. In addition to recognize whether a trend exists, the trend magnitude has been assessed by Sen's Slope Estimator (β), and expanded by Hirsch et al. (1982). To estimate trend magnitude Theils-Sen's slope (β) approach is used in this study. Flowchart (Figure 4b) presents methodology for trend and variability analysis of meteorological variables.

Some trends may not be evaluated to be statistically significant while they might be of practical interest and vice versa. For the present study, change percentage has been computed by approximating it with a linear trend. That is change percentage equals median slope multiplied by the period length divided by the corresponding mean, expressed as percentage (P_c) followed by Yue and Hashino (2003). The percentage change is estimated by following formula.

$$P_c = \frac{\beta * L}{\mu} \quad (1)$$

Where, P_c = Percentage Change, β = Slope Magnitude, L = Length of the year and μ = Corresponding mean.

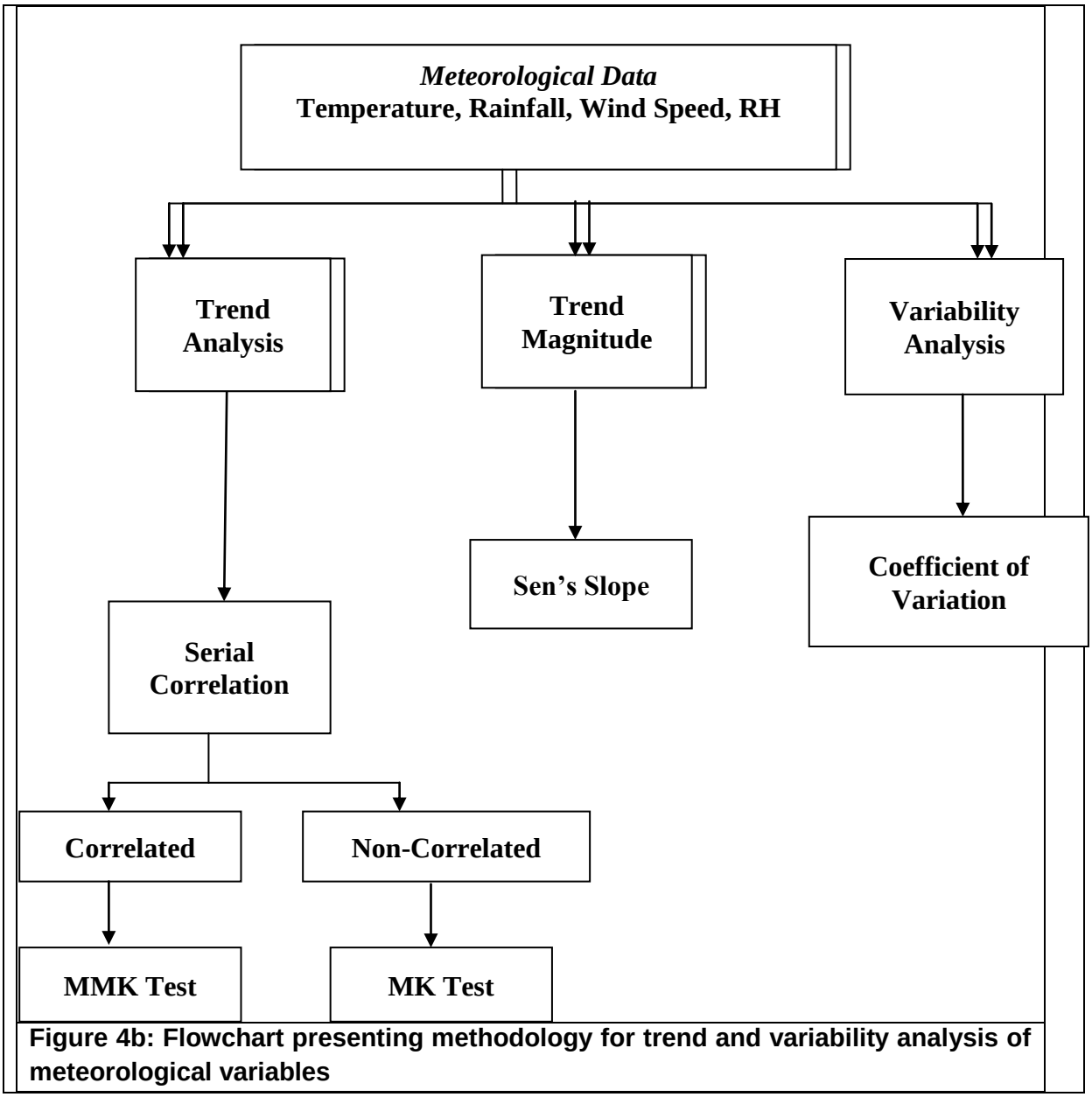


Figure 4b: Flowchart presenting methodology for trend and variability analysis of meteorological variables

Spatial Distribution of trends of rainfall is shown in Figure 4c

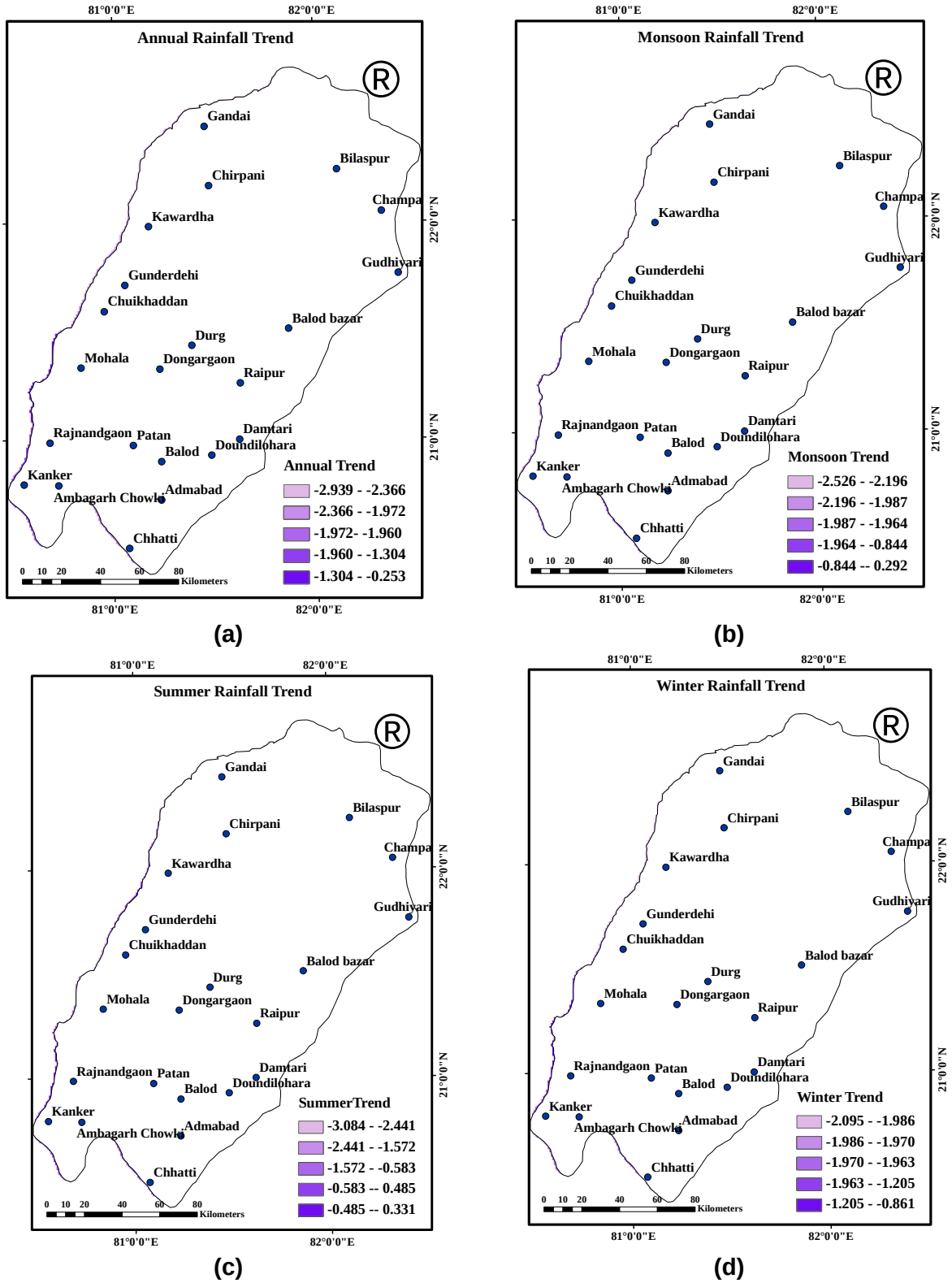


Figure 4c: Trend in annual and seasonal rainfall in Seonath river basin over the period of 1960-2010 (a) Annual (b) Monsoon (c) Summer (d) Winter

Table 1: Results of regional average annual and seasonal rainfall for entire Seonath River Basin.

Entire Seonath River Basin	Rainfall			
	Z-values MK	Sen's Slope (β)	% Change over 51 year	% Variability over 51 year
	(Col.1)	(Col.2)	(Col.3)	(Col.4)
Annual	-0.529	-2.4	-12.33	30.78
Summer	-0.472	-0.5	-9.0	6.95
Winter	-0.444	0.0	-1.7	17.19
Monsoon	-0.994	-2.79	-21.64	43.95

Impact of Climate Change on Irrigation Water Requirement (IWR) has been assessed using predicted climate obtained from projected statistical down scaling. The some results are reported below:

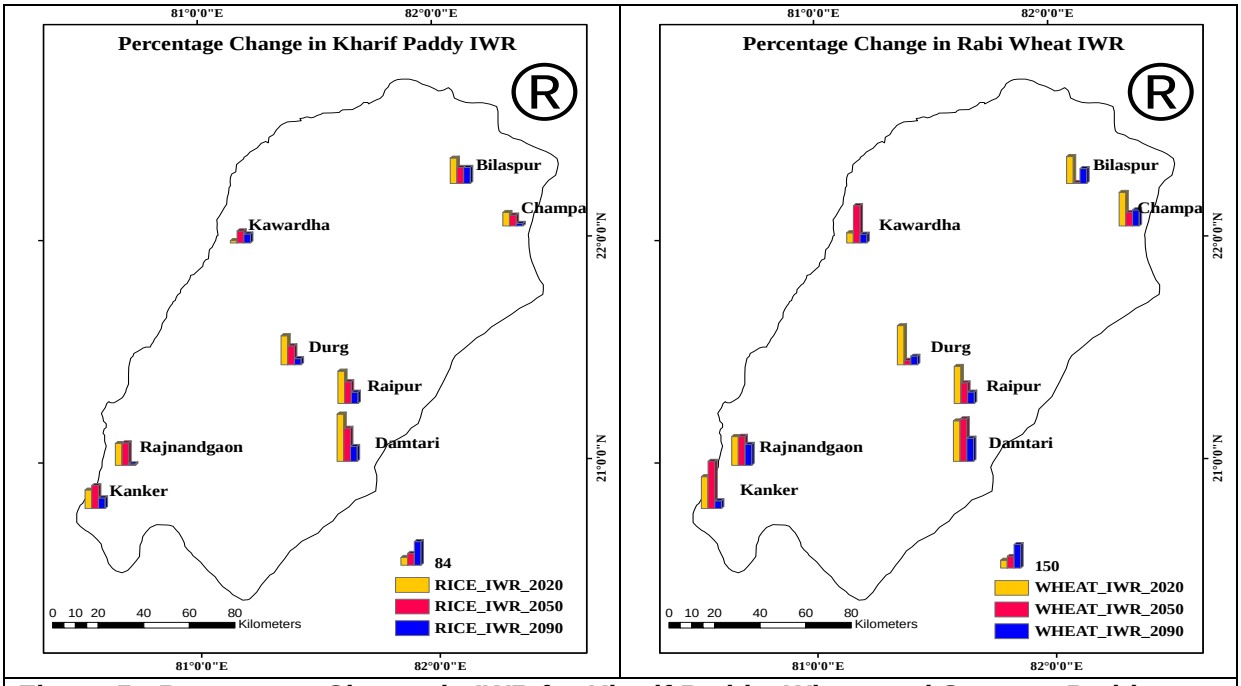


Figure 5: Percentage Change in IWR for Kharif Paddy, Wheat and Summer Paddy

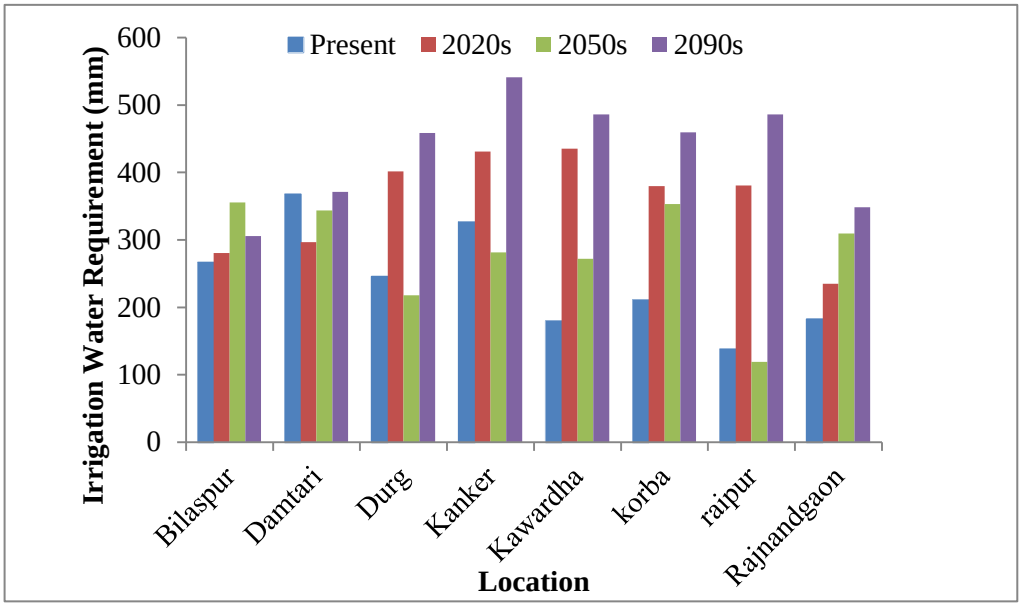


Figure 6: Irrigation Water Requirement of Kharif Paddy

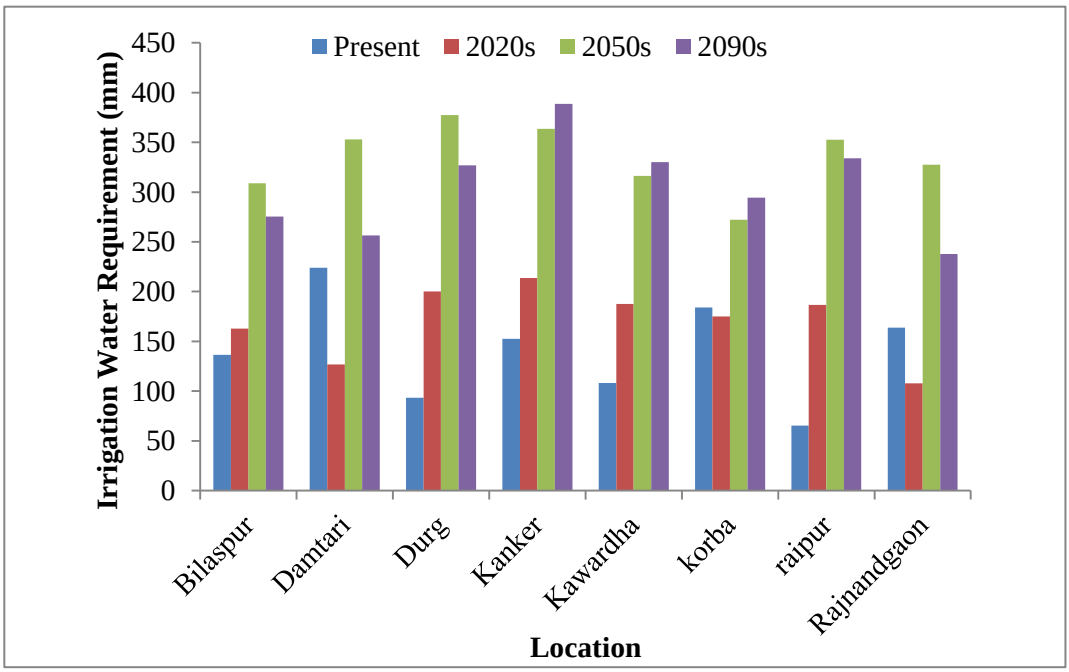


Figure 7: Irrigation Water Requirement of Rabi Summer Paddy

The report has been completed. The draft report will be placed and presented in the Working Group meeting.

4. PROJECT REFERENCE CODE: NIH/SWD/NIH/13-16

1. Title of Study: Quantitative assessment of uncertainties in river discharge estimation.

2. Study Group - Sanjay Kumar, Sc-D, PI
Sharad Jain, Sc-F, Co-PI

3. Objectives of the study:

The objectives of the study are:

1. To estimate uncertainty in river discharge observations.
2. To estimate uncertainty in the stage-discharge (rating) relationship.
3. To estimate uncertainty in stage- discharge relationship using slope as a parameter (back water effects).

4. Statement of the problem:

The uncertainty in the river discharge measurement and estimation is caused by different sources of errors. These mainly includes uncertainty in (a) observations of river stage and discharge used to parameterize the rating curve, (b) presence of unsteady flow conditions, and (c) interpolation and extrapolation errors of the rating curves. The study will provide a framework for analyzing and quantifying the uncertainty in the (i) river flow data (ii) stage-discharge relationship and (iii) stage-slope-discharge relations (for backwater effects) based on the ISO documents GUM (Guides to the expression of Uncertainty in Measurement), HUG (Hydrometric Uncertainty Guidance), ISO 773, 5168, 7066 and 768. The study will also examine various hydraulic factors controlling the flow at a cross section in the river and provides an understanding of independent variables that describes relations among stage, discharge and other parameters specifically discharge measurement under back water effects.

5. Methodology:

Statistical methods/tools and the procedures described in various ISO documents (GUM, HUG) will be used for the estimation of river discharge uncertainties. The uncertainty in discharge measurement (assuming velocity area method) will be quantified as per the ISO 748 which provides the magnitude of these errors at 95% confidence level. The GUM defines the law of propagation of errors for combining uncertainties from several sources and HUG described it for different types of mathematical expressions generally used in hydrometry. This is illustrated by considering the quantity Q as a function of several measured quantities x, y, z . The error δQ in Q due to errors δx, δy, δz…. in x, y, z…., respectively, is given by

$$\delta Q = \frac{\partial Q}{\partial x}\delta x + \frac{\partial Q}{\partial y}\delta y + \frac{\partial Q}{\partial z}\delta z + \cdots$$

The uncertainty of a discharge measurement determined from a stage-fall-discharge rating function (as opposed to a gauged discharge which is determined from a current meter) shall be evaluated using statistical equations based on law of propagation of errors described above. Let X_{rd} be the uncertainty in the recorded discharge, the above error equation is then modified for uncertainty in discharge compution using stage-fall-discharge relationship as

$$X_{rd}=\pm(X_{\alpha}{}^{2} + \beta^{2}X^{2}\, h_{u/s\text{-}h0} + \gamma^{2}X^{2}{}_{hu/s\text{-}hd/s})^{1/2}$$

In practice, X_{α} is the standard error of the mean relation ($S_{mr)}$. $Xh_{u/s\text{-}h0}$ is the standard error of upstream gauge and $X_{h\ u/s\text{-}h\ d/s}$ is the standard error of fall between the u/s and d/s gauges.

6. Deliverables: Revised ISO document**,** Research papers and Report

7. Cost estimate for the FY 2016-17

a. Total cost of the project:
b. Source of funding: Internal
c. Sub head-wise abstract of the cost

S.N.	Sub-head	Amount (in Rupees)
1.	Salary	24,60,000.00
2.	Travelling expenditure (domestic/international)	100,000.00
3.	Infrastructure/Equipment	00.00
4.	Experimental charges	00.00
5.	Misc. expenditure	40,000.00
	Grand Total:	26,00,000.00

d. Justification for Sub-head-wise abstract of the cost

In the year (2016-17), technical services of Sc'G' and Sc 'E' will be utilized for the achieving the targets. Domestic and international travel for attending various meeting of ISO and BIS related to revising the ISO 9123 document. Availing/procuring computing facilities in the institute and miscellaneous contingencies.

2. Quarterly Break up of cost estimate for each year (FY 2016-17)

S.N.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	Salary	615000.00	615000.00	615000.00	615000.00
2.	Travelling expenditure	50,000.00	50,000.00	00.00	00.00
3.	Infrastructure/Equipment	00.00	00.00	00.00	00.00
4.	Experimental charges	00.00	00.00	00.00	00.00
5.	Misc. expenditure	10,000.00	20,000.00	10,000.00	00.00
	Sub- Total:	6,75,000.00	6,85,000.00	6,25,000.00	6,15,000.00
	Grand Total	26,00,000.00			

Note:
(i) The above table has to be prepared for each year of the project period
(ii) PI has to submit the revised table to the Finance Officer for the subsequent year (on or before 15th March of current year) considering the actual expenditure incurred during the current year

8. Action plan and timeline and progress:

S.N.	Major Activities	1st Year		2nd Year		3rd Year + 6 months	
1	Literature review including related various ISO standards						
2	Estimation of uncertainty in river discharge measurements (Interim Report-1)						
3	Estimation of uncertainty in stage-discharge (rating) relationship using slope as a parameter (back water effects) (Interim Report-2)						
4	Estimation of uncertainty in stage-discharge (rating) relationship. (Interim Report-3)						
5	Preparation of final report						

9. Progress:

The study has been completed. The Final Draft International Standard (FDIS) has been submitted in December 2016, to ISO secretariat after incorporating the comments/suggestions received from member countries during October 2016.

5. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

1. Title of the study: Hydrological modelling of Brahmani Baitarani river basin using eWater Source platform.

2. Study group: J. P. Patra, Sc. 'C'; Dr. Rakesh Kumar, Sc. 'G' & Head, Pankaj Mani, Sc. 'D', CFMS, Patna;
Technical assistance: T. R. Sapra, RA.

3. Duration of study: 3 Years (April 2014 to March 2017) : Completed study

4. Type of study: Internal.

5. Location map

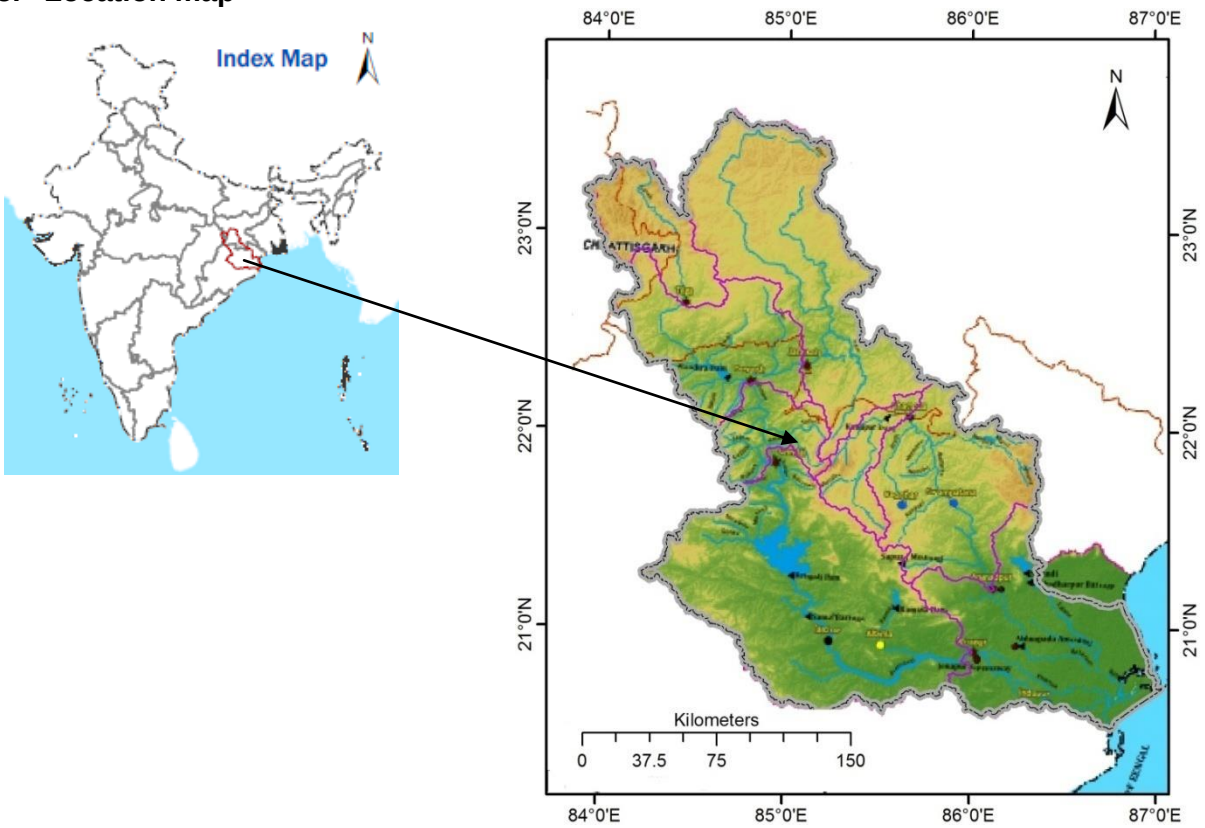


Fig. 1: Location map of study area.

6. Study objectives:

a) Statistical and trend analysis of rainfall and river discharge in Brahmani Baitarani river basin.
b) Development of rainfall runoff model for Brahmani Baitarani river basin using eWater source platform.
c) Investigation of implications of different rainfall inputs on rainfall–runoff simulation.
d) Test the applicability of the eWater source modelling platform in Brahmani Baitarani river basin by generating hydrological time series.

7. Statement of the problem

The eWater source is Australia's first national river basin scale water modelling system. The source modelling platform has been developed to take a holistic approach to water management including human and ecological impacts. This includes integrating policy,

addressing water savings and sharing for a whole river and connected groundwater systems including cities, agricultural and environmental demands.

In the India-Australia Water Science and Technology Partnership programme, Australia is collaborating with the Ministry of Water Resources to pilot the source river basin modelling platform in India. The MoWR, GOI is planning to develop an Integrated Water Resources Management (IWRM) plan for Brahmani Baitarani basin using the source river basin modelling platform. Hence, the present study has been formulated to develop a rainfall runoff model for Brahmani Baitarani river basin in source platform and test its applicability by generating hydrological time series.

8. Approved action plan and timeline

Sl. No.	Work Element	1st Year	2nd Year	3rd Year	Status
1	Literature Review and detailed formulation of research approach				Completed
2	Collection of hydro meteorological data, satellite images, thematic maps etc.				Completed
3	Compilation, statistical and trend analysis of rainfall and river discharge				Completed
4	Rainfall runoff model set up in eWater Source platform				Completed
5	Implications of different rainfall inputs and sub catchment size				Completed
6	Calibration and parameter estimation				Completed
7	Model performance evaluation with in various time periods				Completed
8	Reporting	Interim report	Interim report	Final report	Completed

9. Role of team members

Sl No	Role / Action	Member/(s)
1	Literature Review and detailed formulation of research approach	JPP, RK, PM
2	Collection of hydro meteorological data, satellite images, thematic maps etc.	JPP, TRS
3	Compilation, statistical and trend analysis of rainfall and river discharge	JPP, RK
4	Rainfall runoff model set up in eWater Source platform	JPP, PM
5	Implications of different rainfall inputs and sub catchment size	JPP, RK
6	Calibration and parameter estimation	JPP, PM
7	Model performance evaluation with in various time periods	JPP, RK
8	Reporting	JPP, PM,RK

JPP = J. P. Patra RK = Dr. Rakesh Kumar PM = Pankaj Mani TRS =T. R. Sapra

10. Brief Methodology

The Brahmani Baitarni basin (Fig. 1) extends over states of Odisha, Jharkhand and Chhattisgarh with catchment area of about 51,822 km^2. The basin is bounded by the Chhotanagpur Plateau on the north, by the ridge separating it from Mahanadi basin on the west and the south and by the Bay of Bengal on the east. The Brahmani known as South

Koel in its upper reaches rises near Nagri village of Jharkhand at an elevation of about 600 m and has length of about 800 km. In its tail reach, the river is known as Maipura. The Baitarni rises near Dumuria village in the hill ranges of Kendujhar district of Odisha at an elevation of about 900 m and has a length of about 355 km. The river is known as Dhamra in its lower reaches. Brahmani and Baitarni form common delta area before falling into the Bay of Bengal. The lower reaches of the basin near the deltaic area are subject to floods. Moreover Mahanadi, Brahmani and Baitarani are interconnected near their delta, worst flood occur when there is simultaneous heavy rains in all the three catchments. Floods are also caused from cyclonic storms since the coastal areas of the basin are cyclone-prone. The industrial development potential of this basin is very high due to its rich mineral resources (iron ore, copper, bauxite etc.) and power potential (548 MW at 60% load factor). Rourkela is an important industrial centre located in this basin. There various other industries (Iron and steel, Thermal power plant, fertilizers etc) existing the basin and more than 50 small to large industries are planned to set up in the upper and middle reaches of the basin. Hence, in future there will be very high water demands from industrial sectors.

Historical rainfall and flow data of the Brahmani Baitarani river basin are collected and time series of monthly, seasonal and annual values of rainfall and discharge will be analyzed using statistical methods. Trend analysis will be performed to determine whether or not there have been any significant changes in rainfall and discharge over this catchment. The analogue year's plots are used to identify years with near normal, above normal and below normal conditions, using the long term mean of the variables. Further, the daily rainfall data of .25°×.25° obtained from IMD for the period 1901 to 2013 and ET data from Terrestrial Hydrology Group, Princeton University from 1948 to 2008 are used for rainfall runoff modelling.

Rainfall runoff models are used to derive runoff for a particular sub basin from inputs of rainfall and potential evapotranspiration. All rainfall runoff models in source are conceptual models that represent catchment hydrological response to rainfall as a series of mathematical relationships. They provide runoff output from each functional unit as total discharge, which is split into quick flow (surface flow) and slow flow (baseflow) proportions. The rainfall-runoff models presently available in source are: Sacramento (sixteen parameters), SIMHYD (7 parameter), SMARG, GR4J (modèle du Génie Rural à 4 paramètres Journalier) (four parameters), IHACRES (six parameters), AWBM (3 parameter), SURM. These models will be configured to run the rainfall-runoff models at the catchment scale.

Different methods are available to obtain the daily rainfall time series for conceptual rainfall–runoff models, depending on data availability, time constraints etc. The implications of different rainfall inputs on the calibration and simulation of rainfall–runoff models will be analysed. First, the simulated runoff resulting from single lumped daily rainfall series for each catchment obtained from three methods: single rainfall station, thiessen average, and average of interpolated rainfall surface will be compared. Secondly, runoff generated from catchment modelling using daily/monthly rainfall series and modelling with smaller functional units within a sub catchment will be compared. The source platform includes set of optimisation tools for calibration of various model parameters. These high-level optimisation features include: Shuffled Complex Evolution (SCE-UA), multi-objective complex evolution (MOCOM-UA), Rosenbrock and other optimisation algorithms; predefined and user defined custom objective functions; option for custom optimisation problems such as regional calibration. Some of these techniques will be applied to calibrate the model. Finally, the calibrated model is used to simulate hydrological time series for various time periods and compared with observed time series to test the applicability of the eWater source modelling platform in Brahmani Baitarani river basin.

11. Results achieved with progress/present status

The statistical and trend analysis of various hydrological variables in the Brahmani Baitarani river basin are carried out. The box plots of mean annual flow rate at various gauging sites are shown in Figure 2. It is observed that there are considerable variations in flow rate at various upstream and downstream reaches. Further, Figure 2(b) shows seasonal variation in flow at Champua gauging sites in Baitarani River. Annual and seasonal trends of discharge at various gauging sites are also analysed. The trends at Champua gauging sites in Baitarani River are shown in Figure 3. It is observed that during flood season there is no significant trend. However, during winter season there is a decreasing trend (Figure 3, Figure 4).

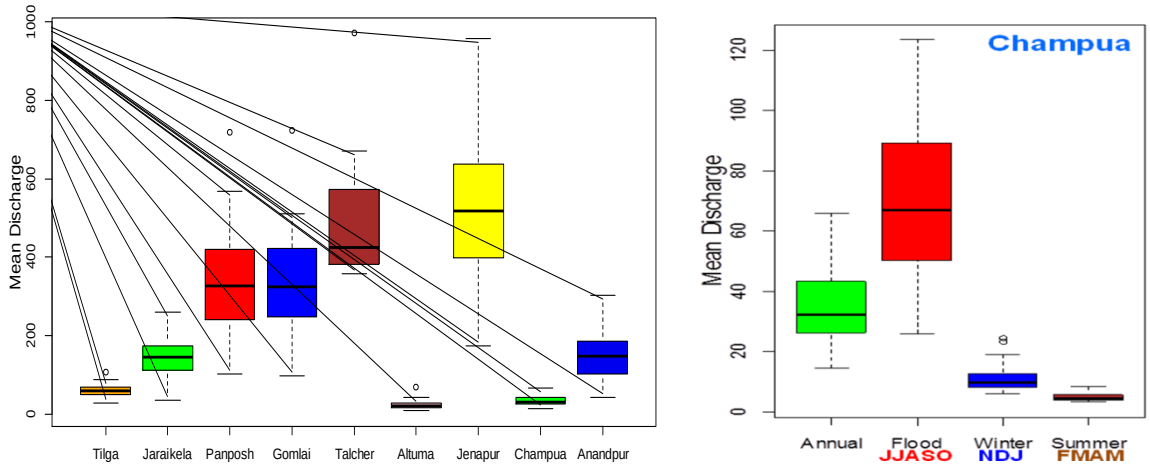


Figure 2: Mean discharge (a) Annual at various gauging sites, (b) Annual and seasonal at Champua.

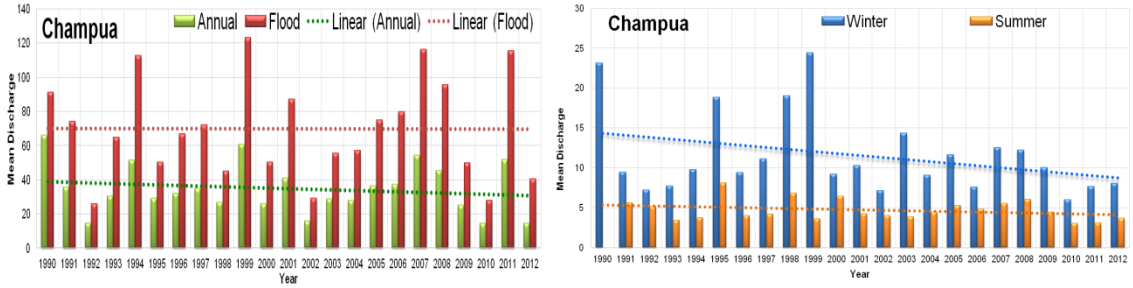
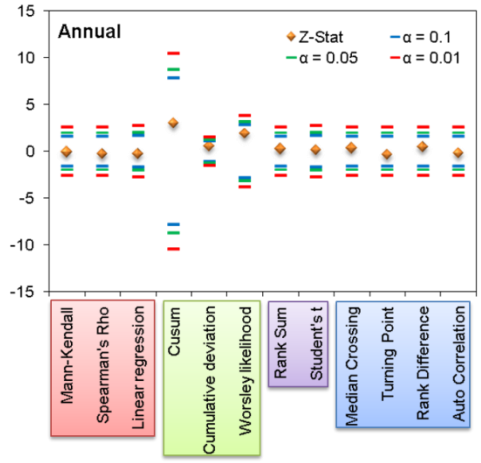
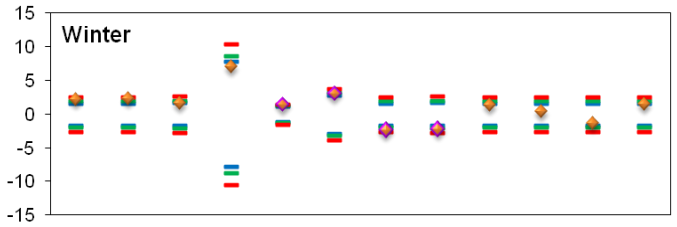


Figure 3: Annual and seasonal trend of discharge at Champua.

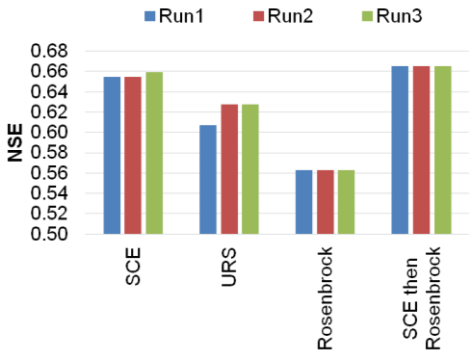




Mann-Kendall	S (0.05)	
Spearman's Rho	S (0.05)	
Linear regression	NS	
Cusum	NS	
Cumulative deviation	S (0.05)	Mean of 1972-1994 is smaller than 1994-2012
Worsley likelihood	S (0.1)	Mean of 1972-1994 is smaller than 1994-2012
Rank Sum	S (0.05)	Median of 1972-1994 < 1995-2012
Student's t	S (0.05)	Mean of 1972-1994 < 1995-2012
Median Crossing	NS	
Turning Point	NS	
Rank Difference	NS	
Auto Correlation	NS	

Figure 4: Annual and seasonal (Winter) trend of discharge at Anandpur.

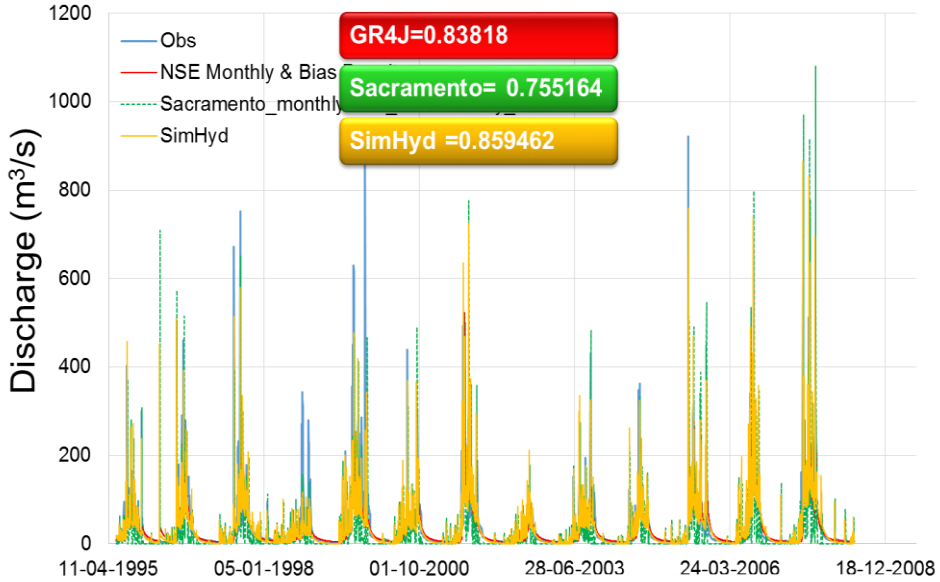
Catchment modelling of Brahmani Baitarani river basin in eWater source platform is developed. The rainfall runoff model is being setup with daily rainfall data of .25°×.25° obtained from IMD and ET data from Terrestrial Hydrology Group, Princeton University. The model calibration is being carried out with gauged sub catchments represented by a small proportion of the basin. Various objective functions viz. NSE Daily, NSE Monthly, NSE Monthly & Bias Penalty, NSE Daily & Flow Duration, NSE Daily & log Flow Duration, Minimise Absolute Bias, NSE Daily & Bias Penalty etc. are used to for calibration model. Further optimization algorithms like Shuffled Complex Evolution (SCE), Uniform Random Sampling (URS), Rosenbrock, SCE then Rosenbrock etc are evaluated for their performance. It is observed that SCE and SCE then Rosenbrock provide best modelling efficiency. However, in case of SCE then Rosenbrock and the variability among different simulation runs are found to be minimum (Figure 5). Comparison of simulated discharge obtained from various model viz. GR4J, Sacramento and SimHyd with observed discharge are shown in Figure 6. It is found that the GR4J model has performed better in comparison to other model for this basin. Further it has only four parameters to calibrate, which also reduces uncertainty.



	Run1	Run2	Run3
SCE	0.65483	0.65483	0.65927
URS	0.60732	0.62774	0.62774
Rosenbrock	0.56272	0.56272	0.56272
SCE then Rosenbrock	0.66549	0.66549	0.66549

Figure 5: Comparison of NSE daily for various optimization algorithm.

(a)



(b)

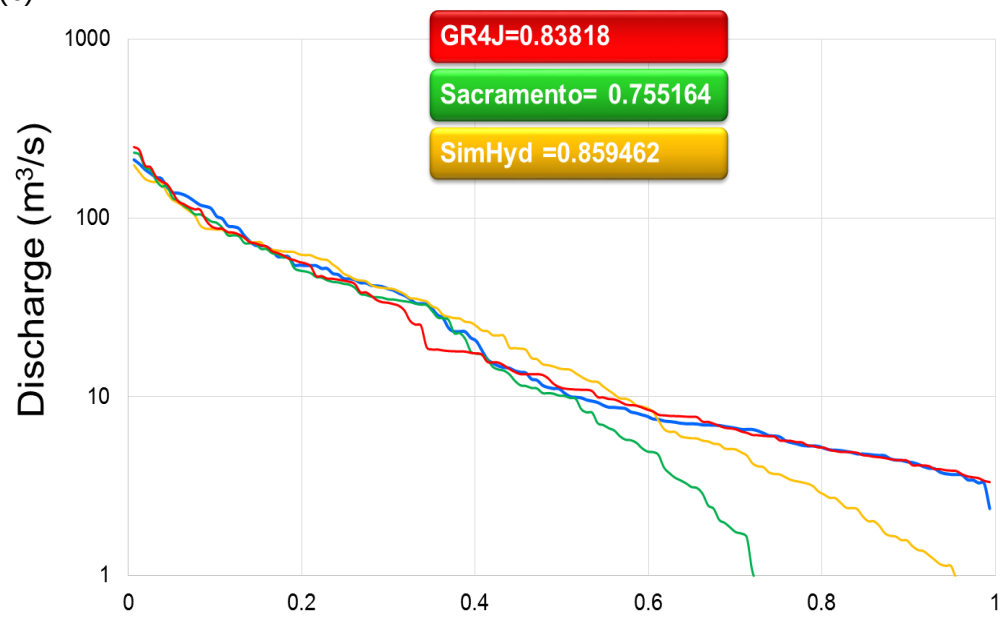


Figure 6: Comparison of various model (a) discharge, (b) flow duration curve.

12. Action taken on comments of previous working group meeting

There were no specific comments.

13. List of deliverables

- Water availability at various river reaches and sub catchments
- Applicability of the eWater source modelling platform in Brahmani Baitarani river basin,
- The rainfall runoff modelling setup will help in development of IWRM plan in Brahmani Baitarani river basin.
- Papers and reports.

14. Data collected/generated

- DEM of the study area is generated from SRTM.
- Land use and land cover map is generated by classifying LANDSAT image.
- Daily rainfalls for eight raingauge stations are collected from IMD. However the data set is having missing values at some stations.
- Monthly rainfalls for 121 raingauge stations are collected from water resources department of Odisha
- Stage and discharge at thirteen gaugiging sites namely, Akhuapada, Altuma, Anandapur, Champua, Gomlai, Jaraikela, Jenapur, Keonjhar, Panposh, Rengali, Swampatna, Talcher and Tilga from water resources department of Odisha.

15. Involvement of end users/beneficiaries

The study has been proposed with reference to the work assigned by MoWR. There has been discussion with the officials of CWC and Odisha water resources department regarding need of the study.

6. PROJECT REFERENCE CODE: NIH/SWD/NIH/16-17

1	**Study group**	**:**	Sushil K. Singh**,** Scientist F
2	**Date of start of study**	**:**	01 April2016
3	**Duration and scheduled**	**:**	01 Year (with 06 month intended extension)
4	**date of completion of study:**		30September 2017
5	**Title**	**:**	**Generalization and parameter estimation of GEV distribution for flood analysis: Specificapplication on Indian data.**
6	**Type of study**	**:**	Internal

7 Objectives of study:

To illustrate and demonstrate the practical application of the generalized GEV on the available Indian data including those collected at NIH.

8 Statement of problem and brief methodology

In an earlier report, the practical unification of both type 2 and type 3 GEV distributions in a single GEV was taken up and a simple and an optimization methods for estimation of its parameters were considered with limited testing/application. In this report, it is intended to take up the methodology as above for application and illustration on measured/published dataon Indian rivers' GD sites.

9 Achievement/progress:

It is an application study in which the developed methodology and analysis by the author is intended to be applied on the published Indian data at various GD sites including those available/collected at NIH.The application of the developed model on available data on few GD sites by CWC is complete and the results are encouraging. During the statistical testing of the results, a concept of deterministic confidence interval has been developed to replace the existing and widely used concept of the probabilistic confidence interval. The application is further intended to extend to possible data available with State Departmentsparticularly of flood prone area of UP, e.g. Raptiriver. The report is writing and finalizing stage.

10 Adopters of the results of study and their feedback

a. Practitioners, field engineers, and academic personals.

11 Deliverables

Research report detailing the developed equation and research papers in International Journals with illustrative application on the published international data and the Indian data available/collected at NIH.

7. PROJECT REFERENCE CODE: NIH/SWD/NIH/16-19

1. **Application and development of analytical models on data collected at NIH under Saph-Pani Project** (Research/Application Study)

2. **Study group** Sushil K. Singh**,** Scientist F
(with possible inclusion of young scientist across the divisions' line)

3. **Date of start of study** 01 April 2016

4. **Duration and scheduled date of completion of study** 03 Year; 31 March 2019

5. **Type of study** Internal; Funding(Tentative) – INR 45.00 Lakh

6. **Objectives of study**

1. To apply and illustrate on the above surface-water groundwater interaction data, the developedand published analytical models by the author, a complied detail of which has earlier been submitted to our Ministry and Institute both directly and indirectly.
2. To possibly develop new analytical models if application on the data as at item 1 suggests so.
3. The items 1 and 2 are also with the aim to suggest general application of these and other methodology concerning the area of surface-water groundwater interaction in general with respective merits/demerits.

4. **Statement of problem and brief methodology**

It is an application study in which the developed methodologies and analyses by the author are intended to be applied on the concerning data collected at NIH as stated above.

The intended development of new analytical model and methodology would be along those adopted in the development of earlier such models by the author.

5. **Achievement/progress:**

The compilation of the developed methodology and analytical models and new innovative solution involved therein is complete and the first part of the report containing these systematically at one place is at the writing state and will be submitted shortly. This report is also in view of a paper published in *Ground Water* out of the collaborative work on Saph-Pani project (mainly concerning to collection of data), which shows unawareness of analytical developments at the Institute taking place 6-12 years back by the author. Non availability of Data and aims and objectives of Saph-Pani project and related new projects will further defeat the objective of this project and induce further possible plagiarism and unprotecting of the intellectual property with an intended technical and value-based financial loss to the institute.

6. **Adopters of the results of study and their feedback**
   a. Practitioners, field engineers, and academic personals.

7. **Deliverables:**
Research report detailing the developed equation and research papers in International Journals with illustrative of ease in application in comparison to existing methods.

8. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

1. Title of the Study: Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State.

2. Name of the Pi & Co-Pi

Dr. Archana Sarkar, Sc C, SWHD (PI)
Sh. N.K. Bhatnagar, PRA, SWHD
Dr. Vaibhav Garg, Sc C, IIRS, Dehradun
Dr. Rakesh Kumar, Sc G & Head, SWHD

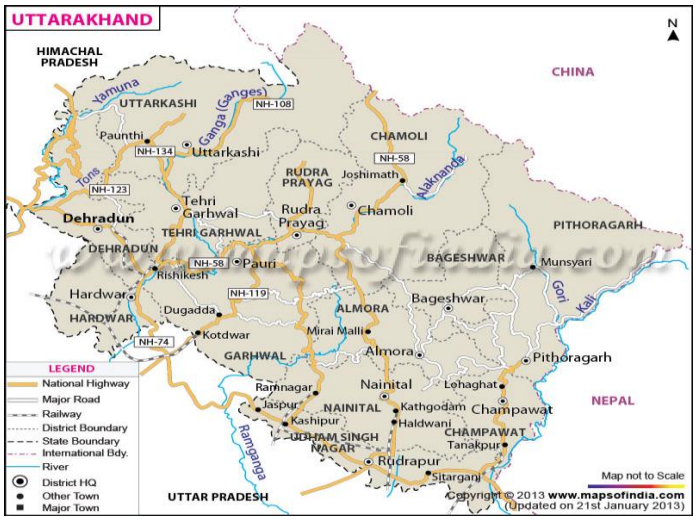
3. Type of Study: Internal

4. Date of Start: 1 April 2014

5. Scheduled Date of Completion: 31 March 2017*

*31 September 2017 (Extension required by six months for final report)

6: Study Area



Uttarakhand is a state in the northern part of India. It is often referred to as the "Land of the Gods" due to the many holy Hindu temples and pilgrimage centres found throughout the state. Uttarakhand is known for its natural beauty of the Himalayas, the Bhabhar and theTerai. It borders the Tibet Autonomous Region on the north; the Mahakali Zone of the Far-Western Region, Nepal on the east; and the Indian states of Uttar Pradesh to the south and Himachal Pradesh to the northwest. The state is divided into two divisions, Garhwal and Kumaon, with a total of 13 districts. Two of the most important rivers in Hinduism originate in the region, the Ganga at Gangotri and the Yamuna at Yamunotri.

Uttarakhand has a total area of 53,484 km², of which 93% is mountainous and 65% is covered by forest. Most of the northern part of the state is covered by high Himalayan peaks and glaciers. Uttarakhand lies on the southern slope of the Himalaya range, and the climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to subtropical forests at the lower elevations. The highest elevations are covered by ice and bare rock. Below them, between 3,000 and 5,000 metres (9,800 and 16,400 ft) are the western Himalayan alpine shrub and meadows. The temperate western Himalayan sub-alpine conifer forests grow just below the tree line. At 3,000 to 2,600 metres (9,800 to 8,500 ft) elevation they transition to the temperate western Himalayan broadleaf forests, which lie in a belt from 2,600 to 1,500 metres (8,500 to 4,900 ft) elevation. Below 1,500

metres (4,900 ft) elevation lie the Himalayan subtropical pine forests. The Upper Gangetic Plains moist deciduous forests and the drier Terai-Duar savanna and grasslands cover the lowlands along the Uttar Pradesh border in a belt locally known as Bhabhar. These lowland forests have mostly been cleared for agriculture, but a few pockets remain.

In June 2013, several days of extremely heavy rain caused devastating floods in the region, resulting in more than 5000 people missing and presumed dead. The flooding was referred to in the Indian media as a "Himalayan Tsunami".

7. Objectives of the Study:

1. Procurement of additional rainfall data of the available rain gauge stations in Uttarakhand State from various agencies and processing of rainfall data.
2. Spatio-temporal trend analysis of historical rainfall data.
3. Downloading and processing of rainfall data (same location as that of rain gauge stations) from TRMM satellite data as well as high resolution gridded re-analysis rainfall data from APHRODITE and IMD.
4. Comparison of rainfall data from various sources.

8. Statement of the Problem

Study of rainfall based on an integrated perspective of its attributes like spatio-temporal variation, persistence, trends, periodicities etc is very essential for understanding the nature of weather and climate patterns. A good knowledge of local rainfall-regime is crucial for planning and management of domestic, urban as well as industrial water use, irrigation and crop practices besides forecasting and management of extreme events like floods and droughts. In view of the recent flood disaster in the Uttarakhand state, it becomes all the more important to carry out a scientific analysis of the rainfall regime of the region.

Rainfall observations are an essential element of studies related to hydrological processes.They are utilized both for a better understanding of these processes and as input in hydrological simulation models indispensable to a correct territorial planning and to an adequate management of water resources system. Rain gauges, radars, satellite sensors, forecasts from high resolution numerical weather prediction models and high resolution gridded re-analysis rainfall data are a part of precipitation monitoring networks/data sources. These data sources provide rainfall data that are further provided to hydrological models to produce forecasts, therefore, their comparative accuracy assessment is of prime importance.

9. Approved Action Plan and Timeline

Year	April - June	July-Sept	Oct-Dec	Jan-March
2014-15	Additional rainfall data procurement, data processing	Additional rainfall data procurement, data processing	Trend Analysis of historical rainfall data	Interpretation of results and preparation of interim report-1
2015-16	Downloading APHRODITE data.Trend Analysis of historical rainfall data (different rainfall intensity series)	Downloading of TRMM satellite data and processing of downloaded data	Statistical analysis and comparison of data from different sources	Interpretation of results and preparation of interim-2

2016-17	Comparison of rainfall data from different sources using a hydrological model	Comparison of rainfall data from different sources using a hydrological model	Comparison of rainfall data from different sources using a hydrological model	Preparation & Submission of Final Report

10. PROGRESS

Objectives	**Achievements**
April 2016- March 2017	
1. Downloading of TRMM satellite data and processing of downloaded data	Completed
2. Trend Analysis of historical rainfall data (using TRMM rainfall series)	Completed
3. Statistical analysis and comparison of data from different sources	Partially completed
4. Interpretation of results and preparation of report	In progress

11. RECOMMENDATIONS/suggestions in previous meetings of Working Group/TAC/GB Nil

12. Analysis and Results

Data Used

Daily observed and gridded rainfall data from APHRODITE, IMD and TRMM for 10 stations in Uttarakhand.

Results

TRMM daily rainfall data for ten stations namely, Almora, Bageshwar, Haridwar, Joshimath, Munsiyari, Pithoragarh, Rudraprayag, Rudrapur, Tehri, Uttarkashi has been downloaded and processed. Annual and seasonal trend analysis has been carried out with TRMM data. Comparison of data from different sources (observed, IMD, APHRODITE & TRMM) is being carried out.

13. Expected Adopters

State Water Resources Dept and other agencies.

14. Deliverables: Research papers and report**.**

15. Data Procured And/Generated During The Study:

Daily rainfall data at 50 raingauge stations around Uttarakhand State with varying length.

16. Future Plan: As per the approved action plan.

9. PROJECT REFERENCE CODE: NIH/SWD/NIH/15-18

1. Title of the Study: Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin

2. Name of the PI & CO-PI

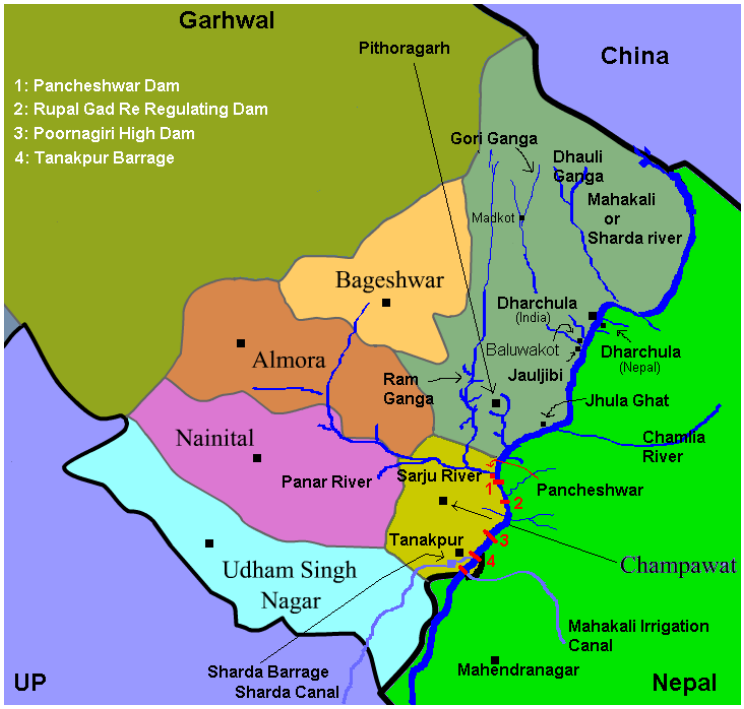
Dr Archana Sarkar, Sc 'D', SWHD (PI)
Er. T. Thomas, Sc D, Regional Centre, Bhopal
Dr. Vaibhav Garg, Sc C, IIRS, Dehradun
Sh. N.K. Bhatnagar, PRA, SWHD

3. Type of Study: Internal

4. Date of Start: April 2015

5. Scheduled Date of Completion: 1 March 2018

6. Study Area



The Sharda Valley in Uttrakhand has a vast potential for Water Resources Development, which was not tapped at all during the initial three decades of planned development. The region is mythological abode of Gods; the pilgrim route to Holy Mansarover passes along the Sarda Valley. The river Sharda (or Kali) form the international boundary between India and Nepal, towards the north, from a point called Bramhadeo, about 5 km upstream of Tanakpur. River Sharda originates in the region of Higher Himalayas, near Indo-Tibetan border, from the Glacier of Zaskara range, at about 5250 M. In the upper reaches, in the hills, it is called Mahakali. The river emerges into plains at Bramhadeo and it is called Sharda. The study area extends between 29°0'–30°38'N and 79°28 – 81°7'E covering an area of about 15280 Sqkm, with elevation ranging from 250 to 7000m above msl. About 1732 Sqkm of the total area of the basin is under glacier landscape. The Main River generally flows in north-south direction and is met with by a number of major tributaries from Indian side, namely, Dhauliganga, Goriganga, Sarju and Ladhia. The major tributary from the Nepal side is Chameliya. The Sharda river finally joins the Ghaghra (Karnali) River as its right-bank tributary in Uttar Pradesh. The Sharda Valley in Uttrakhand has a vast potential for Water

Resources Development. The Tanakpur Hydroelectric Project (120MW) was commissioned in 1992 by the NHPC with a barrage on the Sharda River near the town of Tanakpur in the district of Champawat. Mahakali (Sharda in India) is one of the five major river basins of Nepal which is shared with India and of which about 34 per cent of total basin area lies in Nepal. The hydroelectric potential of the valley on the Indian side of the river as assessed by UP Irrigation Department is over 3000 MW; and the power potential of the main Sharda river is assessed as 2000 MW. Therefore, accurate estimation of the basin runoff (including snowmelt runoff) is of extreme importance.

7. Objectives of The Study

i. Preparation of basin maps including DEM and estimation of snow cover area using remote sensing data
ii. Calibration of conceptual snowmelt runoff models namely, SRM and SNOWMOD for Sharda River basin upto Tanakpur.
iii. Development and training of black-box models (ANN models) for simulation of runoff including snowmelt runoff of the Sharda River basin upto Tanakpur.
iv. Inter-comparison of various models.
v. Investigation of the impact of likely future changes in climate on stream flow using downscaled GCM scenarios in the study area.

8. Statement of the Problem

Rainfall-runoff models are of prime importance in the decision making process of water resources planning, design, development and management activities. Such models are used, for example, in the design and operation of hydraulic structures, for flood forecasting, and for evaluating possible impact of land use land cover changes as well as climate changes over a catchment. However, due to the interrelated character of driving factors, i.e., physiographic and climatic factors, the rainfall-runoff process becomes highly complex to understand and also extremely difficult to model. Further, in Himalayan region, like the Sharda River, snowmelt is a governing factor for runoff generation. So, for snow-fed basins, snowmelt runoff component is also required to be incorporated in the modelling approach. It is, therefore required to apply a suitable methodology for modelling the runoff in the Sharda river basin.

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to water resources throughout the world. The effect of climate on hydrology in tropical Asia has many facets. The Himalayas, which act as a mountain barrier on the earth, where polar, tropical and Mediterranean influences interact, play an important role in maintaining and controlling the monsoon system over the Asian continent. In the Himalayas, the storage of precipitation in the form of snow and ice (in glaciers) over a long period provides a large water reservoir that regulates annual water distribution. The majority of rivers originating in the Himalayas have their upper catchments in snow covered areas and flow through steep mountains. If there is any climatic variability in the Himalayas, the impacts could be felt in regions downstream. Therefore, besides reasonably accurate estimation of the runoff, there is an imperative need to study the impact of climate change on the runoff regime of the Sharda basin in view of its huge water resources potential including uses for hydropower, irrigation etc.

9. Approved Action Plan

S. No.	Work Element	First Year				Second Year				Third Year			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
1	Collection of information and Hydro-meteorological Data												

2	Preparation of base maps												
3	Downloading MODerate resolution Image Spectral radiometer (MODIS) snowcover data products for the study area												
4	Analysis and interpretation of weekly MODIS snowcover data and preparation of snow cover maps												
5	**Preparation & Submission of Interim Report-I**												
6	Input data preparation for SRM Model												
7	Calibration and Validation of SRM Model												
8	Input data preparation for SNOWMOD Model												
9	Calibration and Validation of SNOWMOD Model												
10	Input data preparation for ANN Models												
11	Training and Validation of ANN Models												
12	Preparation & Submission of **Interim Report-II**												
13	Inter-comparison of Models												
14	Downscaling of GCM outputs for the study basin												
15	Preparation of Input data for conceptual model for changed climate scenarios												
16	Simulation of conceptual snowmelt runoff model with changed climate scenarios												
17	Preparation & Submission of Final Report												

10. Progress

Objectives	**Achievements**
April 2015- March 2016	
1. Input data preparation for SRM Model, Calibration and Validation of SRM Model	Completed
2. Input data preparation for SNOWMOD Model, Calibration and Validation of SNOWMOD Model	Completed
3. Input data preparation for ANN Models	Completed
4. Training and Validation of ANN Models	In progress

11. Analysis and Results

12. Data Used

SRTM DEM data and SOI toposheets

13. Results

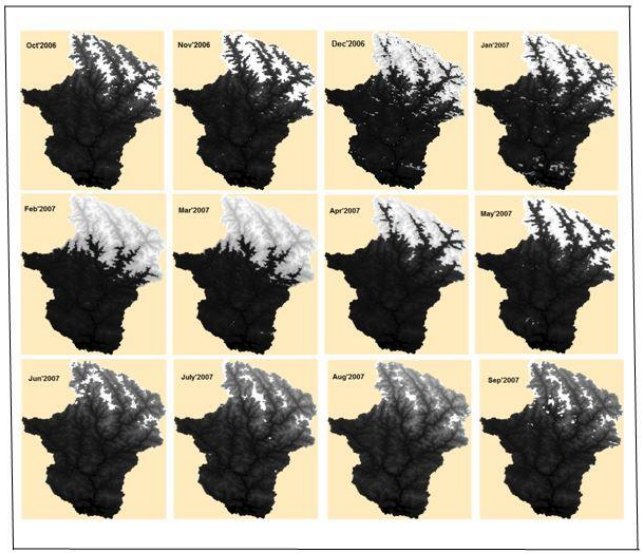


Figure 1: Sequential Snow Cover In Sharda Basin As Seen In Modis Images For The Period Oct'2006–Sep'2007

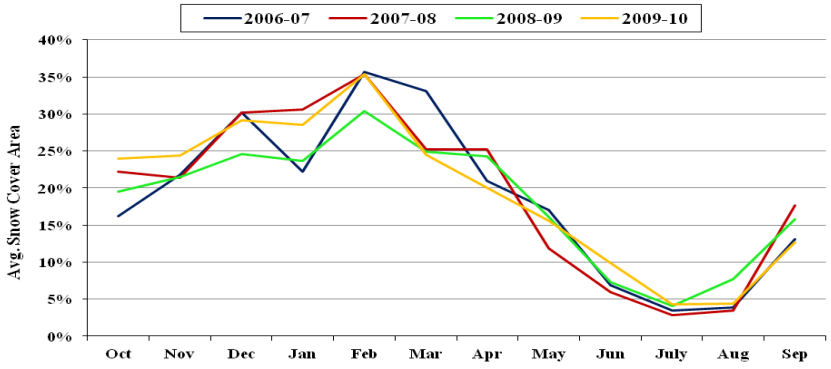


Figure 2: Monthly Distribution Of Sca In Sharda Basin

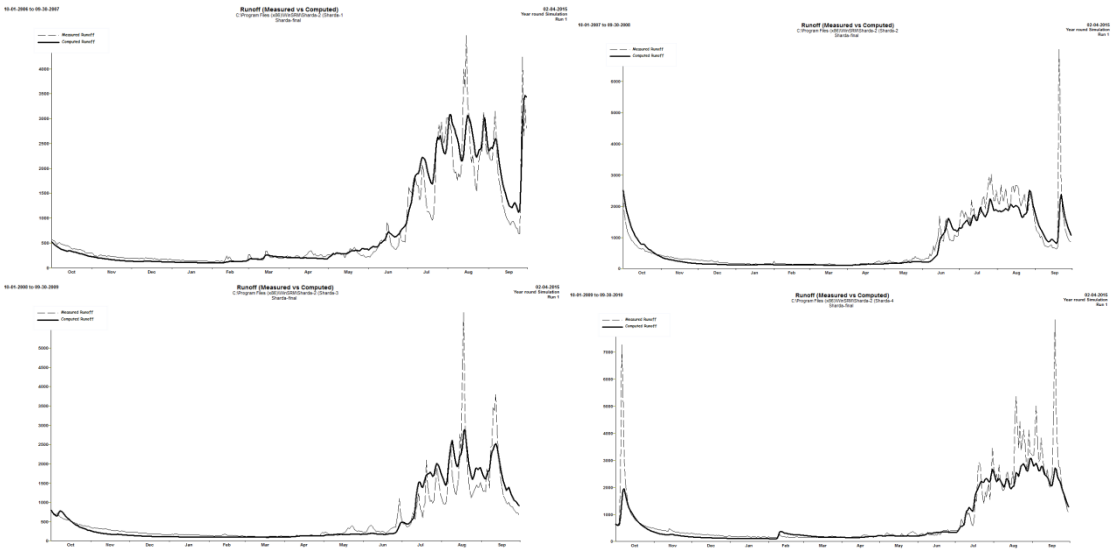


Figure 3: Measured v/s Computed Runoff for the four years

14. Expected Adopters:
State Water Resources Dept and other agencies.

15. Deliverables:
Research papers and report

16. Data Procured And/Generated During The Study:
Nil

17. Future Plan:
As per the approved action plan.

10. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-18

1. **Thrust Area under XII five year Plan**: Water Resources Development and Management

2. **Title of the Study:** Monitoring and modelling of streamflow for the Gangotri Glacier

3. **Study Group** : Dr Manohar Arora Sc 'C'
Dr Rakesh Kumar Sc 'F'

4. **Role of Team Members** :

1. Dr Manohar Arora, Scientist C& PI: Conduction field investigations, analyzing data/information, report preparation and overall responsible for the study completion.

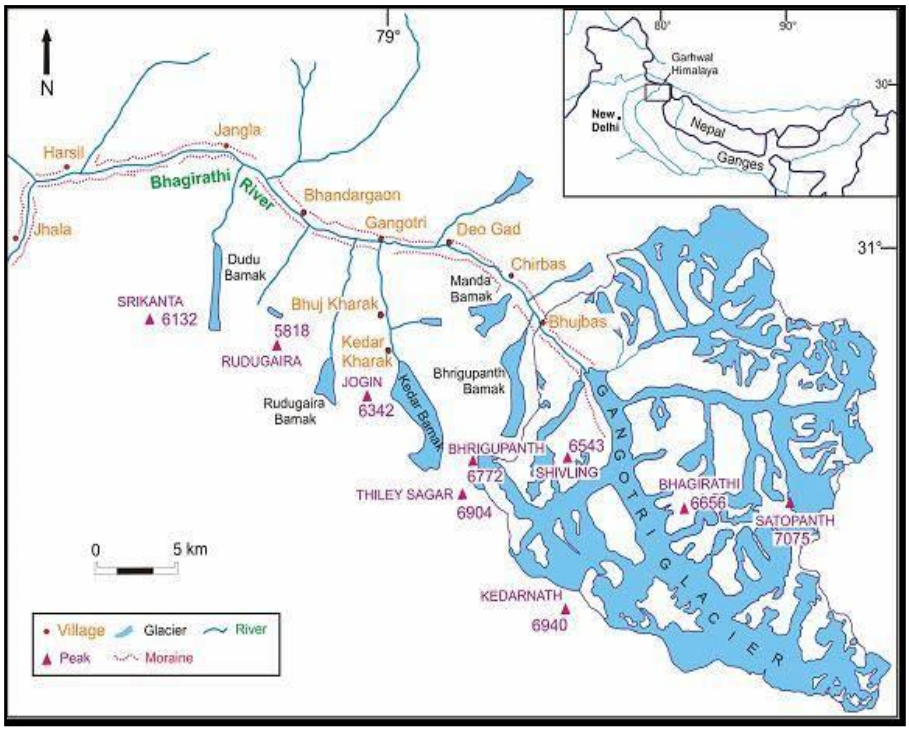
2. Dr Rakesh Kumar, Scientist F & Co-PI: Guidance in development of methodology, modelling and structuring of report.

5. **Type of Study** : Sponsored

6. **Date of start** : 01.5. 2014

7. **Scheduled date of completion :** 31.03.2017. Extension from DST received for 3 months. Further extension till 31.03.2018 in progress.

8. **Location Map:**



9. **Objectives:** The objective of this study includes:

- Continuous observations of meteorological, hydrological and suspended sediment data for the melt season to determine monthly and seasonal specific water and sediment yield from the study glacier.

- To study the melt water storage and drainage characteristics of the glacier and to simulate daily streamflow using a conceptual hydrological model using observed meteorological and hydrological data.
- Modeling the role of glacier in catchment runoff variation.
- Modeling the catchment runoff variation under different climatic scenarios.

10. Statement of the problem: The study involves collection and analysis of hydro-meteorological and discharge data of the glacier site. The second step is to develop and apply a snow melt model for streamflow generation and identification of different runoff components. The third step is to model role of glacier in catchment runoff variation and catchment runoff variation under different scenarios.

11. Approved action plan:

Year	May to October	November to April	Remark
All Years	Field investigations & Data Collection	Data analysis	Report preparation after three years

12. Objectives vis a vis Achievements:

Objectives	Achivements
Continuous monitoring of meteorological and hydrological data for monthly and seasonal specific water yield and its variability from the year to year	The data collected in summer 2016 was processed and analysed. The results will be presented before the Working Group Experts.
To study the melt water storage and drainage characteristics of the glacier and to simulate daily streamflow using a conceptual hydrological model using observed meteorological and hydrological data.	The melt water storage and drainage characteristics for the year 2015 have been completed.
Modeling the catchment runoff variation under different climatic scenarios	The model parameters have been determined. The data files are ready. It has been proposed to DST that the model will be validated on the data of 2016 and 2017.

13. Recommendations of Working Group/TAC/GB:
The study may be continued for long term to link with climate change.

14. Analysis and Results:
The Department of Science and Technology has sponsored this study.

15. Adopters of the results of the study and their feedback:
The study is a sponsored study and the results will be disseminated by DST.

16. **List of deliverables**:

17. Major items of equipment procured: Nil

18. Lab facilities during the study: Analysis of suspended sediment samples will be carried out in Soil Lab.
19. Data generated in the study: Meteorological and hydrological data for the Gangotri Glacier.

20. Study Benefits/Impact: The study is being sponsored by DST. The meteorological and discharge data would be utilised in studying the characteristics of the Gangotri glacier under changing climate.

21. Specific linkages with Institutions/beneficiaries: The data collected is also being shared with the authorities of Gangotri National Park. The details of sediment concentration are being communicated to the downstream Dam authorities.

22. Shortcomings/Difficulties: The study involves four months of extensive field work and maintenance of construction site etc. Without the support of project staff it is difficult to manage data collection.

23. Future Plan: The study will be conducted for long term. The Himalayan glaciers are poorly monitored. There is very little or sparse data of Himalayan Glaciers The collected data will be used for climate change studies.

11. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

1. Title of Study : **'Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India'**

2. Study Group : Dr. Ashwini Ranade, Scientist 'C'(Principal Investigator)

3. Role of Team members : Responsibility of the completion of the project successfully (Literature Survey, Data collection and processing, Analysis, Publications etc.)

4. Type of Study : Sponsored Research

5. Sponsoring Agency : Science and Engineering Research Board (SERB), Department of Science and Technology, New Delhi

6. Budget sanctioned : 12.6 lakh

7. Date of Commencement : 17 October 2014

8. Scheduled date of completion: 17October 2017

9. S**tudy Area:** The proposed work is for theAsia-pacific monsoonal regime (25^0- 150^0E; 25^0S 150^0N)with special emphasis on theIndian subcontinent.

10. Statement of the problem:

In recent global temperature change scenario, Indian summer monsoon rainfall shows unusual characteristics each year even though the seasonal rainfall for the country as a whole is near normal. Severe rain events are becoming more frequent and erratic. The peculiarities are mostly regarding the location, frequency, intensity and areal extent of heavy rain spells and its occurrence in drought years also. Experiences suggest that extreme rain events are large-scale embedded, long period intense rainfall activities during monsoon. Every year parts of India experience extreme rain events, surprisingly even during large-scale droughts. It is required to study weather extremes case-by-case basis in order to understand the role of global and local climate changes. Most heavy rains over India during 1951-2007 occurred from 23-28 July 2005. Each day the country received 20.2 billion cubic meters (bcm) rainwater. The highest rainwater was collected on 25th July (98.2 bcm) over 45.9% area of the India (Fig 1). Global atmospheric thermal and circulation patterns causing heavy rain event are studied using 2.5° gridded NCEP-CFSR reanalysis data.

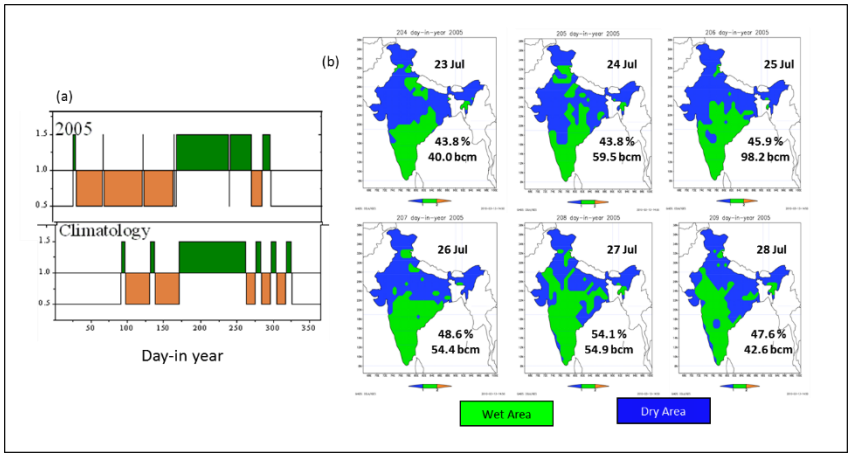


Fig. 1 a) Normal sequence of large-scale wet and dry spells over India, and those of the year 2005; and b) Percentage area of India (PAI) under wet condition and rainwater (in bcm) during each day of 6-day most severe storm (23-28 July 2005).

11. Objective:

The sole objective of the present study is to understand deviation in 3-dimensional structure of the monsoon circulation from normal and associated global atmospheric thermal condition, pressure and moisture field and circulation pattern that caused most-intense, persistent large-scale wet spell over India during 23-28 July 2005.

Objectives vis a vis Achievements:

Objectives	**Achievements**
To understand the 3-D structure of Asia-pacific Monsoon circulation during different phases of Indian Monsoon season	The annual cycle of Global tropospheric parameters (Temperature, MSLP, PPW, GPH, U&V wind etc.) averaged at global, interhemispheric, zonal and regional scale during onset, establishment and withdrawal phases of Monsoon are studied in details in order to understand the intensity of Monsoon circulation and location of area under monsoon condition.
Quantitative analysis of global atmospheric parameters during 23-28 July 2005	Area averaged atmospheric parameters e.g. T and Z at all standard isobaric levels, thickness, mean mslp etc. at global, hemispheric, zonal, regional scales averaged for the period 23-28 July 2005 are studied in comparison with their normal values (1979-2013).
Qualitative analysis of global weather charts of 25th July 2005	i. Global weather charts showing *global weather regimes* (GWR), streamlines and globally conditioned horizontal wind speed (GC-W) at standard isobaric levels (1000-100hPa) ii. Weather charts showing global distribution of departure from normal in mslp and temperature and geopotential height at standard isobaric levels

12. Analysis and Results:

(1) Dataset collected/used:

1. NCEP Climate Forecast System Reanalysis (CFSR) 6 hourly products from 1979-2014 at 2.5X2.5 degree resolution (Temperature, Geopotential height, U and V wind at 12 isobaric levels, Mean sea level pressure, and Precipitable water)
2. 0.5 degree gridded rainfall data from India Meteorological department.

(2) Features of Global Atmospheric parameters during peak period of monsoon season

During boreal summer, modification and redistribution of the thermal and pressure field and general circulation features take place predominantly as compared to austral summer. During peak boreal summer monsoon (at the end of July), the troposphere of northern hemisphere (NH) is heated by 5.3^{0}C and that of southern hemisphere (SH) is cooled by 2.4^{0}C from their respective normal annual mean values (NAMVs). NH is appeared to be warmer by 4.7^{0}C than that of the globe by creating tropospheric temperature (T_{Trop})contrast of 9.5^{0}C with SH. The anomalous warmest tropospheric area of the globe (~+12-16^{0}C than NAMV) is over the Tibet, North China, Mongolia, and Northeast Russia, while the coolest area is over the Southern temperate region. Entire land area of NH up to its Pole shows strong negative pressure anomaly. The whole Asian continent is covered up with the intense low-pressure area (10-12mb lower than NAMV).

Departures in atmospheric parameters from their corresponding equatorial mean value (CEMV) termed as equatorially conditioned (EC) parameters (EC-T_{level} and EC-Z_{level} at 12 isobaric levels, EC-mslp, and EC-ppw) are calculated) in order to understand the spreading of equatorial weather condition and hence intensity, depth and areal coverage of

monsoon circulation/condition across Asia-pacific region during summer monsoon season. The highest EC-temperature core is at Tibet and Iran-Afghanistan sector (+10°C) and United States of America (+8ºC). Most part of the NH continental area is seen warmer and thinner than the equator. The high pressure belts in both subtropical hemispheric oceans are +70m thicker than CEMV creating effective geopotential gradient from Asian continental low pressure areas. Throughout the troposphere, the entire equatorial-tropical Indo-pacific region, Africa and North America up to 40ºN shows positive EC-TTrop field. The south Asia's cordillera (Tibetan-Himalaya-Karakoram-Hindukush Highlands or THIKHIHILs; 25°–40°N; 60°–100°E) is the warmest (EC-TTrop >+10ºC) and thickest (EC-ZTrop >+250m) area of the globe and both poles are always cooler than equator throughout the troposphere generating effective slope for the transfer of the mass polewards within troposphere. Spreading of negative EC-mslp field starts at the end of April and attains peak in the month of July. It covers the entire area between equator and Middle East-Mongolia sector, which experiences higher T_{Trop}, lower mslp, and higher ppw than the equator (Fig. 2a). On 25th July 2005, Actual thermal low pressure with negative EC-mslp is confined around Tibetan plateau and only a small area in southeast Canada (Fig. 2b). The low-pressure field in south temperate-subpolar is narrow but intense (core area less than -35mb). A Large portion of the NH is with positive EC-mslp (highest over north polar +15mb), and the area in combination with larger than normal size south subtropic makes a huge positive EC-mslp field around limited-size negative pressure field of south Asia. Further, south polar positive EC-mslp field is large and intense (core area more than +30mb) which is an indicator of intense monsoon condition than normal. Normal EC-ppw field shows that the entire South Asia, South-east Asia, and east Asia is having ppw 10-12 mm higher than the equator, while rest of the tropical landmass and oceanic area it is 4-6mm more than CEMV.

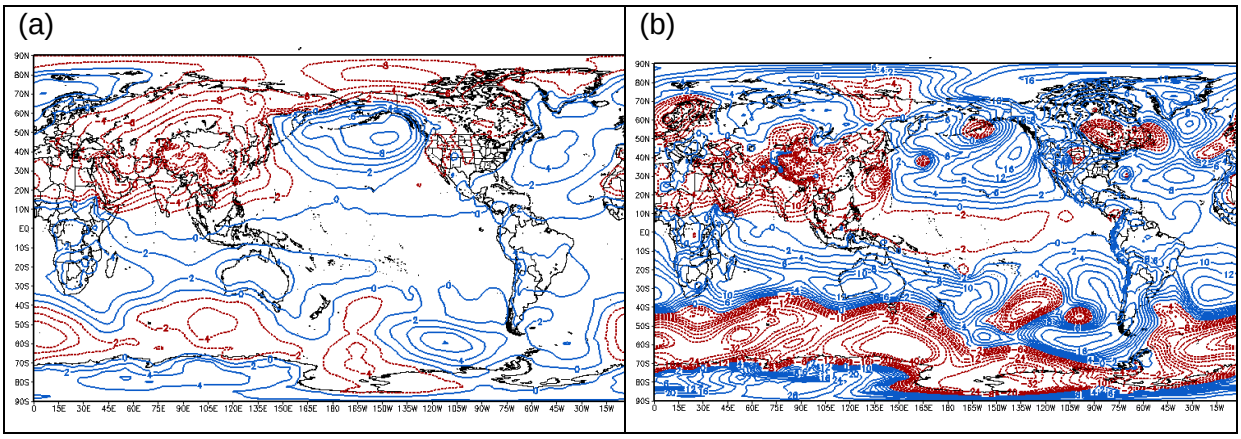


Fig. 2 Global distribution of (a) normal EC-mslp field on 25 July and b) actual EC-mslp on 25 July 2005

(3) Quantitative analysis of global atmospheric parameters during 23-28 July 2005

Area averaged atmospheric parameters e.g. T and Z at all standard isobaric levels, thickness, mean mslp etc. at global (GLB), hemispheric (N&S hemisphere), zonal (N&S subtropics; N&S pole), regional (core monsoon area and Tibet) scales averaged for the period 23-28 July 2005 are studied in comparison with their normal values (1979-2013). The whole globe appears to be warmer (+0.53ºC) and thicker (+23.3m) than its normal mean value. The NH is marginal warm (+0.6ºC) and thick (+25.7m) compared to the southern SH (0.5ºC/20.8m), creating favorable NH-SH contrasts in both parameters (+0.2ºC/+6.8m) for the occurrence and maintenance of Asia-pacific monsoon circulation. North Pole (NP: 65ºN-90ºN) is more warm and thick than normal (+1.1ºC/+61.5m) compare to South Pole (SP: 65º-90ºS), where T_{Trop} is lower than normal (-2.5ºC/-87.5m) all across. Significant contrast (+3.6ºC/151.6m) is seen to be developed between NP-SP than its normal value during 23-28 July. Tibet is slightly warmer, thicker (+0.6ºC/22.3ºC) and with lower atmospheric pressure (-0.34mb) than its normal value. Extreme east Tibet is more warm and thick (1.0ºC/41.9m) than normal as compared to other parts of Tibet, indicating eastward shifting of monsoon circulation favorable for the good monsoon rains in southern and western parts of the

country. Tropospheric temperature and thickness gradients from Tibet to other parts of the globe are positive and near normal, while to the South Pole are steeper than normal. It indicates the best favorable condition for the subsidence of the outflow from the Tibetan anticyclone encircling the vast Asian landmass primarily over the South Pole and marginally to other subtropical high pressure cells in both hemispheres.

(4) Qualitative analysis of global weather charts of 25th July 2005

Weathers across the globe are associated with either convergence or divergence of the air mass, under warm or cool temperature condition. The warm and cool atmosphere is relative to the corresponding equatorial mean temperature. We observe that equatorially conditioned atmospheric parameters like EC-T_{level} and EC-Z_{level} in combinations are helpful to segregate the areas under different types of weather conditions e.g. tropical, subtropical, temperate, subpolar and polar across the globe. At the standard isobaric level, the following four types of weather regimes across the globe are identified.

1.Warm (low-pressure) convergence regime(WCR)
2.Cool (low-pressure) convergence (CCR)
3.Warm (high-pressure) divergence regime (WDR)
4.Cool (high-pressure) divergence regime (CDR)

The regimes are classified based upon general relationship amongst four atmospheric parameters temperature, geopotential height, pressure and the wind. We believe that warm convergence and warm and cool divergence regimes may be collectively referred to as barotropic regime, and cool convergence as baroclinic regime. Different weather regimes are collectively referred to as general or global weather regimes (GWRs). All the regimes may not occur all-time at all the isobaric 'levels', it could be two to four. At 1000-hPa barotropic condition occurs between parallels 40°S-75°N. The zonal spread of the barotropic regime decreases in the vertical to 17.5°S-37.5°N and then spreads out to parallels 70°S-90°N. From 1000-hPa to 400-hPa, the areal extent of the warm convergence and cool divergence decreases while that of warm divergence and cool convergence increases. At 300-hPa and 250-hPa levels, only warm divergence and cool convergence prominently exist across the globe. A 150 hPa warm convergence confined over north of 40ºN. and warm divergence still persists over South Asia Cordillera. The South Pole and equatorial Indian ocean and Africa are under cool convergence and equatorial pacific cool divergence. Subtropical westerly jet stream south of Australian high is highest (GC-W >35m/sec) at 200-hPa and decreases downward to 5m/sec at 700-hPa. The temperate westerly jet stream across 50°S latitude is highest (GC-W > 30m/sec) at 100-hPa and decreases downward to 5m/sec.

At 925 hPa, the entire tropical and subtropical regions of the hemisphere are showing a marginal positive anomaly in temperature and negative in geopotential height. Above tropopause, the area under positive temperature anomaly shrinks and confined over Iran-Tibet, Indian subcontinent, and Canada in NH and southern temperate regions with positive geopotential field. NP is cooler by 6-8ºC while SP is warmer by 2-6ºC. Warming (cooling) of NP (SP) in the troposphere and cooling (warming) above tropopause are anomalous features seen in the weather charts of heavy rain event day. More than intense negative pressure field over entire tropical and subtropical areas of the globe, presence of high pressure cell over Siberia, positive anomaly over north and South poles, intense north subpolar lows, wavy patterns in north and south temperate subpolar atmosphere, weak north subtropical highs and marginally intense south subtropical highs are some of the peculiar characteristics observed in mslp charts of 25th July 2005 heavy rain event day. The EC-PPW field across Asia-Pacific on 25 July 2005 was similar to its normal (+5mm to +15mm in core area), but the vigorous conditions persisted for a longer period with minor spatio-temporal variations.

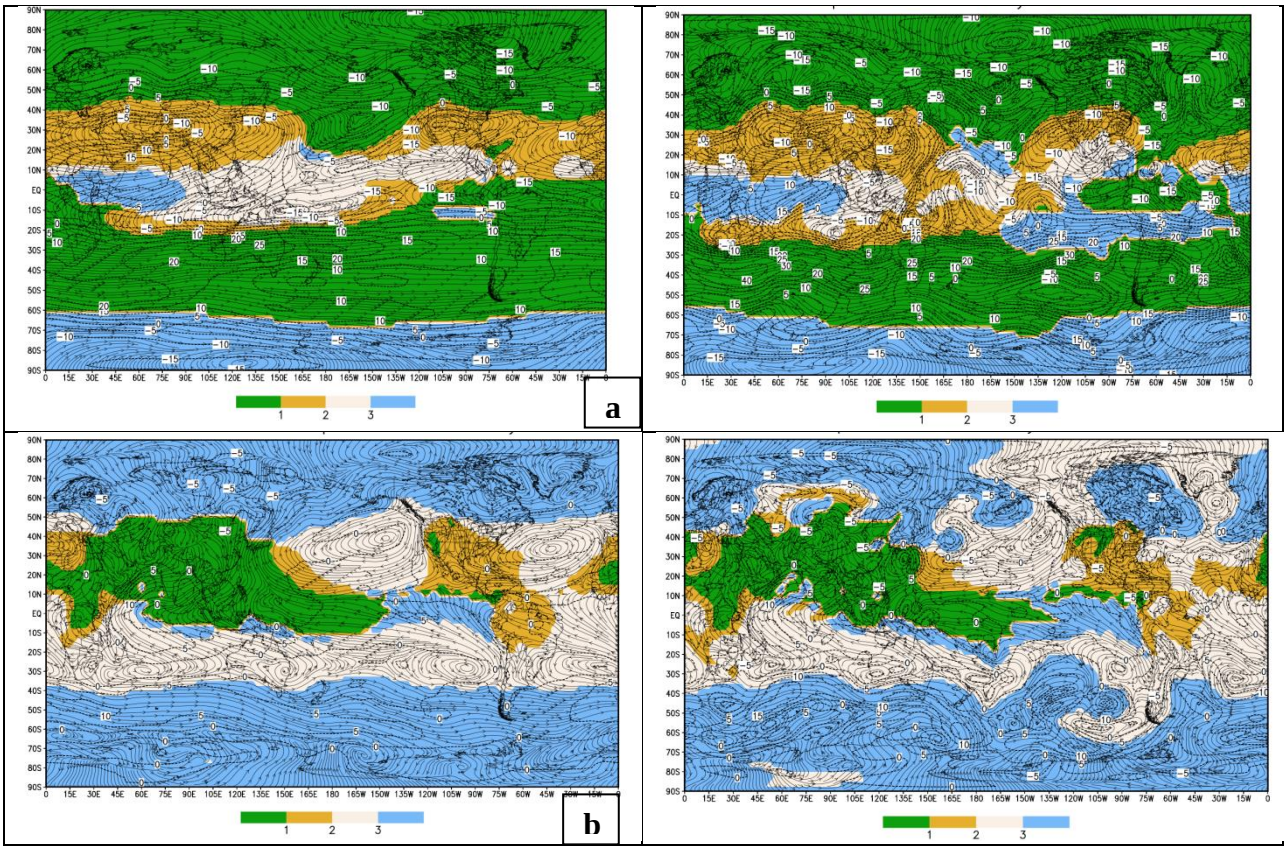


Fig. 3 Normal distribution of Global Weather Regimes (GWR) and GC-W at a) 150-hPa on 25 July (left panel) and actual distribution on 25 July 2005 (right panel); b) 925hP a(Number1 in color bar indicates WCR, 2: WDR,3: CDR and 4: CCR)

(5) Possible mechanism of Heavy rain spell

Eastward stretched, moderately intense and persistent eastern monsoon component due to the intensification of lower level convergence across entire Asia-Pacific region from Indian region through the Aleutian Islands as well as atmospheric dynamism over southern hemisphere produced the heaviest rainstorm over India during 23-28 July 2005.

13. Adopters of the results of the study and their feedback:

- Funding Agency
- Operational Forecasters if interested

14. Major items of equipment procured:

1. Workstation
2. Printer
3. UPS

15. Lab facilities during the study:

None

16. Data generated in the study:

1. Yearwise daily equatorially-conditioned atmospheric parameters maps
2. Yearwise daily global weather regime maps

17. Study Benefits/Impact:

The results from this study will be helpful in order to develop operational forecasting scheme for the assessment and prediction of heavt rain spell duirng summer monsoon across the country. The study will also give some insight about the relationship between occurrences of extreme rain events and changes in general circulation features in order to cope up their consequences in advance.

18. Specific linkages with Institutions/beneficiaries:
None

19. Shortcomings/Difficulties:
Shortage of high resolution observed data of meteorological parameters in order validate the results

20. Future Plan:
Near real-time Thematic global monitoring system for the assessment and forecast of large-scale extreme wet spells.

12. PROJECT REFERENCE CODE: NIH/SWD/NIH/15-18

1. Title of the study:

Study on effect of climate change on sediment yield to Pong reservoir.

1. Study Group:

Dr. A. R. Senthil kumar Sc E, SWHD
Dr. J. V. Tyagi, Sc "G", SWHD
Dr. Suhas Khobragade, Sc "F", HID
Dr Manohar Arora, Sc "D", SWHD

2. **Date of start:** 1 April 2015
3. **Duration of the study**: 3 Years
4. **Whether externally funded or not:** No
5. **Objectives Of The Study:**

- To model sediment yield at Pong dam.
- To investigate the impact of likely future changes in climate on sediment yield up to Pong dam using future climatic scenarios.
- To assess the life of the reservoir for the likely sediment yield under the projected different climatic scenarios.

6. Brief Methodology:

7. Sediment yield model:

The sediment yield up to Pong reservoir is modeled by Soil and Water Assessment Tool (SWAT) with the information about weather, soil properties, topography, vegetation and land management practices occurring in the watershed.

9. **Climate Scenarios:**

The different scenarios of climatic conditions such as RCP2.6, 4.5, 6 and RCP8.5 are obtained from CMIP5 models available from different institutes.

10. **Computation of sediment yield under different scenarios:**

The parameters of the SWAT are calibrated using the historical hydro-meteorological data. The future sediment yield is simulated using SWAT with the data of different climatic scenarios. The impact of likely future changes in climate on stream sediment yield up to Pong is analyzed by the output of SWAT for future climate scenarios.

11. Revision of elevation-area-capacity table:

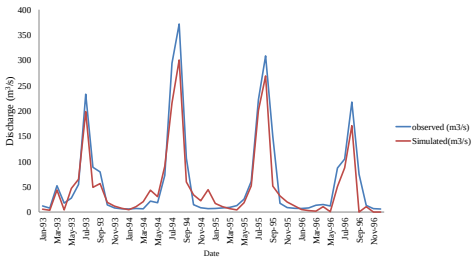
The projected sediment volume for future periods is distributed in the reservoir by empirical-area reduction method to find out the revised elevation-area-capacity table.

12. Results achieved with progress/present status :

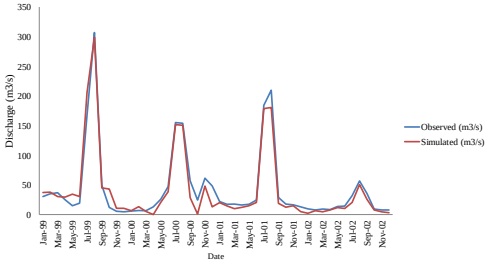
The sediment entering into Pong Reservoir is measured at Jwala Mukhi (Nadaun Bridge) located on Beas River. The major tributaries which directly enter into the reservoir are Baner Khad, Gaj Khad, Dehar Kahd and Buhl Khad. The suspended sediment concentration from Baner Khad, Dehar Khad and Gaj Khad are measured at Haripur, Jwali and Nagrota respectively. The sediment yield at Jwala Mukhi is

modelled by Soil and Water Assessment Tool (SWAT). The data requirement for running the SWAT model are landuse, soil map, DEM, rainfall, wind velocity, relative humidity, temperature, solar radiation, potential evaporation, runoff at outlet, sediment yield outlet, runoff and sediment yield to the storage structures in the catchment and elevation-area-capacity curve of the storage structures. The inputs such as Land Use Land Cover, DEM, Soil map, Aspect map for running the SWAT have been generated using different sources available in the web sites of different organizations such as NASA, National Bureau of Soil Survey and Land Use Planning (NBSSLUP) and NRSC. Grid based meteorological data such as daily rainfall, minimum and maximum temperatures are obtained from Indian Meteorological Department (IMD) and European Centre for Medium-Range Weather Forecasts (ECMWF) (ERA Interim data). The parameters of SWAT for the modelling discharge and sediment yield are calibrated manually (trial and error method) by considering the data from 1993 to 1996 for calibration and 1999 to 2002 for validation. The calibration and validation results of discharge and sediment yield are presented as follows:

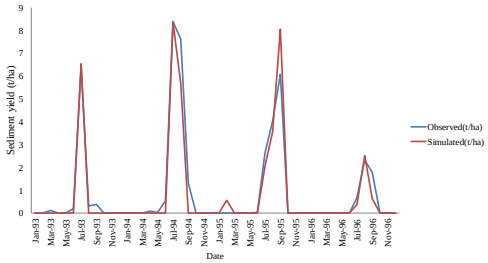
Calibration(4yr) results of discharge of ARCSWAT



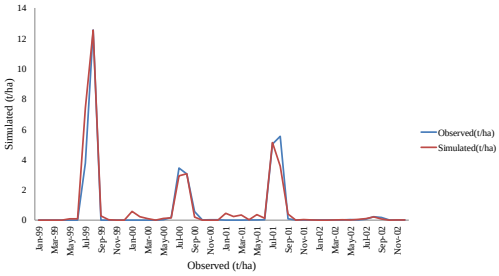
Validation(4yr) results of discharge in ARCSWAT



Calibration(4yr) results of Sediment Yield in ARCSWAT



Validation(4yr) results of Sediment Yield in ARCSWAT



The sediment yield at Haripur is being modelled. The future scenarios of minimum and maximum temperature and rainfall for the climatic conditions such as RCP2.6, 4.5, 6 and 8.5 are being downscaled from GCM models such as MRI-CGCM3 (Coupled General Circulation Model, version 3), **BCC-CSM 1.1-m(**Beijing Climate Center (BCC), China Meteorological Administration Model), **UKMO-HadGEM2(**Office Hadley Centre Global Environmental Model version 2), **CSIRO BOM ACCESS1(**Bureau of Meteorology, Australian Community Climate and Earth-System Simulator, version 1.0), **MPI-ESM LR(**Meteorological Research Institute Coupled Atmosphere–Ocean General Circulation Model, version 3), **NCC_NorESM1_M(**Norwegian Earth System Model, version 1) and bias corrected by linear bias correction.

13. Expected date of completion: 31 March 2018

13. PROJECT REFERENCE CODE: NIH/SWD/NIH/14-17

1. **Title of the study**: **Effect of climate change on evaporation at point scale**

2. **Study Group:**

Sh. Digambar Singh, Sc B, SWHD
Dr. A. R. Senthil kumar Sc E, SWHD
Dr. Manohar Arora, Sc D, SWHD

3. **Date of start:** **1 June 2014**

4. **Duration of the study:** 3 Years

5. **Whether externally funded or not: No**

6. **Objectives of the Study:**

a. To develop evaporation model by empirical and soft computing techniques
b. To downscale the data of temperature, rainfall and humidity from GCM model
c. To determine the effect of climate variables on evaporation by using the downscaled data

7. Brief Methodology:

Evaporation model
Empirical models such as Penman Method, Meyer Model, Multiple Linear regression (MLR) and soft computing techniques are applied to model the evaporation with rainfall, temperature and humidity as input vectors.

Development of climate scenarios
The rainfall, minimum and maximum temperature and humidity for future can be generated by GCM models. The different scenarios of climatic conditions such as RCP2.6 4.5, 6 and 8.5 are obtained from CMIP5 models available from different institutes. The historical data used for the downscaling and the bias correction are maximum and minimum temperature, rainfall, wind speed and solar radiation computed from extra terrestrial radiation. The empirical and the best model developed by soft computing techniques are applied to simulate the evaporation from the downscaled values of rainfall, maximum and minimum temperature and humidity for different climatic scenarios as mentioned above.

8. Results achieved with progress/present status :

A Multiple Linear Regression (MLR) model has been developed using the inputs considered in the development of ANN model for the simulation of Evaporation. The inputs considered in the modelling are the observed data from NIH observatory. A comparison between the MLR and ANN models is carried out by performance indices such as coefficient of correlation, root mean squared error, Nash-Sutcliffe Model efficiency. The future scenarios of minimum and maximum temperature, rainfall, wind speed, solar radiation for the climatic conditions such as RCP2.6, 4.5, 6 and 8.5 are downscaled from GCM models such as MRI-CGCM3 (Coupled General Circulation Model, version 3), **BCC-CSM 1.1-m(**Beijing Climate Center (BCC), China Meteorological Administration Model), **UKMO-HadGEM2(**Office Hadley Centre Global Environmental Model version 2), **CSIRO BOM ACCESS1(**Bureau of Meteorology, Australian Community Climate and Earth-System Simulator, version 1.0), **MPI-ESM LR(**Meteorological Research Institute Coupled Atmosphere–Ocean

General Circulation Model, version 3), **NCC_NorESM1_M(**Norwegian Earth System Model, version 1) and bias corrected by linear bias correction. The data of downscaled scenarios will be used in the empirical and ANN models to simulate the evaporation for the period.

9. **Expected date of completion:**

The project is to be completed by May 31, 2017. But an extension of 6 months up to October 2017 is required to apply the downscaled data of GCM models to simulate the evaporation for different climatic condition

14. PROJECT REFERENCE CODE: NIH/SWD/NIH/15-18
PROFORMA FOR SUBMITTING INTERNAL RESEARCH PROJECTS

1. Thrust Area under XII five year Plan: Flood & Sediment Modelling

2. Project team:

1. Project Investigator: Dr. A.K. Lohani, Scientist G
2. Project Co-Investigator(s): Dr. S.K. Jain, Scientist G

3. Title of the Project: Flood and Sediment studies in Himalayan basin using MIKE-11 Model

4. Objectives

To model the floods generated due to cloud burst events.
To develop discharge-sediment relationship.
To assess sediment dynamics in the river system.

5. Present state-of-art

In upper Ganga basin, several water resources projects are under operation and many more are coming up to harness these resources. These projects are of considerable national and local importance in terms of hydropower generation, irrigation, flood control and subsequent socio-economic development of the region. In the recent past various cloud burst events have been observed in the Himalayan region. Therefore, it is important to analyse the cloud burst generated floods in the basin. Furthermore, the Himalayan rivers carry very high sediment load. The waters of the Ganga carry one of the highest sediment loads anywhere in the world. Therefore, keeping in view the up coming projects and development in the Himalayan region modeling of the sediment dynamics in a river system is need of the day.

6. Methodology

Steps of the methodology are:

- Analysis of available precipitation data for different return period for the identified sub basin.
- Historical study of cloud bursts in the Himalayan Region.
- Study of phenomenon of cloud bursts
- Quantification of cloud burst phenomenon into flood hydrograph at the critical section in the river stream.
- Flood routing of cloud burst flood.
- Development of MIKE-11 based sediment model to assess the sediment dynamics of the river system.

7. Analysis and Results:

Collection of data/information related to cloud burst and sediment is in progress. Contacted various Central and State organizations working in the area for the required data/ information. Model for cloud burstflood modeling has beenfor a cloud burst event of the Uttarakhand. MIKE-11 model has been used for cloud burst flood routing purpose. For routing the flood in the river cross-sections of the river have been derived from the DEM. Further flood water discharge, water depth inundation have been estimated at the downstream locations in the river.

8. Research outcome from the project:

The research outcome will be in the form of technical report, research papers. Development of methodology for the cloud burse flood modeling and sediment modeling.

9. Work Schedule:

Sl. No.	Work Element	2015-16	2016-17	2017-18
1	Data Collection	Partly Completed	Mostly completed	
2	Procurement of Mike-Software	Cloud solution for MIKE-11 obtained from DHI		
3	Historical study of cloud bursts in the Himalayan region.		completed	
	Quantification of cloud burst phenomenon into flood hydrograph at the critical section in the river stream	Review of Literature	Partly completed/In progress	
	Flood routing of cloud burst flood.		Partly completed/In progress	
	Development of MIKE-11 based sediment model to assess the sediment dynamics of the river system.		In progress	
	Report writing			

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15. PROJECT REFERENCE CODE: NIH/SWD/NIH/16-18

Title of the Study: **Snow cover variability in the Upper Yamnotri Basin**

Study Group : Naresh Kumar, Scientist B
Dr. Manohar Arora, Scientist D
Dr. Rakesh Kumar, Scientist G

Role of Team Members:

Naresh Kumar, Scientist B

- Literature review
- Down loading of MODIS Mod 10 A2 data from National Snow and Ice Data Center (NSIDC)
- Data base preparation in ArcGIS (Basin map and drainage network)
- Snow cover analysis of the study area
- Preparation of snow depletion curves for the study area for different years
- Preparation of report

Dr. Manohar Arora, Scientist D

- Guidance, Supervision and review of the work

Dr. Rakesh Kumar, Scientist G

- Guidance, Supervision and review of the work

Type of Study : Applied research

Date of start : April 2016

Scheduled date of completion: June 2018

Location Map:

Upper Yamuna Basin(Upto Dakpathar)

Basin Area: 7487 Km^2, Elevation Range: 461 to 6284m

Objectives:

i. Study of snow cover variability in the Upper Yamnotri Basin
ii. Development of snow depletion curves for Upper Yamnotri Basin

Statement of the problem :

The extent of snow cover is considered as an important parameter for various hydrological applications. In terms of spatial extent, snow cover is second largest component of the cryosphere and covers approximately 40 – 50 % of the Earth's land surface during Northern Hemisphere winters. Annual precipitation of snow feeds the accumulation zone of the glaciers. Himalayas being the loftiest mountain of the world are abode of the snow and glaciers. The three major river systems of India i.e the Indus, the Ganga and the Brahmputra have their origin in the snow and glacier fed areas of the Himalayas. Snow melt is also the source of fresh water required for drinking, domestic use, agriculture and industrial sectors for the low lying areas of these river systems. Estimation of snow cover is one of the important parameters for the runoff estimation and forecasting for the snow and glacier fed rivers. However the mapping and monitoring of seasonal snow cover is a challenging task especially in the harsh climatic conditions and rugged terrain of the high mountainous areas.

Remote sensing has emerged as a useful technique for snow monitoring. Snow cover monitoring using satellite images started in 1960 and since then potential for satellite based mapping has been enhanced by the development of sensors with higher temporal frequency and higher spatial resolution. Sensors with better radiometric resolutions, such as MODIS and AWiFS have been used for generating the snow products. MOD10A2, a product of MODIS is used for mapping of maximum snow cover extent over eight days. The algorithm used to generate maximum snow cover over eight days uses MOD10A1 data as input. The multiple days of observations for a cell are examined. If snow cover is found for any day in the period then the cell in the "Maximum_Snow_Extent" SDS is labeled as snow. The logic minimizes cloud cover extent in that a cell would need to be cloud obscured for all days observations to labeled as cloud. If all the observations for a cell are analysed but a result is not reached then that cell is labeled as no decision. Snow cover extracted from earlier data and snow products prepared using satellite images have been analysed to know the trends in the snow cover variability in many studies.

Approved action plan:

S.N	Work Element	**First Year (2016-17)**				**Second Year (2017-18)**				**Third Year (2018)**
		April-June	Jul-Sep	Oct-Dec	Jan-Mar	Apr-June	Jul-Sep	Oct-Dec	Jan-Mar	April-June
1	Literature Review & Data Downloading									
2	Preparation of basin maps etc.									
3	Data analysis									
4	Preparation of report									

Objectives vis a vis Achievements:

Objectives	Achivements
Literature Review & Data Downloading	Literature review has been completed. MODIS Mod 10 A2 data for the ten years period (2007 to 2016) for basin has been down loaded from National Snow and Ice Data Center (NSIDC).
Preparation of basin maps etc.	Basin maps etc. have been prepared from the Aster DEM with the help of ArcGIS tool

Recommendations of Working Group/TAC/GB:

Analysis and Results: Analysis work is in progress

Adopters of the results of the study and their feedback:

State Disaster Management Authority
Hydropower Companies in the downstream

List of deliverables:

Snow depletion curves for Upper Yamnotri Basin
Snow cover area matrix
Extent of maximum and minimum snow cover

Major items of equipment procured: Nil

Lab facilities during the study: NIH

Data generated in the study: Nil

Study Benefits/Impact: Snow depletion curves are necessary for melt runoff studies and works as input in modeling of melt runoff. The results of the study will work as input for forecasting the stream flow of the Yamuna River.

Specific linkages with Institutions/beneficiaries:

Linkage will be established with Hydropower Companies in the downstream and State Disaster Management Authority.

Shortcomings/Difficulties:
As the study area elevation range varies from 461 to 6284 meter above sea level. Snow free scenes for all the dates are difficult to get.

Future Plan:
The results of the study will be used by Hydropower Companies in the downstream and for water management issues related to Yamuna River.

NEW STUDY
16. PROJECT REFERENCE CODE: NIH/SWD/NIH/17-18

1. Development and regionalization of unit hydrograph for runoff modeling on Indian catchments

a. (Research/application Study)

2. Study group Sushil K. Singh**,** Scientist F

3. Date of start of study 01 April 2017

4. Duration and scheduled date of completion of study 01 Year; 31 March 2018

5. Type of study Internal

6. Objectives of study

1. To develop and systematically compile the new unit-hydrograph model for runoff modelling by the author. This is in view to analyze the parameters of the models for possible regionalization.
2. To develop the regionalization approach for the model-parameters to enable possible applicability to ungauged catchments.

7. Statement of problem and brief methodology

1. Event based rainfall runoff modeling has been a concern for practitioners, field engineers, and academicians. It is useful for event-based runoff modelling for a catchment in general and modelling of floods in particular.
2. Possible regression approach and fitting of equation to data and possible development of useful empirical equations.

8. Achievement/progress:

The study is at initial stating stage.

9. Adopters of the results of study and their feedback

a. Practitioners, field engineers, and academic personals.

10. Deliverables

Research report detailing the developed equation and research papers in International Journals with illustrative of ease in application to ungauged catchments.

17. PROJECT REFERENCE CODE: NIH/SWD/NIH/17-21

1. Title of Study: Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)

2. Study Group - Sanjay Kumar, Sc-E, PI
Rakesh Kumar Sc-G, Co-PI
J. P Patra Sc 'C'
Pankaj Mani, Sc 'E'

3. Objectives of the study:

The objectives of the study are:

(i) To develop regional relationships for (surface) water availability analysis.
(ii) Development of at site and regional flood frequency analysis using L Moments.
(iii) Development of at site and regional rainfall frequency analysis using L moments.
(iv) Development of regional relationships for Nash and Clark IUH models parameters.

4. Statement of the problem:

The surface water availability analysis is the foremost task for planning any project on a river. Accurate estimation of the total quantity of surface water availability and its variation is important for the success of any project. Depending on the type of data availability different methods and regional relationships would be used/ developed for water availability computations.

The study would also estimate design flood for various return periods needed for different types of water resources structures. These structures are often planned in regions with less or no hydro-metrological information/data. Studies carried out for such conditions are limited and based on various types of conventional techniques. This study specifically focuses on developing design flood estimation methods for such partially gauged or un-gauged regions based on the concept of regionalization. In regions where only rainfall data is available, the study would carry out at-site and regional rainfall frequency analysis using L-moments. The study would also develop relationship between mean annual peak floods and physiographic characteristics of the basin and develop regional relationships for NASH and Clark IUH model parameters. These developed relationships would finally used for estimation of floods of various return periods.

5. Methodology:

For estimation of T-year return period flood at a site, the estimate for mean annual peak flood is required. For gauged catchments, such estimates can be obtained based on the at-site mean of the annual maximum peak flood data. At-site and regional flood frequency analysis will be performed using the L-Moments approach, which includes various frequency distributions: viz. Extreme value (EV1), Generalized extreme value (GEV), Logistic (LOS), Generalized logistic (GLO), Normal (NOR), Generalized normal (GNO), Uniform (UNF), Pearson Type-III (PE3), Exponential (EXP), Generalized Pareto (GPA), Kappa (KAP), and five parameter Wakeby (WAK). Screening of the data, testing of regional homogeneity and identification of distribution will be carried out.
However, for ungauged catchments at-site mean cannot be computed in absence of the flow data and in such a situation, a regional relationship between the mean annual peak flood of gauged catchments in the region and their pertinent physiographic and climatic characteristics is needed for estimation of the mean annual peak flood. For example, the form of this regional relationship may be:

$$\overline{Q} = a\, A^{b} S^{c} D^{d} R^{e}$$

Here, ($\overline{Q}$) is the mean annual peak flood, A is the catchment area, S is the slope, D is the drainage density, R is the annual normal rainfall or rainfall for the duration of annual

maximum peak flood for the catchment etc., a, b, c, d, and e are the regional coefficients. Further, relationship of various other characteristics like length of main stream (L), centroidal longest flow path (L_c) etc. with peak flood will also be evaluated. The regional coefficients will be estimated using the mean annual peak floods of the gauged catchments and their pertinent physiographic and climatic characteristics for a region. The physiographic and climatic characteristics which are considered pertinent for generation of annual maximum peak floods from a catchment and can be obtained from the observed records e.g. rainfall for the duration of occurrence of the annual maximum peak floods and derived from the toposheets/maps of the gauged catchments may be considered for development of this relationship.

6 Deliverables

- Regional relationships for water availability analysis,
- Flood estimates for various return periods for gauged catchments.
- Regional Relationship between mean peak floods of various return periods with catchment characteristics.
- Regional Relationships for estimation of floods of various return periods for un-gauged catchments.
- Regional relationships for Nash and Clark IUH model parameters.
- Research papers and Report

7 Cost estimate

a. Total cost of the project:
b. Source of funding: Internal/PDS(NHP)

S.N.	Sub-head	Amount (in Rupees)
1.	Salary	32,20,800.00
2.	Travelling expenditure (domestic/international)	11,10,000.00
3.	Infrastructure/Equipment/furniture	10,00,000.00
4.	Misc. expenditure	2,00,000.00
	Grand Total:	55,30,800.00

Salary/wages for hiring one RA/SRF and one JRF/Resources person is proposed for the duration of the study. Travelling expenditure to visit study area; visits related to data collection and training. Cost towards equipment/infrastructure and miscellaneous expenditure. A total cost of Rs. 55,30,000.00 is proposed for the study to be completed in 4 years.

8. Action plan and timeline and progress:

S.N.	Work Element	1st	2nd	3rd	4th
9	Collection of hydro meteorological data, satellite images, thematic maps etc.				
10	Compilation, statistical analysis of rainfall and river discharge				
11	Regional water availability analysis				
12	At-site frequency analysis for point rainfall data				
13	Regional frequency analysis for point rainfall data				

S.N.	Work Element	1st				2nd				3rd				4th			
14	At-site and regional flood frequency analysis for gauged catchments																
15	Estimation of catchment characteristics and parameters of IUH																
16	Development of regional relationships for peak floods with catchment characteristics.																
17	Workshop/ Training																
18	Report																

18. PROJECT REFERENCE CODE: NIH/SWD/NIH/17-20

1. Proposal -

2. Project team:

a. Project Investigator: **Dr A. R. SENTHIL KUMAR, Sc "E" SWHD**
b. Project Co-Investigator(s):
Dr. Manohar Arora, Sc 'D'
Sh. Digambar Singh, Sc 'C'
Dr. M S Rao, Sc 'E'
Sh. R K Nema, PRA
Dr. Pradeep Kumar, Sc 'C'
Dr. S K Mishra, Prof, IIT Roorkee

Staff: Sh. R. K. Nema, PRA, SWHD and Sh. Omprakash, SRA, SWHD

3. Title of the Project : "An integrated assessment of a middle Himalayan watershed for sustainability of its water resources"

4. Objectives:

- To monitor the existing springs in the watershed
- To model the runoff by SCS method considering the slope factor
- To develop an ANN model to simulate the runoff
- To compare the results of ANN model with SCS CN method
- To determine the isotopic and chemical characterization of springs
- To identify rechargeable zone by isotope techniques
- To suggest the measure for the rejuvenation of few springs of the watershed
- To study the impact of climatic variability on runoff and spring flows

5. Present state-of-art:

Sustained and safe water supply from streams, springs and groundwater in the hilly terrain requires a clear knowledge of rainfall pattern & its variability and its relation with runoff generation, mapping of surface & groundwater flow pattern for taking up suitable measures to augment the water resource of the region. Climate trends in the Himalayan region are sparsely known due to limited instrumental meteorological records both in terms of length of periods of observation and density of observatories. Since the run-off generation depends on several factors like initial soil moisture, land use types, watershed geomorphology, evaporation, infiltration, rainfall pattern (distribution, intensity & duration) etc and, field data of all these parameters are not available, therefore, relation between rainfall and runoff is not available in large parts of Himalayan region. Further, almost no data on groundwater level is available from these mountainous areas leaving a blind spot regarding groundwater assessment of these regions. No proper documentation of changes in spring types from perennial to seasonal or vanishing of old streams is available. Thus, management of water resource of these hilly watersheds strongly demands generation of primary meteorological data, assessment of local hydrogelogical details, linking the climate variability & topography with the hydrograph characterization streams and springs etc. It may also be noted that Himalayas are tectonically active regions and man-made activities like roads & reservoir constructions, deforestation etc are directly or indirectly affecting the regional hydrology in terms of landslides, subsidence, etc. The present project is intended to address some of these issues along with suggesting suitable management measures for development & management of water resource of the region for sustainable development ecosystem and progress of the region. For estimation of relation between rainfall and runoff SCS CN and ANN will be used; interaction between surface water and groundwater and, groundwater flow will be assessed using isotopic & chemical tracer method. The required

raw data for this assessment will be generated through direct measurement of field based parameters.

6. Methodology:

For the present project, a watershed located in Jakhnidhar Tehsil of District Tehri Garhwal in the Middle Western Himalayan will be monitored for rainfall, runoff, meteorological details and for the discharge in selected springs (around ten) and streams. Automatic/manual rain Gauges will be installed at suitable sites. Discharge in river flows will be monitored at few stream-sites and, for this, water level recorders will be installed at the gauging sites (new composite v-notch and rectangular weir). At a representative site, a fully automatic with self-data recording/transmitting system will be installed. Land-use, soil cover, DEM will be prepared. Demographic details will be recorded. Temperature and EC of water sources will be monitored at suitable locations.

The monitored data will be used for generating springs and stream hydrographs. These hydrographs will be inter-compared to identify inter-relation between streams & springs and the time delay between rain event and its appearance in the discharge points. This is useful in observing the cloud-burst events in surface water and spring discharges. The shape of hydrographs of springs will be inter-compared to identify their common source of origin (whether common or different) and also for sustainability of these springs for local water supplies. Stream hydrographs will be resolved for separation of base flow component. Variation in stream discharge with sediment load & grain size will be compared to identify correlation between run-off and soil erosion.

SCS CN & ANN procedures will be applied to compute the run-off for the rainfall amount. Runoff generation for unit rainfall will be mapped for each sub-watershed. On the sub-watershed scale, using the stream flow data and the estimated run-off the base flow will be computed. Groundwater storage and spring water discharge will be intercompared.

Water samples will be collected for isotopic and chemical analysis. Water quality of spring and stream water will be examined for its suitability for drinking needs. Water quality and isotopic data of different springs will be inter-compared to identify the interlink between these springs, extent of evaporation at the time of recharge (by comparing d18O-dD line with GMWL) and chemical enrichment of dissolved constituents during the sub-surface flow. Since the region is devoid of industries the only anthropogenic contribution is expected to be sewage waste. Considering this, anthropogenic influence will be monitored by measurement the dissolved nitrate concentration in water. If fertilizers are getting used then the corresponding dissolved chemicals will also be monitored. Temperature and EC of springs will be measured to get average recharging water temperature and total build-up of salinity during the groundwater flow. Isotopic data and temperature data if possible will be used to resolve recharge occurring from summer and winter precipitation. Isotopic composition of rainfall, surface water and spring water will be analyzed to infer isotopic-altitude effect towards the objective of identification of recharge sources. The combined use of discharge, isotopic composition and water quality will be attempted to differentiate multiple recharging sources of spring. A few samples will be analyzed for environmental tritium and dissolved radon to examine the groundwater recharge zones and groundwater flow rates.

Changing rainfall pattern, shifting of streams, changing pattern of springs, changing water quality of water sources, erosion activity (using sediment load data in different streams) etc will be classified in terms of vulnerability of water resource to climate change, local geology (erosion, landslide or due to any other man-made activity) and water quality.

For water resource management aspect, water availability and its demand (from different sectors and, its requirement envisaging the population & economic growth of the region) will be examined. This will be done on sub-watersheds scale. Accordingly, methods for improving water resource conditions of the region will be suggested. Towards this, isotopic &

chemical data will be combined with DEM and sub-watershed scale maps to identify the recharge zones. Depending upon the local hydrogeology, suitable cost-effective structures for rejuvenation of springs, rain water harvesting structures, or other methods like check dams, river bank infiltration, gully plugging etc will be suggested. .

7. Research outcome from the project:

The following outcomes are envisaged from the project:

- A continuous data will be generated for small watershed of the Uttarakhand hills.
- Model for the contribution of stream flow and spring flow from small watersheds will be developed.
- Spring classification for the mid-Western Himalaya, Uttarakhand will be available.
- Assessment of water quality of spring water
- A comprehensive and synoptic view of surface water and groundwater flow conditions of the region will be prepared by integrating field data, SCS CN & ANN modeled data and water quality and isotopic results
- Assessment of climate and anthropogenic impact on water resources of the study area and management steps to safeguard these water resources and to augment them for their long term sustainability.

8. Cost estimate:

I. Total cost of the project: 50.00

II. Source of funding: **NIH budget**

	Item	**Budget, lacks**			**Total**
		1st Year	2ndYear	3rd Year	lakhs
1	Salary Project Staff	6.36	6.76	6.76	19.88
2	Travel	2.25	2.30	2.31	6.86
3	Infrastructure/ Equipment	7.30	--	--	7.30
4	Experimental charges	4.54	3.19	3.23	10.96
5	Mics. Expenditure	0.5	1.5	3.0	5.0
	Total	20.95	13.75	15.30	50.00

III. Justification for Sub-head-wise abstract of the cost

10. Justification for salary:

Salary for Field Deployed staff: The major part of the project is collection and analysis of the data from the field and the success of the project depend on it. The data is to be collected continuously from 20 springs, 2 gauging sites and 1 observatory in the remote areas at high altitude followed by data analysis on the computer. Two observer and two skilled workers are required for the collection of data from springs, gauging sites and maintenance of the sites. The qualifications of staff appointed will be as per rules of NIH.

11. Field Deployable Project Staff

Sl No	Designation	No. of post	Pay Scale (per month), lacks	Salary, lakhs			Total
				1stYear	2ndYear	3rdYear	lakhs
1	Observer	02	0.05 Consolidated	1.2	1.2	1.2	3.6
2	Skilled worker	02	0.10 Labour rate contract	2.4	2.8	3.2	8.4

Total	**3.6**	**4.0**	**4.4**	**12.0**

12. Salary for Staff deployed in Laboratory and for Data Analysis

During the project, over 3000 water samples will get collected from field for various chemical and isotopic analysis (about 15,000 total analysis will be done). All this data will be synthesized in an appropriate framework and will be clubbed with the 5 years continuous data on meterological parameters, discharge data to deduce the required results. The project is also intended to deduce various thematic maps based on the analysis of this data, remote sensing data, geohydrological data etc . The results are required to be produced in the form suitable for implementation in the field. This also require organizing workshops for knowledge dissemination at local level (mass awareness programmes) and to higher government officials (organizing trainings) and suitable publications. For help in executing these tasks 1no of semi skilled and 2 nos of Sr/Jr Project Officer will be hired as per the norms of NIH.

Salary of staff for Laboratory Work, Analytical Computational work and Knowledge dissemination:

Sl No	Post	No. of post	Amount per month (in lakhs)	Salary (Rs in lacks)			Total
				1st Year	2nd Year	3rd Year	lakhs
1	Sr/Jr Project Officer	01	1.5	1.8	1.8	1.8	5.4
2	Highly skilled person	01	0.08	0.96	0.96	0.96	2.88
Total				**2.76**	**2.76**	**2.76**	**8.28**

Total Budget under salary Head: Rs. (12.0+8.28) Lakhs = 20.28 lakhs

Justification for travel:

PI, Co-PI and Scientific staffs are required to travel frequently to field (approx 120 days over the entire project period). The region is remotely situated and therefore can only be approached by taxi/Jeep. Travel charges also include travel to various places for knowledge dissemination & for meetings with offices for project work. The travel expenditure involves Taxi charges, miscellaneous field work expenditure and TA/DA of officers.

Head	Expenditure, Rs.			Total
	1st Year	2nd Year	3rd Year	
Travels TA/DA	1.00	1.00	1.10	3.10
Taxi	0.75	0.80	0.65	2.20
Misc. Field work expenditure	0.50	0.50	0.56	1.56
Grant total	2.25	2.30	2.31	**6.86**

Justification for Infrastructure/ Equipment:

The minimum required instrumentation is proposed for the study using the infrastructure of already running project with modification for suggested objectives. The emphasis in this project is given on spring of the watershed along with the watershed behaviour. The instruments from sl. no. 1 to 2 are essentially required for water balance and runoff studies.

Sl no	Equipment details Including installation	no	Rate, lakhs	T. Cost, lakhs
1	Construction of V Notch cum Composite weir	2	1.0	2.0

2	Upgradation of AWS/New AWS	1	4.0	4.0
3	Instruments: Repair, replacement, maintenance, insurance, etc.		1.5	1.5
	Total			**7.5**

Justification for Experimental charges:

Construction of gauging sites is essentially required and it is a part of instrumentation. The maintenance of gauging sites is a big job and the cost may go higher as we do not have any control on natural processes. Test for rejuvenation of springs is an objective of the project.

Head	Expenditure, lakhs			Total
	1st Year	2nd Year	3rd Year	lakhs
Experimental charges : Filters, chemicals, standards, EC, pH & digital temperature meters, specialized syringe for isotopic analysis, plastic bottles, trays, minor expenditure for fabrication of items, stationary items, pen drives, cartridge, photocopy & binding, packing & transportation charges, purchase of data/imagery, batteries, note pads, and any other miscellaneous expenditure as required for smooth execution of laboratory work	1.5	1.5	1.5	4.5
Cleaning of V Notch sites,	0.50	0.50	0.50	1.50
Local security for each instrument at the sites (15) @ Rs. 200/pm	0.36	0.36	0.38	1.10
Establishment of site office: Table chairs, curtain, Steel cabinet (Almira), racks, mats, towels, glassware, other mics. running items etc.	1.00	0.15	0.15	1.30
Site office cum store: Rent	0.18	0.18	0.20	0.56
Field working support items: field kit, Tool kit, medical charges, field shoes, Gum boots, Umbrella, Rain coats, Winter jackets, Blankets, Sleeping bags, gas cylinder and heater, field bag etc.	1.00	0.50	0.50	2.00
Grant total	**4.54**	**3.19**	**3.23**	**10.96**

14. Justification for Miscellaneous Expenditure

The results and knowledge gained from the project will be disseminated/exchanged with stakeholders and government officials through mass awareness programme (1 no) and by organizing trainings/Workshops (2 nos) and by presenting results in conferences. Since the project involves multitasking work (field, laboratory, modelling and knowledge dissemination) some unforeseen expenditure may also incur for smooth function of the project. A budget of Rs 5.0 lakhs will be required for this.

Sl no	Miscellaneous expenditure	1st Yr (Rs Lakhs)	2nd Yr (Rs Lakhs)	3rd Yr (Rs Lakhs)	Total (Rs Lakhs)
1	Knowledge dissemination (Mass awareness 1 no+ 2 nos of	1.5	1.5	2.0	5.0

	Training/ Workshops/ Brainstorming) + Other Miscalenous expenditure				
	Total	1.5	1.5	2.0	5.0

15. Monthly time schedule for data collection & Field work

Activities	**Jan to Dec.**
Manual data collection by local project staff at field	At least once in two days
Inspection of instruments and site, visit by local project staff of field	At least twice in a week
Field and site visit by technical staff and inspection of instruments	At least once in a month
Site visit by PI/Co-PI	At least six times in a year

c. Stages of work and milestone

Sl. No.	Work Element	1st Year	2nd Year	3rd Year
1	Deliverables	1st Interim Report	2nd Interim Report	Final Report

16. Work Schedule:

a. Probable date of commencement of the project: **April, 2017.**
b. Duration of the project: **3 years**
c. Stages of work and milestone:

Activity	1st Year		2nd Year		3rd Year	
Selection of site. Identification of camp office. Construction/ renovation of v-notch gauging site.						
Purchase of Equipments/insturments						
Test for rejuvenation and development of springs						
Installation of Equipment						
Appointment of project staff						
Electronic data collection						
Manual data collection						
Site monitoring						
Database updating						
Lab Analysis						
Data Interpretation & Analysis						
Model development, calibration & validation						
Interim annual report/ Final report						

19. PROJECT REFERENCE CODE: NIH/SWD/NIH/17-20

1. **Thrust area** Regional Hydrology

2. **Project team:**
   a. Project Investigator: J.P.Patra, Sc. – C, SWHD
   b. Project Co-Investigator: Dr. Rakesh Kumar, Sc. – G & Head SWHD
      Pankaj Mani, Sc – E, CFMS Patna
      Sanjay Kumar, Sc– E, SWHD'

3. **Title of the Project**
   Development of regional methods for design flood estimation in Uttarakhand.

4. **Objectives**

   a. Development of at-site flood frequency relationships using L-moments.
   b. Development of at-site and regional flood frequency relationships using L-moments.
   c. Development of regional relationships between mean annual peak floods and physiographic and climatic characteristics.
   d. Development of at-site rainfall frequency relationships using L-moments using point rainfall data.
   e. Development of at-site and regional rainfall frequency relationships using L-moments using gridded rainfall data of various sources.
   f. Development of regional relationships for the Nash and Clark IUH model parameters.
   g. Estimation of floods of various return periods for Ganga basin in Uttarakhand.

5. **Present state-of-art**

The commonly used design floods estimation approaches can be categorized as: flood formulae, flood frequency analysis and hydrometeorological approach (CWC, 2010). Various empirical flood formulae have been developed for regions. These include Dicken's, Ryve's, Nawab Jung Bahadur, W P Creager's, Jarvis f, Modified Myer's etc. When long term and short term rainfall and runoff records are not available the design flood is obtained using these formulae. However, the value obtained from these can only be used for preliminary estimates for small catchments and the concept of return period flood is generally not included in this approach. The flood frequency approach can be adopted in case data of peak floods series are available for a longer period of time. In, Indian generally Gumbel or Generalized Extreme Value (GEV) distributions are fitted to the peak flood series without considering other available frequency distributions. Further, there is a need to use better parameter estimation technique for estimation of parameter of candidate distribution. In India for many catchments, streamflow data are not available or the data are inadequate at the site of interest. In such cases the methods of frequency analysis using data from a single site have limited applicability because of large sampling errors, and as a result, regional flood frequency analysis is performed. The various commonly used methods of regional flood frequency analysis are: USGS method, Pooled curve method, analytical method and L-moments approach. Hosking and Wallis (1997) presented the L-Moments based regional frequency analysis approach. The authors mention that regional flood frequency analysis resolves the problem of short data records or unavailability of data by "trading space for time"; as the data from several sites are used in estimating flood frequencies at any site. Kumar et al. (2003, 2005, 2015) applied L-moments approach for development of regional flood frequency relationships for some of the regions of India. Komi et al. (2006) carried out regional frequency analysis based on L-moments and identified three homogeneous based on cluster analysis and a homogeneity test. Finally,

regression models of the mean annual flood with the size of the drainage area, mean basin slope and mean annual rainfall are proposed to enable flood frequency estimation of ungauged sites within the basin. Design flood estimates in the United Kingdom are routinely obtained by using the improved Flood Estimation Handbook (FEH) statistical procedure (Kjeldsen, 2015). The author assessed uncertainty of design flood estimates at ungauged catchments for a range of return periods. The results show that the inclusion of data from nearby gauged catchments increases the reliability of the estimates when compared to an automated application of the improved FEH methods relying on catchment descriptors only. Analysis of 190 storm events in seventeen small Northern Ireland catchments, along lines developed by the UK Institute of Hydrology, shows that the time-to-peak of the instantaneous unit hydrograph can be estimated from catchment characteristics and from the time between the centroid of mass of a flood-producing rainfall event and of the resulting peak flow, but that equations calibrated on British data overestimate the time-to-peak (Gardner and Wilcock, 2003). This might be due to the distinctive hydrology of Northern Ireland. Kumar et al. (2007) developed geomorphological instantaneous unit hydrograph (GIUH) based Clark and Nash models and applied for simulation of the direct surface run-off (DSRO) hydrographs for ten rainfall-runoff events of the Ajay catchment up to the Sarath gauging site of eastern India. The GIUH is derived from the geomorphological characteristics of a catchment and it is related to the parameters of the Clark instantaneous unit hydrograph (IUH) model as well as the Nash IUH model for deriving its complete shape. Inter comparison of the performances of the GIUH based Clark and Nash models shows that the DSRO hydrographs are estimated with comparable accuracy by both the models.

Over the year, efforts have been made toward regionalisation of catchment model parameters of various complexity and scale (Seibert, 2009; Merz and Blöschl, 2004; Littlewood, 2004; Heuvelmans et al., 2006; Bastola et al., 2008; Bárdossy and Singh, 2011; Beck et al, 2016). A comparison of regionalisation methods for catchment model parameters is provided by Parajka et al., (2005). Hydrologic model parameters obtained from regional regression equations are subject to uncertainty. Consequently, hydrologic model outputs based on the stochastic parameters are random. The uncertainty associated with linear reservoirs (N) and storage coefficient (K) of Nash's IUH are assessed by various researchers. The uncertainty from regional regression equations is some time too significant to be ignored (Yeh et al., 1997). The assumption of the parameter K having the same value in all reservoirs is obviously unphysical as it results in the estimated value of N not being integral (Li, et al. 2008). Seong et al. (2007) proposed a practical approach to determining a regionalized Clark instantaneous unit hydrograph (IUH) model in limited data availability condition. The proposed model is described in terms of the synthetic time–area concentration curve, the concentration time, and a special regional similarity value that is valid in the whole basin. By introducing the regional similarity value into a Clark IUH, a statistically best estimate of IUH for given data conditions and its quantified degree of uncertainty were realized. Application of the model to Wi River basin in Korea showed a reliable estimation of hydrograph within the study area even with limited data availability.

Considerable work has been done to estimate flood characteristics and long-term mean annual flow using regression relationships with catchment parameters in Indian, but most of these methods were developed a long time ago and may need to be revisited Jha and Smakhtin (2008). Goel (1998) presented the details of flood estimation procedures for Indian catchments in general and for mountainous watersheds in particular. The flood peak data of 11 small and medium catchments ranging from 6 km^2 to 2,072 km^2 in and around the sub-Himalayan Region (Zone 7) have been analyzed and flood frequency analysis for these streams has been carried out using methods based on L-moments. The Central Water Commission in association with the India Meteorological Department and Research Design and

Standard Organization unit of the Indian Railways have classified the country into 7 zones and 26 hydro-meteorologically homogeneous sub-zones, for each one of which flood estimation guidelines have been published. These reports contain ready to use chart and formulae for computing floods of 25, 50 and 100 year return period of ungauged basins in the respective regions.

The studies carried out for regional flood frequency estimation in India are limited to a few regions, scattered as well as they are mostly based on the various types of conventional techniques. The L-moments form basis of an elegant mathematical theory for carrying out regional frequency analysis and are being used by many organizations the worldwide. The L-moments are capable of characterising a wider range of distributions, compared to the conventional moments. There are comparison available, which demonstrates how the standard and weighted *Bulletin 17B* quantile estimators perform relative to alternative Log Pearson Type-III (LP3) quantile estimators that also make use of regional information.

6. Methodology

This study aims at development of at-site and regional flood frequency relationships using L-moments approach for Uttarakhand state (Figure 2). For estimation of T-year return period flood at a site, the estimate for mean annual peak flood is required. For gauged catchments, such estimates can be obtained based on the at-site mean of the annual maximum peak flood data. At-site and regional flood frequency analysis will be performed using the L-Moments approach, which includes various frequency distributions: viz. Extreme value (EV1), Generalized extreme value (GEV), Logistic (LOS), Generalized logistic (GLO), Normal (NOR), Generalized normal (GNO), Uniform (UNF), Pearson Type-III (PE3), Exponential (EXP), Generalized Pareto (GPA), Kappa (KAP), and five parameter Wakeby (WAK). Screening of the data, testing of regional homogeneity and identification of distribution will be carried out. However, for ungauged catchments at-site mean cannot be computed in absence of the flow data and in such a situation, a regional relationship between the mean annual peak flood of gauged catchments in the region and their pertinent physiographic and climatic characteristics is needed for estimation of the mean annual peak flood. For example, the form of this regional relationship may be:

$$\overline{Q} = a\, A^{b} S^{c} D^{d} R^{e}$$

Here, ($\overline{Q}$) is the mean annual peak flood, A is the catchment area, S is the slope, D is the drainage density, R is the annual normal rainfall or rainfall for the duration of annual maximum peak flood for the catchment etc., a, b, c, d, and e are the regional coefficients. Further, relationship of various other characteristics like length of main stream (L), centroidal longest flow path (L_c) etc. with peak flood will also be evaluated. The regional coefficients will be estimated using the mean annual peak floods of the gauged catchments and their pertinent physiographic and climatic characteristics for a region. The physiographic and climatic characteristics which are considered pertinent for generation of annual maximum peak floods from a catchment and can be obtained from the observed records e.g. rainfall for the duration of occurrence of the annual maximum peak floods and derived from the toposheets/maps of the gauged catchments may be considered for development of this relationship.

The lengths of historical data records are very less, particularly in hilly areas. Considering this aspect frequency analysis using L-moments will be carried out using gridded rainfall data of various sources (IMD, APHRODITE) and will be compared. Regional Nash and Clark IUH models will be developed for Uttarakhand. Floods of various return periods for selected locations of Ganga basin in Uttarakhand will be estimated.

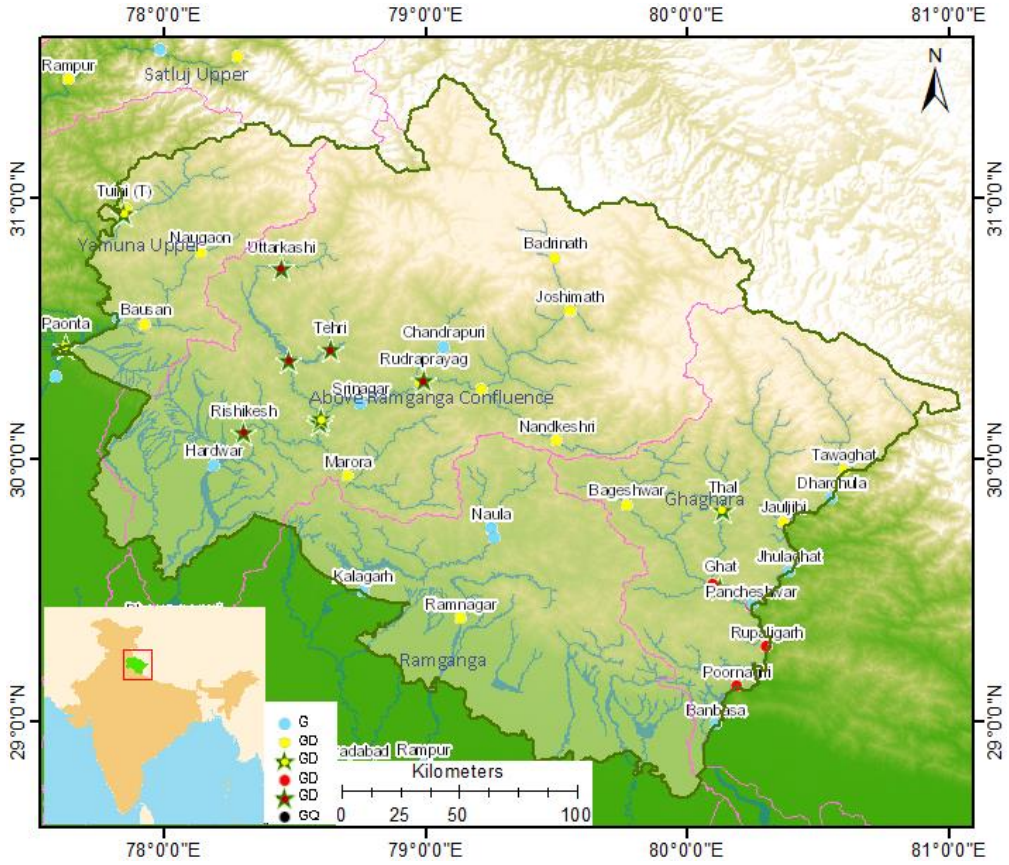


Figure 1: Index map of the study area.

7. Research outcome of the project

- Isopluvial maps of various return periods (Viz. 10 year, 25 year, 50 year, 100 year) for Uttarakhand.
- Assessment of usefulness and limitation of gridded rainfall data for estimation of rainfall for various return periods.
- Development of relationships between mean peak floods of various return periods with catchment characteristics.
- Research papers and reports.

8. Cost estimates

a. Total cost of the project: ₹ 15,07,200
b. Source of funding: PDS (NHP)/ Internal
c. Sub Head wise abstract of the cost

S. No.	Head	Amount (Rs.)
1	Remuneration/Emoluments for Manpower	24,55,200
2	Travelling Expenditure	3,36,000
3	Infrastructure/Equipment	7,75,000
4	Experimental Charges/Field	1,00,000
5	Capacity building/Technology transfer	3,00,000
6	Contingency	50,000
	Total	**40,16,200**

d. Justification for Sub-head-wise abstract of the cost
Remuneration/Emoluments for Manpower: The project proposal involves a wide variety of work elements viz. data collection, statistical analysis of data from various sources, GIS applications etc. Considering the work element

broadly in two different areas, one RA/SRF and one JRF/ Resources person is proposed.

Travel Expenditure: TA/DA is required for field visit to study area and various departments including CWC and MoWR R&GR for data collection and sharing of results etc. In addition, it is proposed to participate in various workshop/ seminar/ training etc. for sharing various findings of the study with stake holder and researchers..

Infrastructure/Equipment: It is proposed to purchase one workstation to carry out simulations etc. and two desktop computers for two project staffs. Basic furniture like computer table, chair, storage/book case etc. are also required. Data like rainfall, discharge are required for this study.

Experimental charges/ Data: Miscellaneous charges include cost towards purchase of stationary, printing charges, books/scientific materials, pen drive, external hard disk etc. and for meeting expenses of other unforeseen needs of the project.

9. **Work Schedule:**

a. Probable date of commencement of the project: April 2017
b. Duration of the project: 3 Years
c. Stages of work and milestone:

S.N.	Work Element	1st Year	2nd Year	3rd Year
19	Collection of hydro meteorological data, satellite images, thematic maps etc.			
20	Compilation, statistical analysis of rainfall and river discharge			
21	At-site frequency analysis for point rainfall and gridded rainfall data			
22	Regional frequency analysis for point rainfall and gridded rainfall data			
23	Preparation of isopluvials maps for various return periods.			
24	At-site and regional flood frequency analysis for gauged catchments			
25	Estimation of catchment characteristics and parameters of UH			
26	Development of regional relationships for peak floods with catchment characteristics.			
27	Workshop/ Training			
28	Report			

Work Program for the Year 2017-18

S.No. & Ref. Code	Title	Study Team	Duration
ONGOING STUDIES			
1. NIH/SWHD/NIH/16-17	Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data	Sushil K. Singh	1 year (April 2016 to September 2017)
2. NIH/SWHD/NIH/16-19	Application and development of analytical models on data collected at NIH under Saph-Pani Project	Sushil K. Singh	3 years (April 2016 to March 2019)
3. NIH/SWHD/NIH/14-17	Study of Rainfall Patterns and Comparison of Rainfall Data from different Sources for Uttarakhand State	Archana Sarkar Vaibhav Garg Rakesh Kumar N.K. Bhatnagar	3 years (April 2014 to Sept. 2017)
4. NIH/SWHD/NIH/15-18	Snowmelt Runoff Modelling and Study of the Impact of Climate Change in Sharda River Basin	Achana Sarkar T. Thomas Vaibhav Garg	3 years (April 2015 to March 2018)
5. NIH/SWHD/NIH/14-17	Monitoring and modelling of streamflow for the Gangotri Glacier	Manohar Arora Rakesh Kumar	4years (May 2014 to March 2018)
6. NIH/SWD/NIH/14-17	Effect of Changing Global Tropospheric Temperature on Asia-Pacific Monsoon Circulation and Rainfall Fields across India	Ashwini Ranade	3 years (Oct. 2014 to Oct 2017)
7. NIH/SWHD/NIH/15-18	Study on effect of climate change on sediment yield to Pong reservoir	A. R. Senthil Kumar J. V. Tyagi Avinash Agarwal Suhas Khobragade Manohar Arora	3 years (April 2015 to March 2018)
8. NIH/SWHD/NIH/14-17	Effect of climate change on evaporation at point scale	Digambar Singh A. R. Senthil kumar Manohar Arora	3years (June 2014 to Oct 2017)
9. NIH/SWHD/NIH/15-18	Flood and Sediment studies in Himalayan basin using MIKE-11 Model	A.K. Lohani	3 years (April 2015 to March 2018)
10. NIH/SWD/NIH/16-18	Snow cover variability in the Upper Yamnotri Basin	Naresh Kumar Manohar Arora Rakesh Kumar	2 years (April 2016 to June 2018)
NEW STUDIES			
11. NIH/SWHD/NIH/17-18	Development and regionalization of unit hydrograph for runoff modeling on Indian catchments	S.K. Singh	1 year (April 2017 to March 2018)
12. NIH/SWHD/NIH/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakeh Kumar J. P Patra Pankaj Mani	4 years (April 2017 to March 2021)

13. NIH/SWHD/NIH/17-20	An integrated assessment of a middle Himalayan watershed for sustainability of its water resources	A. R. Senthil Kumar Manohar Arora Digambar Singh M S Rao R K Nema Pradeep Kumar S K Mishra	3 years (April 2017 to March 2020)
14. NIH/SWHD/NIH/17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P.Patra Rakesh Kumar Pankaj Mani Sanjay KumarPan	3 years (April 2017 to March 2020)

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. S K Jain	Scientist G & Head
2	Dr. Sanjay K Jain	Scientist G
3	Dr. M K Goel	Scientist G
4	Mrs. Deepa Chalisgaonkar	Scientist F
5	Er. D S Rathore	Scientist F
6	Dr. Renoj Thayyen	Scientist D
7	Sri L N Thakural	Scientist C
8	Sri. Manish Nema	Scientist C
9	Dr. P K Singh	Scientist C
10	Sri P K Mishra	Scientist B
11	Sri P K Agarwal	Scientist B
12	Sri Yatvear Singh	PRA

WORK PROGRAMME FOR THE YEAR 2017-2018

SN	Title	Study Team	Duration	Funding (Rs. in Lakhs)
Completed Sponsored/ Internal Studies				
1.	Glacier change and glacier runoff variation in the upper Satluj river basin	Sanjay K. Jain Sharad K. Jain Renoj J. Thayyen	2.5 years (10/13-03/16)	NIH (12)
Ongoing Internal Studies				
1.	NIH_Basin – A WINDOWS based model for water resources assessment in a river basin	M. K. Goel Sharad K. Jain Deepa Chalisgaonkar P. K. Mishra	3 years (04/13-12/17)	NIH (16)
2.	Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh	Renoj J. Thayyen S. P. Rai Sanjay K Jain Sudhir Kumar	3 years (04/14-03/18)	NIH (48)
3.	Hydrologic Modelling of a part of Satluj Basin using SWAT Model	P. K. Agarwal Sharad K. Jain M. K. Goel Sanjay K. Jain M. K. Nema	2 -3/4 years (06/14-03/18)	NIH (23)
4.	Decision Support System for Water Resources Planning in Upper Bhima basin, Maharashtra	D. S. Rathore M. K. Goel R.P. Pandey Sanjay Kumar Surjeet Singh	2 years (07/14-12/17)	NIH (34)
5.	Modeling of Narmada basin by using the GWAVA model	T. Thomas (RC-Bhopal) P. K. Mishra M. K. Nema Sanjay K. Jain Sharad K. Jain P. K. Agarwal	2.25 years (12/14-03/18)	NIH
6.	Runoff modeling of Shyok River, Karakorum Range	Renoj J.Thayyen Sanjay K.Jain	3 years (12/14-12/17)	NIH (38)
7.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain Sanjay K. Jain Renoj J.Thayyen P. K. Mishra P. K. Agarwal	5 Years (12/14-12/19)	NIH+
8.	Development of Ganga Information Portal	Deepa Chalisgaonkar Sharad K. Jain D. S. Rathore Sanjay K. Jain Sudhir Kumar P. K. Mishra P. K. Agarwal M. K. Nema	3 years (04/15-03/18)	MoWR (65.55)
9.	Study of hydrological changes in selected watersheds in view of climate change in India.	L. N. Thakural D. S. Rathore Surjeet Singh Sanjay K. Jain Sharad K. Jain	3 years (04/15-03/18)	MoWR (44.30)

Ongoing Sponsored Studies				
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	R.J. Thayyen Farooq Azam P.G. Jose A.P. Dimri	3 years (03/16-02/19)	SERB (65.14)
2.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel et al.	5 years (01/16-12/20)	DST (52.15)
3.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore et al.	5 years (01/16-12/20)	DST (48.83)
4.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain et al.	5 years (01/16-12/20)	DST (36.79)
5.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	Renoj J.Thayyen et al. (NIH) & Dimri et al. (JNU)	5 years (01/16-12/20)	DST 51.43 (NIH) + 28.29 (JNU)
6.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	Sharad K. Jain et al.	5 years (01/16-12/20)	DST (54.07)
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra et al.	5 years (01/16-12/20)	DST (90.99)
New Sponsored Study for the year 2017-2018				
1.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya	Renoj J.Thayyen et al.	3 years 2016-2018	MoEF (58.76)
2.	Suspended sediment dynamics and sediment potential assessment in parts of Upper Ganga Basin (UGB) of Lesser Himalayan region through modeling techniques	Pushpendra K. Singh Sharad K. Jain Sanjay K. Jain M. K. Goel Renoj. Thayyen Suman Gurjar M. K. Nema	3 years 2017-2020	NHP (51.51)
3.	Hydrological monitoring and Modelling of a Himalayan Basin	L. N. Thakural Sanjay K. Jain D. S. Rathore A. K. Lohan Renoj J Thayyen C. K. Jain S. P. Rai M. K. Sharma	4 years 2017-2021	NHP (76.63)
4.	Investigating water stress using hydro-meteorological and remote sensing data	D. S. Rathore L. N. Thakural Sanjay Kumar B. Venkatesh M.K. Jose	3 years 2017-2020	NHP

		T. Chandramohan		
OTHER SCIENTIFIC ENGAGEMENTS				
1.	Strategic basin planning for Ganga River basin in India	Sharad K. Jain M. K. Goel L. N. Thakural	-	MoWR, RD&GR
2.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)	Sanjay K. Jain et al.	-	NERC-MoES
3.	Water resources status and availability of north west Himalayas	Sanjay K. Jain et al.	-	IIRS

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2017/01

1. Thrust Area under XII five year Plan: Integrated Water Resources Development & Management

2. Project team:

a. Project Investigator:	Dr. M. K. Goel, Sc. "G"
b. Project Co-Investigator(s):	Dr. Sharad K. Jain, Sc. "G"
	Smt. D. Chalisgaonkar, Sc. "F"
	Dr. P. K. Mishra, Sc. "B"
3. Title of the Project	NIH_Basin – A WINDOWS based model for water resource assessment in a river basin

4. Objectives

Envisaged objective of the study is to develop a WINDOWS interface (named as NIH_Basin – NIH_Basin-Simulation) of a model developed for assessment of water resources in a river basin for easy application by the user groups. It is also proposed to carry out a number of modifications in the model (developed in earlier study) for comprehensive analysis of water resources at basin scale.

5. Methodology

Model is planned to work in two modes: a) monthly mode (in which the simulation is carried out at daily time step for a month and then the spatial recharge and discharge pattern are externally used to find the revised water table in the basin with some groundwater simulation model, say Visual MODFLOW, and the revised groundwater table is used for the subsequent month), and b) continuous mode (in which the simulation is carried out at daily time step for the complete period for which hydro-meteorological data are available). In the second mode, grid-wise pumping and recharge estimations are accumulated over each sub-basin and then divided by the S_y of sub-basin to convert water withdrawal/ recharge to corresponding change in groundwater level which can be applied to initial groundwater surface to find the revised surface in the sub-basin, thus avoiding the necessity of detailed groundwater simulation.

In WINDOWS interface of the model, various data input forms are being developed. Four important modules of the software include:

a) Database preparation
b) GIS analysis
c) Model execution
d) Analysis of results

The "Database Preparation" module is planned to include forms for the entry of attribute and temporal data of hydrological variables and model parameters. In the "GIS Analysis" module, it is planned to link the free domain GIS (ILWIS system) for creating and processing geo-spatial data. This module will also contain provisions for converting raster data to ASCII format. In the "Model Execution" module, various sub-models which are run for aggregating spatial information will be provided. In addition, the main Basin model will also be provided in this module. In the "Analysis of Results" module, provision will be made to view spatial and hydrological results of the model.

6. Research outcome from the project

Research outcome from the project is a WINDOWS based spatially distributed river basin planning and management model for integrated water resources assessment and

management at basin scale. The study can help water resources departments and river basin authorities in the analysis at river basin scale. It can also help in assessing the impact of various natural and anthropogenic activities on various components of the hydrological cycle at basin scale.

7. Cost estimate

Total cost of the project (initially assessed at Rs. 16.00 Lakh) includes mainly the salary of the Scientists. Though the WINDOWS based program is being developed with in-house capability of NIH scientists, it was planned to reserve an amount of Rs.1.00 Lakh for professional enhancement and modifications of the software.

8. Present Progress

A number of modifications (not envisaged at the time of project conceptualization) have been made (with the continuous experience gained from on-going studies) in the model methodology and the source code for making it more practicable and realistic. Some of these modifications include:

a) GW potential factors specified for two conditions – Temporal (GWPFT) which depends on increase in GW development with time and Position of current average GW table in a sub-basin (in-between maximum and minimum levels). Every day, av. GW depth is computed in each sub-basin and revised GW potential is estimated.
b) Consideration of known population of some important cities for computing urban water supply demand.
c) Diversion of urban water supply from river segments.
d) Outlet from hydropower to join a stream segment (immediate downstream or some other river segment or go outside of the basin).
e) For the conditions when there is no crop on a grid and next season crop is yet to be planted, a land use (say, barren land) can be specified.

Most of these modification have been made in the computer code, being developed in FORTRAN language. First the computer program is being finalized with all modifications and subsequently, the WINDOWS based forms for database preparation would be developed. For past some time, considerable efforts were made in the completion of another field project related to large system water availability analysis and integrated operation of structures. The program development under this project is nearing completion but interface development needs considerable time. It is suggested to increase the time period of this study by 9 months.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/02

1. **Thrust Area** **:** Himalayan Cryosphere and Climate Change
2. **Project team** **:** Dr. R.J. Thayyen, Dr.S.P. Rai, Dr**.** Sanjay Jain, Dr. Sudhir Kumar
3. **Title of the project** **:** Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh.
4. **Objective**
   1. To improve the understanding of the climate forcing on cold-arid cryospheric system and hydrology.
   2. To improve the understanding of the melt water generation process and the role of permafrost.
   3. To study the temporal variations in isotopic characteristics of winter base flow and summer flow of the perennial reach and its cryospheric linkages.
5. **Methodology**
   a) Monitoring of weather parameters by AWS at 3500 m a.s.l., 4700 m a.s.l. and 5600 m a.s.l. for studying the orographic forcing
   b) Monitoring discharge and Electrical conductivity at 4700 m a.s.l & 3500 m a.s.l.
   c) Measuring ground temperature for permafrost studies
   d) Geophysical investigation of potential permafrost zones
   e) Isotope studies of stream discharge at 4700 m a.s.l. and 3500 m a.s.l.
   f) Runoff modeling by SNOWMOD by incorporating the new SELR concept
6. **Research Outcome from the Project:** The project is aimed at quantifying various hydrological components in the catchment and its seasonal responses. Better understanding of the lean season winter outflow from the groundwater system is intended to bridge the critical knowledge gap of the mountain groundwater resources and its linkages with the surface water. Understanding of the orographic processes and mountain climate at the nival/ glacier systems to decipher the climate change impact on the cold-arid cryospheric system better.
7. **Cost estimate:**
   a. Total cost of the project: 48 lakhs
   b. Source of funding: NIH
   c. Sub Head-wise abstract of the cost

S. No.	Sub-head		Amount (in Rupees)
	Salary	Sr. Project Officer	800000
2.	Travelling Expenditure		500000
3.	Infrastructure / Equipment / Data		2500000
4.	Experimental charges		500000
5.	Misc. expenditure		500000
	Grand Total:		48,00,000

8. **Work Schedule**

S. No.	Work Element	First Year				Second Year				Third Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

1.	Monitoring weather											
2.	Monitoring Q											
3.	Permafrost temp.											
4.	Geophysics -permafrost											
5.	Isotope studies											

9. Analysis and results

Discharge and electrical conductivity measurements at 4700 m a.s.l. were carried out during the summer period (May to September 2016). The Monitoring of weather at 3700 and 4700 m a.s.l. continued during the project period also. 25 ground temperature sensors were purchased and installed at 09 plots in the catchment from 4700 to 5600 m a.s.l. in August 2016. These ground temperature sensors are going to provide critical information on ground thermal regime and freeze thaw cycle leading to ground ice melt processes in the catchment. Ground temperatures of two months were downloaded and studies during the reporting period. Three locations showed lower ground temperature than the air temperature during August – September period. Runoff peak from seasonal snowmelt occurred in June and was systematic low discharges prevailed during the rest of the summer season indicating ground ice melt contribution. Surface energy balance at 4700 m a.s.l. is also estimated during the observation period. Slope Lapse rate of Air temperature (SELR) has been calculated during the study period between various stations in the catchment and that of Leh (3500 m a.s.l.) data from Air Force which showed consistent high lapse rate >9.8 K/km in the region.

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2016/03

1. Thrust Area under XII five year plan: Integrated water resources management/ watershed hydrology

2. Project team:

a. Project Investigator: Shri P. K. Agarwal, Sc B

b. Project Co-Investigator(s): Dr. Sanjay K. Jain, Sc G
Dr. Sharad K. Jain, Sc G
Dr. M. K. Goel, Sc G
Shri M. K. Nema, Sc C

3. Title of the Project: Hydrological modeling of a part of Satluj basin using SWAT Model

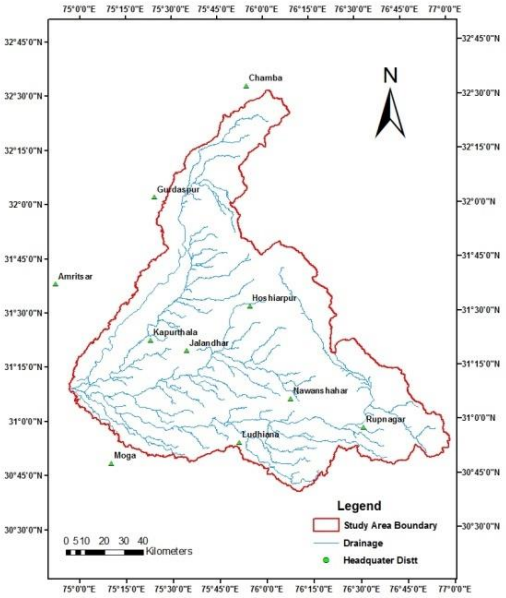
4. Objectives:

i. To develop the data base of a part of Satluj river basin (between Ropar D/s of Bhakra dam to Harike) and

ii. To carry out hydrological modeling of the basin using ArcSWAT model to find out water balance components, e.g. actual evapo-transpiration etc.

5. Methodology

Study Area selected Satluj river basin (between Ropar D/s of Bhakra dam to Harike) as given figure:



In the present study, the following methodology will be adopted:

- Data base preparation in ArcGIS (DEM, Land use, soil map)
- Collection of meteorological data (rainfall, temperature, wind, solar radiation, humidity)
- Setup, calibration and validation of SWAT model
- To understand the effect of land use & other changes on stream flows.

6. Research Outcome from the Project

Water balance components (runoff, evaporation, base flow, etc.) for the basin.

7. Cost Estimate:

a. Total cost of the Project: Rs. 23.00 lakhs

b. Sources of Funding: NIH

c. Sub head wise Abstract of Cost

S N	Sub Head	Amount (in Rupees)
1.	Salary	Rs. 15,00,000.00
2.	Travelling Expenditure	Rs. 3,00,000.00
3.	Infrastructure/Equipment/Data	Rs. 3,00,000.00
4.	Experimental Charges	-
5.	Misc. Expenditure	Rs. 2,00,000.00
	Total	Rs. 23,00,000.00

8. Quarterly Break up of cost estimate for each year

Year: 2015-16

Sl. No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	Salary	150000.00	150000.00	150000.00	150000.00
2.	Travelling expenditure	40000.00	40000.00	40000.00	40000.00
3.	Infrastructure/Equipment	40000.00	40000.00	40000.00	40000.00
4.	Experimental charges	NIL	NIL	NIL	NIL
5.	Misc. expenditure	20000.00	20000.00	20000.00	20000.00
	Sub- Total:	250000.00	250000.00	250000.00	250000.00
	Grand Total	Rs. 10,00,000.00			

9. Work Schedule

a. Date of commencement of work June 2014

b. Duration of Work 2-3/4 Years

c. Stage of work and Milestone

SN	Work Element	First Year (2014-15)			Second Year (2015-16)				Third Year (2016-17)			
		Jun-Sep	Oct-Dec	Jan-mar	April-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jen	Jul-Sep	Oct-Dec	Jan-Mar
1	Literature Review & Data Collection	■	■	■								
2	Development of data base for a river basin for SWAT model		■	■	■							
3	Application of SWAT model				■	■	■	■				
4	Analysis of Results							■	■	■		
5	Preparation of Report									■	■	■

10. Progress made

- From the meteorological data downloaded earlier, input weather data for the model has been prepared.
- The outflow at Bhakra and Pong dam is available. For simulation of the model, discharge data at Harike barrage is required. For discharge data at Harike, Chief Engineer, Irrigation Department, Punjab was contacted and discharge data for 2011-15 have been obtained. However, for the simulation of the model, data for the period of 1995-2010 is required, which is not available in digital form. After that calibration & validation of the model will be carried out.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/04

1. **Thrust Area under XII five year Plan**: Integrated Water Resources Development and Management
2. **Project team**:
   a. **Project Investigator**: D.S. Rathore, Sc F
   b. **Project Co-Investigator(s)**: M.K. Goel, Sc G
      R.P. Pandey, Sc F
      Sanjay Kumar, Sc D
      Surjeet Singh, Sc D
3. **Title of the Project**: Decision support system for water resources planning in Upper Bhima basin, Maharashtra
4. **Objectives**:
   a. Rainfall- runoff modeling and estimation of water availability in the basin
   b. Multi-reservoir operation in the basin for project complexes
   c. Drought prediction
   d. Water quality modeling in the basin
   e. Conjunctive use operation in command area
   f. Rainfall- runoff modeling and river basin simulation for climatic change scenarios
5. **Present state-of-art**

   A Decision Support System (Planning) has been developed under Hydrology Project - II for State and Central implementing agencies. The project has two components, namely DSS platform and modelling systems. For modelling system, MIKE HYDRO Basin model was chosen. This is a water allocation model which also has conceptual lumped rainfall- runoff model NAM in built for generation of long term runoff time series. The platform has GIS, spreadsheet, scenario, script, time series and dashboard (for web applications) managers. On the platform, data and model scenarios may be handled. The scenarios are run with available MIKE HYDRO Basin engine.
6. **Methodology**

   MIKE HYDRO Basin is being used and database for the Upper Bhima basin up to Ujjani dam developed in HP-II project will be transferred to the new system. Rainfall- runoff modelling will be done using NAM for finding different hydrological components at sub-basins scale. Rule curves would be developed for various project complexes and multi reservoir operation would be carried out to optimize the water use in the basin. Meteorological and hydrological drought indices would be computed using rainfall and hydrological data. Conjunctive use scenario in canal command areas will be run. River water quality modelling will be carried out. Web-interfaces through Dashboards would be developed for dissemination of input and results of simulation in DSS (Planning). Downscaling will be done for climatic scenario. Downscaled climate data will be utilized and model runs would be taken to find their impact on the water availability and allocation in the basin.
7. **Research outcome from the project**
   a. Water availability in various sub-basins in present and changed future climate.
   b. Reservoir operation rules for existing and future climatic scenarios: Model was set up for reservoir operation and optimization in Khadakwasla complex.

c. Meteorological and hydrological drought indices: Data preparation was done for computing meteorological drought indices.
d. Conjunctive use in canal command areas.
e. River water quality modeling in river reaches and impact of climate change: Water quality model was set up.
f. Interfaces for decision support.

8. Location map/ study area

Upper Bhima basin up to Ujjani in Maharashtra state

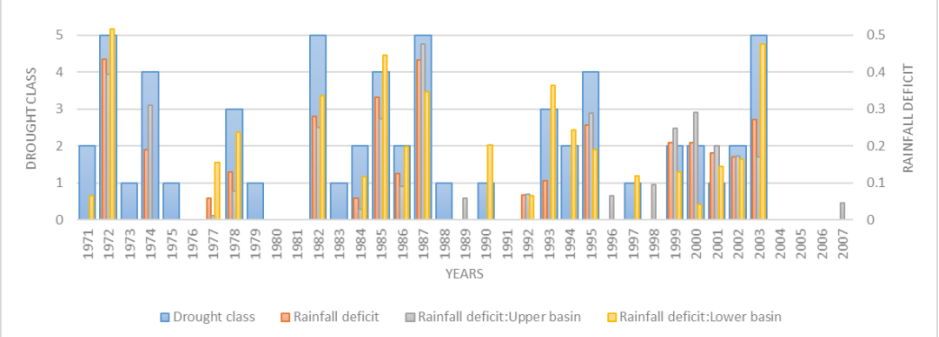
9. Approved action plan and time line

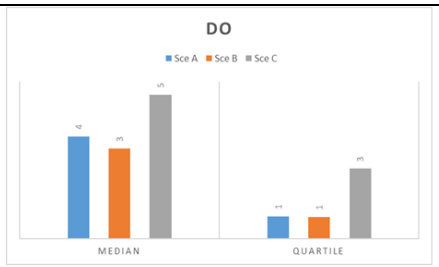
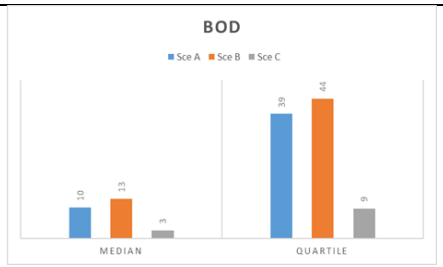
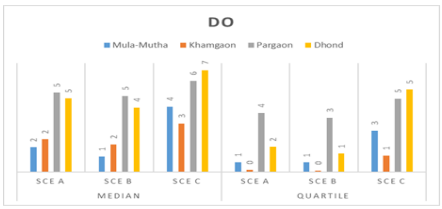
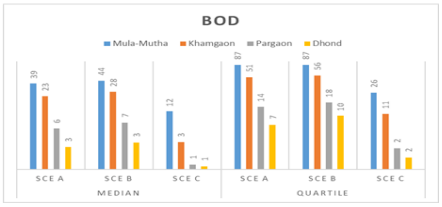
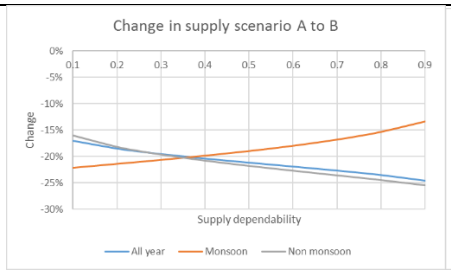
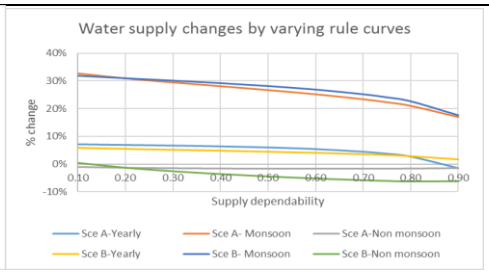
S. No.	Work Element	2014-15			2015-16			
		II	III	IV	I	II	III	IV
1	Data collection							
2	Rainfall- runoff modeling							
3	River basin modeling							
4	Drought indices							
5	conjunctive use							
6	River water quality modeling							
7	Interfaces for decision support							
8	Climatic change scenarios							
9	First Interim Report							
10	Final Report							

10. Recommendations / suggestions in previous WG

It was recommended to investigate drought in 2016 in the basin.

11. Achievements

Year	Objectives	Achievements
2016-17	Drought study	 Regional drought was investigated for the basin by combining drought classes from drought magnitude and seasonal SPI for period 1971-2007. Percent regional rainfall deficit is also shown in Figure. Drought class of higher severity were resulted for historical droughts.

2016 -17	Water quality modeling	    Scenarios of historical inflows (A), 20% reduction in inflows (B) and increased STP capacity to 90% organic pollutant load (C) were investigated. Mula- Bhima reach. Over all and stations water quality are shown in Figure. Water quality deterioration is observed in scenario B and improvement in scenario C.
2016 -17	Reservoir operation	  Two scenarios of historical inflows and 20% reduction in inflows were investigated for cases of low and high monsoon demands. By changing rule curves in two cases, it was possible to increase releases at various dependability in monsoon and yearly period by increasing monsoon demand.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/05

1. Thrust Area under XII five year plan: Hydrology for sustainability of water resources

2. Project team:

a. Project Investigator:

b. Project Co-Investigator(s): Dr. T. Thomas, Sc D
Dr. P K Mishra, Sc B
Er. Manish Nema, Sc C
Er. P.K. Agarwal, Sc B
Dr. Sanjay K. Jain, Sc G
Dr. Sharad K. Jain, Sc G

3. Title of the Project: Modelling of Narmada Basin Using GWAVA Model

4. Objectives:

A major goal of the proposed study is to do hydrologic modeling of the basin. The objectives of the proposed study are as follows:

- Collection and processing of historical data
- Future climate projections will be applied to see the changes in meteorological variables.
- Modelling of rainfall runoff.
- Impact of changes on stream flow in the basin.

5. Present state-of-art

Accurate water resources assessment and re-assessment is need of the hour in view of the altered water demand and utilization scenario world-wide. This requires robust hydrological model to accurately assess the water availability at present and in the future. Narmada basin is one of the highly regulated basins in India. Several water resources projects are being implemented, under construction and proposed in the basin. Since last few decades, urbanization and population growth has also driven additional water requirement in the basin. This requires revisiting water resources assessment in the Narmada basin.

6. Methodology

Study area: Narmada basin up to Hoshangabad including Tawa basin (D/s of confluence with Tawa)

GWAVA is a hydrological model which incorporates additional water resource components such as reservoirs, abstractions, and water transfers that modify water quantity and flow regime. It was developed with funding from DFID (UK Department for International Development). The model typically operates on 0.5 or 0.1 degree latitude-longitude grid. The choice of grid size is a compromise between that needed to represent spatial variability and the availability of suitable data. The model outputs include simulated monthly flows and a cell-by-cell comparison of water availability. GWAVA can be used to examine scenarios of change, both for climate and water demands.

Inputs for first tier GWAVA application

- Spatially and temporally explicit inputs
    - Rainfall, temperature (at least daily resolution)
    - Potential evapotranspiration or wind speed + relative humidity + solar radiation (at least daily resolution)

    - If the modelled area does not include some upstream areas: River discharges into the modelled area
- Spatially explicit inputs
    - Elevation or flow direction grid
    - Coverage by different irrigated crop types
    - Map of rivers and other water bodies
    - Soil texture and land cover
    - Lake, reservoir and wetland parameters (areal cover, maximum water volume, vertical shape, type of reservoir)
    - Urban and rural water demand per capita, Industrial water demand
    - Rural population and total population, Cattle, sheep and goat population
- Temporally explicit inputs
    - Gauged river discharge
- Parameters (constants)
    - Per capita water demand for sheep, goats, and cattle
    - Irrigation efficiency
    - % Leakage from urban and rural water supply systems
    - % return flow
    - Crop characteristics and growth stage durations for individual irrigated crop types, and the start and end of their growing season

Once the database data base of the study area(s) is collected and/or procured, model set up will be done. Then model will be calibrated and validated before going for sensitivity analysis.

7. Research Outcome from the Project

- Stream flow from the study area
- Water balance components (runoff, evaporation, lateral flow etc) for the sub-basin.

8. Work Schedule

a. Date of commencement of work — November 2014
b. Duration of Work — 2-3/4 Years
c. Stage of work and Milestone

1st. Interim report	**2nd. Interim report**	**Final report**
April 2015	April 2016	March 2017

9. Progress

The hydro-meteorological data for the study area have been procured from India Meteorological Department, Pune, and the hydrological data have been obtained from Central Water Commission, Bhopal. The model has been setup for the study area at a finer resolution of 0.125^o x 0.125^o. All the mandatory input data layers including land use/land cover, soil type, population density map, livestock density map etc. have been completed. The information from these layers have been extracted for each of the 0.125^o x 0.125^o grid and converted to the ascii format to be used as data input for running the source codes in FORTRAN pertaining to pre-processor, GWAVA engine and post-processor. Similarly, the SRTM Digital Elevation Model (DEM) with 90 m resolution has been used to extract the topographic information for each of the 0.125^o x 0.125^o grid and converted to ASCII format. The season-wise cropping pattern has also been prepared and the information for each of the 0.125^o x 0.125^o grid extracted and converted to ASCII format.

The normal run of the model (without calibration) has been carried out successfully. During this process, the bugs in the pre-processor as well as GWAVA engine were rectified and new EXE versions of these were used to have the normal runs. The major issue due to which the codes had to be modified pertained to the computation of total flows and local flows in the grid cells which was erroneous. After completion of the normal run of the model, efforts were made to calibrate the model manually by the trial and error approach, to have an idea of the range of the various sensitive parameters. The multisite calibration approach has been attempted with discharges available at Manot, Mohgaon and Hoshangabad. However due to many other issues and errors, the calibration was initially confined to Manot gauging site, so that once all the issues are sorted out for a single-site calibration, the same approach can be extended for the calibration using the discharge data available at Mohgaon and Hoshangabad as well. Presently the calibration is carried out up to Manot gauging site, but the issue of the observed data being overwritten by simulated data still persists, when the simulation period is more than two years. There has been regular interaction with the GWAVA modelling team at CEH, but since last month two of the involved staff has left CEH, and CEH is trying for their replacements. Along with the issues pertaining to bugs in the software, the shortage of the manpower at CEH has delayed the progress of the study. Discussion were held with the senior team at CEH very recently, and it is expected that very soon the appropriate replacement of the CEH staff will be done after which the modelling exercise is expected to gain momentum. Therefore this study needs an extension of 12 months for finalizing the multi-site calibration and validation alongwith the application of the future climate change scenarios for the assessment of future stream flows and water availability in the basin.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/06

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
   Project Investigator: Dr. R.J Thayyen, Sci-D
   Project Co-Investigators: Dr. Sanjay Jain, Sci-G
3. **Title of the Project:** Runoff modelling of Shyok River, Karakorum Range
4. **Objectives:**
   1. To generate runoff data at Km 150 for BRO-HIMANK
   2. To develop a baseline runoff and meteorological data of Shyok basin
   3. Runoff modelling of Shyok River at KM 150 & Shyok village

5. **Methodology**
   1. Monitoring of weather parameters and discharge by AWS at Km 150 (5600 m a.s.l.) for generating climate data for runoff modeling.
   2. Generation of snow cover depletion curves through melt season
   3. Runoff modeling by SNOWMOD and Win SRM at this two stations

6. **Research Outcome from the project:** Discharge & Meteorological data, Research papers and project reports and better understanding of the Cryospheric response of the Karakorum mountains.

7. **Cost Estimate**

   Total cost of the project: Rs. 37.64 lakhs
   b. Source of funding: NIH
   c. Sub Headwise abstract of the cost

S. No.	Sub-head		Amount (in Lacs)
1.	Salary	Resource person @Rs.22,000/- pm	2.64
2.	Travelling & Fieldwork		3.0
3.	Permanent Equipments (AWS, AWLR etc)		28.0
4.	Contingency		3.0
5.	Misc. expenditure		1.0
	Grand Total:		37.64

8. **Work Schedule**

S. No.	Work Element	First Year				Second Year				Third Year			
1.	Monitoring weather												
2.	Monitoring Q												
4.	Runoff modeling												

9. **Analysis and result**

Runoff data of Shyok River is generated at discharge station set up at km 150 at Durbuk-DBO road. Water level monitoring is carried out upto 5 minutes interval. The data is downloaded in the month of September 2016 from the remote site and analysis of the data has been carrying out. Rating curve is generated by this data and cross section measurement of the discharge site and discharges for 2015 summer months is calculated.

Snow cover depletion curves of the basin for 2016 were generated and trend in the snow cover depletion is studied during the reporting period. Further runoff modeling studies are halted due to the non-availability of temperature data in the basin.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/07

1. **Thrust Area under XII five Year Plan**: Sustainable water systems management: Adaptation of hydro-system to climate change
2. **Project Team:**
   a. Project Investigator: Manish Kumar Nema, Scientist 'C'
   b. Project Co-Investigators: Dr. Sharad K. Jain, Scientist 'G'/ Head, WRSD,
      Dr. Sanjay K. Jain, Scientist 'G'
      Dr. Renoj J. Thayyen, Scientist 'D' and
      Dr. P. K. Mishra, Scientist 'B'
3. **Title of the Project:** Hydrological Processes and Characterization of Lesser Himalayan Catchments
4. **Objectives:**
   a. To establish an instrumentation and experimental setup to measure various hydrological and meteorological variables in a watershed in the upper Ganga basin within the state of Uttarakhand for better understanding of their behavior and to study the dynamic linkages between the two.
   b. Analysis and comparison of estimated Evapotranspiration (ET) by different methods like RS/SEBAL, FAO56 method and actual field measurements
   c. To study the various water balance components in the watershed

5. **Methodology**

(A) Study Area:

A Himalayan watershed of Hinval River up to Jijli in Upper Ganga basin (Uttarakhand) is proposed for the study. This study area is a paired watershed of two kinds. One of them is a forested catchment (undisturbed) and the other is an agricultural watershed with anthropogenic interventions including an urban habitat at Chamba (Uttarakhand). The geographical extent of the study area is from $30^0$17'N–$30^0$26'N latitude and $78^0$16'E–$78^0$25'E longitude. This area is a typical representative of a combination of lesser Himalayan hilly temperate climatic conditions with average annual rainfall range of 1200-1800 mm. The total area under study is about 120 km^2 (20 km^2 forested catchment and 100 km^2 the other one) with an elevation range of 999-2676 m. The location map of the watershed and their digital elevation model are given in the Figure 1. The stream in the forested sub-catchment is the source of drinking water for 87 nearby villages. A study of the topography and land use shows that the watershed is representative of the surrounding areas.

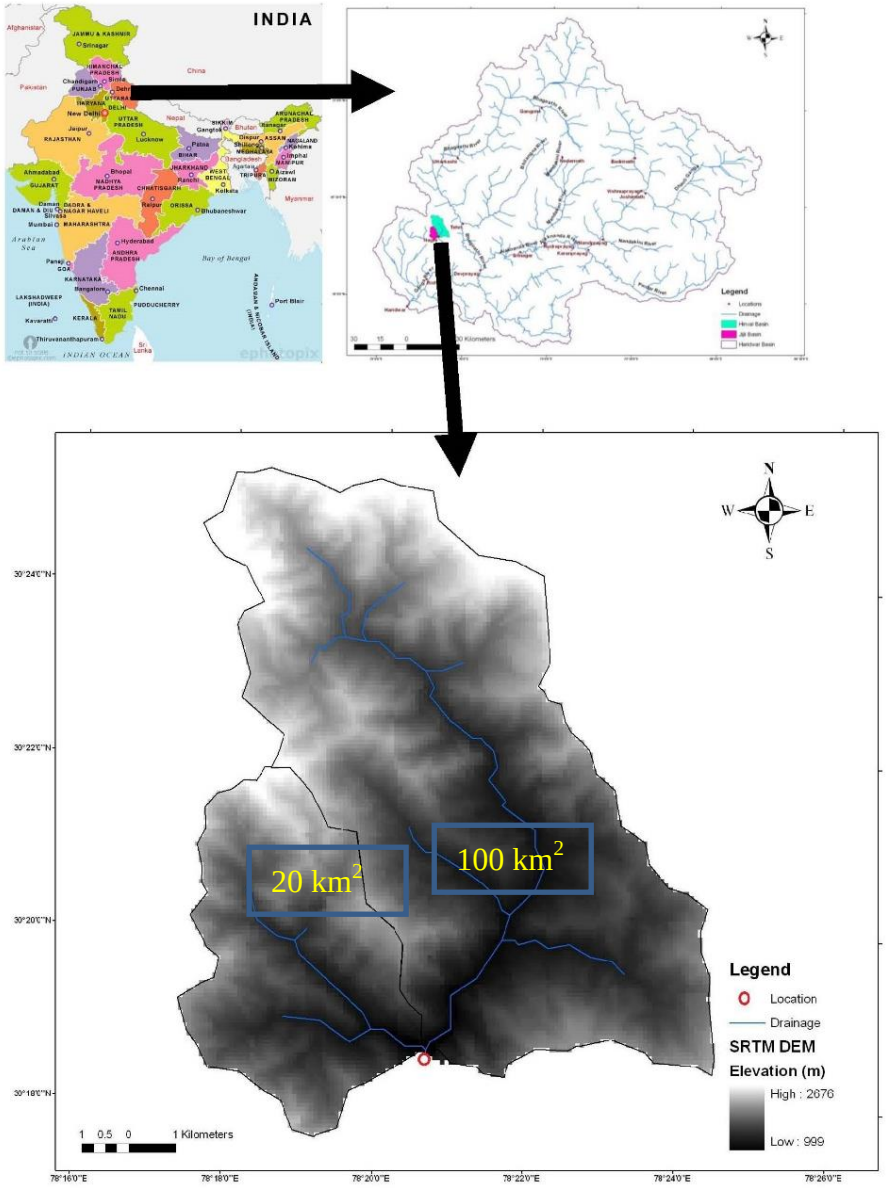


Fig. 1.0 Location of the Hinval watershed up to Jijli within India

(B) Experimental setup

Variables and parameters to be observed: organized in four categories, i.e., hydrological and ecological variables, atmospheric forcing variables, vegetation parameters, and soil parameters.

(C) Soil Heat Flux

Soil heat flux represents the amount of radiant energy absorbed or released at the soil surface during a given time period. Soil heat flux is a necessary input for many evaporation measurement and prediction techniques. One of the objectives of this study is to estimate soil heat flux using soil temperature collected at various soil depths. It is also intended to study the diurnal variation of soil heat flux in various seasons.

(D) Evapotranspiration (ET)

Accurate estimates of ET are needed for numerous agricultural and natural resource management tasks, hydrological modelling and to project changes in hydrological cycles

due to potential climate change. In the present study, the estimates of ET from various sources will be compared with the actual field observations.

(E) Soil Moisture

Soil moisture in the uppermost 1–2 m of the earth's surface is recognized as a key variable in many environmental studies, including those related to meteorology, hydrology, agriculture and climate change. An understanding of the soil moisture variability is necessary to characterize the linkages between a region's hydrology, ecology and physiography (Jackson, 1993). The proposed objectives under this theme are to understand spatio-temporal variability of soil water potential and soil moisture content under different land covers in the temperate lesser Himalayan region and to evaluate differences, if any in spatial and temporal patterns of soil moisture content as influenced by nature of land cover. We propose to establish sampling points for measuring the soil moisture content under different land covers in selected watersheds, spread spatially to cover topographic highs and lows. Soil matric potential measurements are proposed using resistance-type probes. At each sampling point, probes will be installed at different depths. A roving instrument (handheld read-out unit) shall be used to record matric potential (kPa).

(F) Hydrologic Modelling

It is planned to apply distributed models such as the Soil and Water Assessment Tool (SWAT) and VIC Models

6. Research Outcome from the project:

Development of a world class field hydrological laboratory in the lesser Himalaya. Development of better understanding of monsoon forcing on regional hydrology under changing climate for the end users/beneficiaries from the relevant Sectors. Research Papers and Reports.

7. Cost estimates:

a. Total cost of the project: Rs. 90, 55, 000. 00
b. Source of funding : NIH
c. Sub-head wise abstract of the cost :

S. No.	Sub-head	**Amount in Rs. (Lac)**
1.	Salaries/ wages	33.60
2.	Travelling Expenditure	10.00
3.	Infrastructure / Equipment / Data	39.45
4.	Experimental charges	7.50
5.	Misc. expenditure	0.00
	Grand Total:	90.55

d. **Justification for sub-head wise abstract of the cost**: due to lots of instrumentation involve in the project the non-recurring cost is the major component followed by the salary of the project staff.

8. Quarterly Break up of cost estimate for Year: 2015-16

SN	Sub-head	Amount (in Rupees)			
		JFM (Q1)	AMJ (Q2)	JAS (Q3)	OND (Q4)
1.	Salary	168000.00	168000.00	168000.00	168000.00
2.	Travelling expenditure	50000.00	50000.00	50000.00	50000.00

3.	Infrastructure/Equipment	986250.00	986250.00	986250.00	986250.00
4.	Experimental charges	0.00	0.00	0.00	0.00
5.	Misc. expenditure	37500.00	37500.00	37500.00	37500.00
	Sub- Total:	1011800.00	1011800.00	1011800.00	1011800.00
	Grand Total:				4047200.00

9. Work Schedule:

a. Date of commencement of the project: 01.01.2015
b. Duration of the project: 5 years
c. Stages of work and milestones:

SNo.	Description of Activity	2015				2016				2017				2018				2019			
		J	**A**	**J**	**O**	**J**	**A**	**J**	**O**	**J**	**A**	**J**	**O**	**J**	**A**	**J**	**O**	**J**	**A**	**J**	**O**
1.	Development of Procedure for scientific work																				
2.	Recruitment and deployment of Project Personnel																				
3.	Purchase of instruments and experimental setup																				
4.	Data generation and acquisition																				
5.	Data analysis and modelli																				
6.	Final Reporting																				

10. Progress until date:

An attempt is being make towards establishing a classical hydro-meteorological field observatory in the Lesser Himalayan environment under this field-oriented project. On the part of instrumentation, one automatic weather station (AWS) with soil parameters monitoring station and automatic water level recorder (AWLR) with telemetry has been setup and properly fenced at main Henval catchment. Compound rectangular weirs have been constructed on-site for gauging the streamflow. Two more AWS and one AWLR delayed due to some administrative issues are supposed to be installed in near future. Meanwhile, the recruitment of one RA and one field staff has also been done from another sponsored project for dual purpose. We have now one year of meteorological data of various variables and few preliminary plotting and inter annual and diurnal variability have been analyzed for air temperature, wind velocity, solar radiation, soil temperature, soil moisture and rainfall.

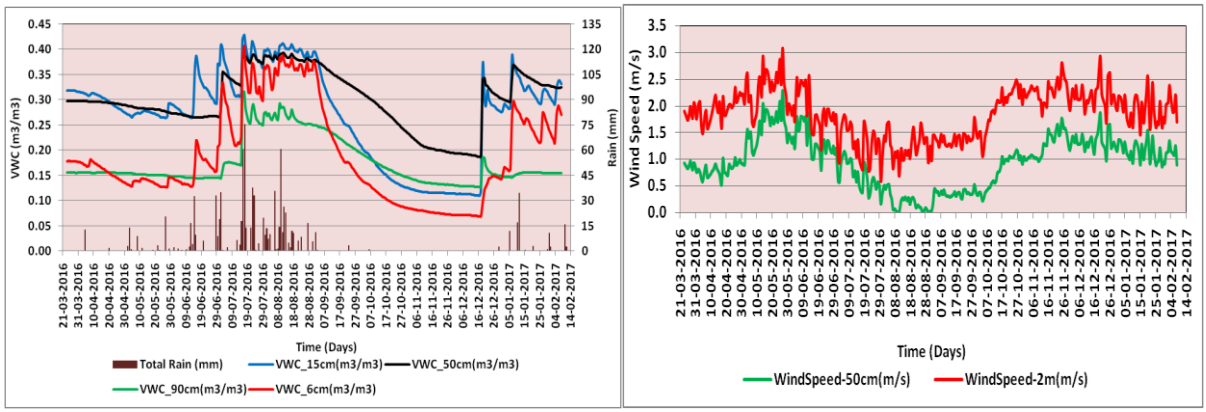


Fig.1 Inter-annual variability of Rainfall Vs Soil Moisture at different depths (Left) and wind velocity at different height (Right) from March-2016 to Feb-2017

The daily reference evapotranspiration for the period Mar to Oct, 2016 estimated using temperature-based (Hargreaves-Samani & Blaney-Criddle) and radiation-based (Priestley-Taylor & Makkink) methods have been compared with renowned Penman-Monteith (PM) method (FAO-56). Using the statistical indices like R^2 & RMSE it has been observed that the radiation-based methods performs comparatively well than temperature-based methods.

Remote sensing based evapotranspiration estimation method Surface Energy Balance Algorithm for Land (SEBAL) is being tested for the experimental catchment. SEBAL model estimates actual ET by solving the terms of the surface energy balance derived from the visible, near-IR, and thermal-IR bands of the electromagnetic spectrum. LANDSAT 8 data used in determining land surface temperature (LST) and normalized difference vegetative index (NDVI).

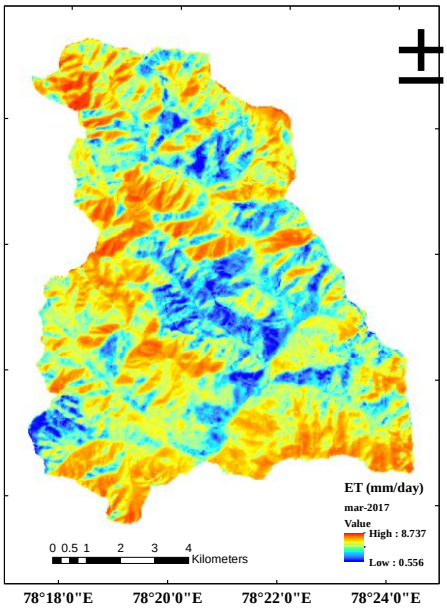


Fig.2 ET_0 map of the study area by SEBAL for the Month of March-2017

Since the project is about experimental hydrology, so only once we have some long-term data in hand then some conclusive inferences can be drawn. In between, the project team has also visited the site many a times for various objectives.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/08

1. **Thrust Area under XII five year Plan** : Hydrological information
2. **Project team:**
   a. Project Investigator: Deepa Chalisgaonkar, Sc F
   b. Project Co-Investigator(s): Dr. Sharad K. Jain, Sc G
   Er. D. S. Rathore, Sc F; Dr. Sanjay K. Jain, Sc G
   Dr Sudhir Kumar. Sc G; Dr. P.K. Mishra, Sc B
   Er. P K Agarwal, Sc B; Er. Manish Nema, Sc C
3. **Title of the Project :** Development of Ganga Information Portal
4. **Objectives**

Ganga Information Portal is envisaged to provide a unique platform comprising multisource data and information on Ganga basin. The major objective for developing such a portal is:

- To develop a knowledge/ information e-portal (Ganga Information Portal) with updated information on Ganga basin
- To provide a world class platform as resource centre for data sharing, retrieving pertaining to Ganga basin
- To operate and maintain the e-portal on 24x7 basis

5. **Present state-of-art**

The Government of India has recently launched the ambitious 'Namami Gange' an Integrated Ganga Conservation Mission with activities related with conservation and rejuvenation of the Ganga. Recognizing the multi-sectoral, multi-dimensional and multi-stakeholder nature of information in the Ganga basin, it is need of the hour to develop a web-based platform where different types of data/ information (facts; publications; data; maps; photographs; etc.) related to Ganga basin is available at one place. 'Ganga Information Portal' (GIP) is a step in this direction to develop a web-based information portal where variety of information on Ganga basin will be uploaded and maintained at National Institute of Hydrology, Roorkee.

6. **Methodology**

The GIP is being developed by using the World Wide Web (WWW) technology which is based on an open unstructured distributed hypermedia information system. It consists of non-linear, flexibly linked HTML (Hyper Text Media Language) documents, in which different types of WWW objects are being embedded.

The system is being developed in HTML and java script language. The main and drop down menus will allow the user to interact with the system very easily. The information relating to the Ganga will be collected from many different sources, agencies and organizations and will be arranged between the time-spaces, and it will be possible to share, to search, to display, and to output (print) it.

7. **Research outcome from the project**

A portal as shown in Fig.1 will be developed which will support quick and timely access of the information related to Ganga, anytime and from anywhere in the world.

8. **Cost estimate:**
   a. Total cost of the project : Rs.65.55 lakhs
   b. Source of funding : NIH
   c. Sub Headwise abstract of the cost

Sl. No.	Item	Nos. required	Duration (Man months)	Unit amount (Rs.)	Amount (Rs.)
A	**Manpower**				
i.	Scientist G and above	3	1 (Total)	175000.00	1750000.00
ii.	Scientist F	2	8	150000.00	2400000.00
ii.	Scientist B and C	3	1	80000.00	240000.00
iv.	JRF	2	30	28000.00	1680000.00
B	**Equipments (Hardware & Software)**				
	Workstations with UPS	2		50000.00	100000.00
	Scanner-A3	1		55000.00	55000.00
	Printer	1		30000.00	30000.00
C	**TA/DA**				
	Traveling by experts & JRFs	LS			300000.00
	Total (A+B+C)				**6555000.00**

9. Quarterly Break up of cost estimate for each year

2015-2016

Sl.No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1	Salary	365800.00	365800.00	365800.00	365800.00
2	Traveling expenditure	-	-	-	50000.00
3	Infrastructure/Equipment	-	-	-	185000.00
5	Misc. expenditure	-	-	-	50000.00
	Sub- Total:	365800.00	365800.00	365800.00	650800.00
	Grand Total				1748200.00

10. Work Schedule:

a. Date of commencement of the project : April 1, 2015
b. Duration of the project: 3 years, however, GIP is an integrated information portal which requires continuous efforts in up-gradation and maintenance.
c. Stages of work and milestone:

Sl.No	Item/Activity	Timeframe
i.	Creation/ Establishment of Infrastructures	9 months
ii.	Collection of different types of data/ information from different stakeholders on Ganga basin	6 months & beyond
iii.	Portal development and management	6 months & beyond
iv.	Operation and maintenance of GIP on 24x7 basis	On regular basis
v.	Retrieving critics, comments and feedback from different users	On regular basis

The system is being developed in HTML and java script language. The main and drop down menus will allow the user to interact with the system very easily. The information relating to the Ganga basin is being collected from different sources, agencies and organizations.

11. Progress :

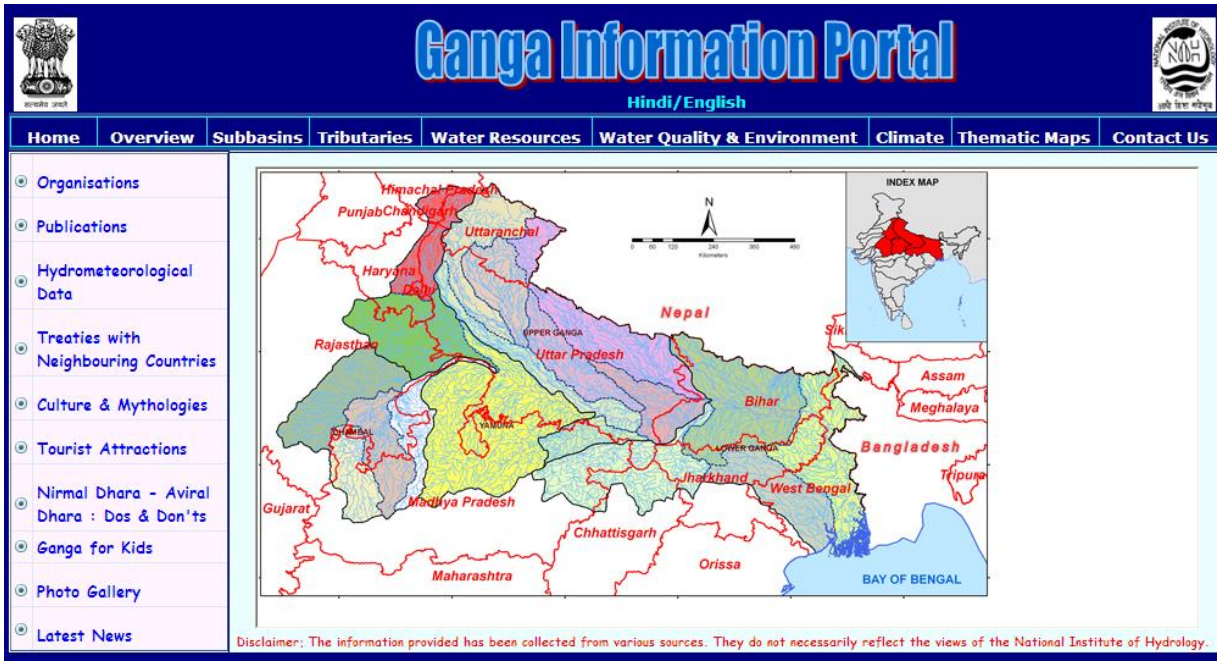
The portal is being developed as per the sitemap shown below:

- Overview (Topography, River Line Diagram, Landuse / Landcover, Soils, Agro_Climatic Zones, Agro_Ecological Zones, Demography, Dynamic Map of the Basin, Tourism, Inland Navigation, Major Sub-basins
- Sub Basins (Above Ramganga Confluence, Banas, Bhagirathi & Others (Ganga Lower), Chambal – Lower, Chambal - Upper, Damodar, Gandak & Others, Ghaghara, Ghaghara Confluence to Gomti Confluence, Gomti, Kali Singh & others confluences with Parbati, Kosi, Gomti, Sone, Tons, Upstream of Gomati Confluence to Muzaffarnagar, Yamuna - Lower, Yamuna - Middle, Yamuna - Upper)
- Watersheds
- Tributaries (Ajay, Banganga, Chambal, Damodar, Gandak, Ghaghara, Gomti, Hindon, Kali, Karamnasa, Ken & Betwa, Kosi, Mahananda, Mayurakhi, Punpun, Ramganga, Sindh, Sone, Tons, Yamuna)
- Water Resources (Water Resources Projects, Drinking, Irrigation, Hydropower, Industrial Use, Environmental Use Ecology, Inter Basin Water Transfer, Water Quality (River Water Quality, Surface Water Quality Observations), Ground Water Resources (Ground Water Observation Wells, Ground Water Level Fluctuations), Lithology, Lakes, Glaciers
- Climate (Rainfall (Annual Precipitation, Summer Monsoon, Winter Monsoon, Monsoon Onset, Western Disturbances, Cyclones), Temperature, Evaporation, Humidity, Radiation, Wind Velocity, Dew Point
- Thematic Maps (Agro_Climatic Zones, Agro-Ecological Zones, Annual Average Rainfall, Command Areas & Canal Network, Drainage & Sub_basins, Elevation Zones, Ganga Basin Map, Ground Water Level Fluctuations, Ground Water Observation Wells, Index Map, Interbasin Transfer, Landuse / Landcover, Litholog Well Locations, Hydrometeorological Stations, Population Density, Structures & Projects, Satellite Imagery, Soil Erosion, Soil Productivity, Soil Slopes, Soil Texture, Water Tourism Sites, Inland Navigation Waterways)
- Photo Gallery
- Contact Us
- Organisations
- National Ganga Basin Authority
- River Development & Rejuvenation
- Publication (Technical Reports, Technical Notes, Project Reports, Case Studies, Research Papers in International Journals)

- Data Repository
- Treaties (Mahakali Treaty between India and Nepal, Ganga Treaty between India and Bangladesh)
- Mythologies
- Nirmal Dhara - Aviral Dhara : Dos & Don'ts
- Cultural
- Ganga for Kids
- Latest News

12. Research outcome from the project

A portal as shown in fig.1 will be developed which will support quick and timely access of the information related to Ganga, anytime and from anywhere in the world.



ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2017/09

1. **Thrust Area under XII five year Plan**
2. **Project team:**

a. Project Investigator	Dr. L. N. Thakural, Sc-C, PI
b. Co-PI Project Co-Investigator(s)	Er. D. S. Rathore, Sc-F
	Dr. Surjeet Singh, Sc-D;
	Dr. Sanjay Kumar Jain, Sc-G,
	Dr. Sharad Kumar Jain, Sc-G

3. **Title of the Project** - Study of hydrological changes in selected watersheds in view of climate change in India.

4. **Objectives**-

- Development of database related to hydro-meteorological data.
- Long-term spatio-temporal analysis of hydro-meteorological variables.
- Assessment of variation in surface water and groundwater availability.
- Spatial variation of Ground water levels.
- Drought characterization.
- Climate change scenarios/analysis.
- Inter-comparison of water resources variability in selected basins and suggestions for IWRM.

5. **Methodology**

- Literature survey on the guidelines and pre-requisites for the selection of watersheds.
- GIS database development.
- Field visits for ground truth and data collection of exiting hydro-meteorological and groundwater related data and processing of data.
- Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches.
- Application of lumped conceptual rainfall-runoff model (NAM) for assessment of surface and ground water availability.
- Computation of SPI, hydrological drought indices, analysis of change in rainy days.
- Downscaling of meteorological data, generation of climatic scenarios based on IPCC-SRES using actual data
- Impact of climate change on streamflow using statistically downscaled data for each catchment
- Inter-comparison of watersheds and suggestion for irrigation water management.

6. **Research outcome from the project**

The outcome of the study will help in assessment of water resources availability and impact of climate change at basin scale.

7. **Cost estimate:**

a. Total cost of the project : Rs. 44.30 Lakh
b. Source of funding : NIH
c. Sub Headwise abstract of the cost

S.No.	Sub-head	Amount (in Rupees)
1.	Salary	9,00,000
2.	Travelling expenditure	20,00,000
3.	Infrastructure/Equipment	30,000
4.	Experimental charges	Nil
5.	Misc. expenditure	15,00,000
	Grand Total:	**44,30,000**

8. Quarterly Break up of cost estimate for each year

Year: 2015-16

S.No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	Salary	75,000	75,000	75,000	75,000
2.	Travelling expenditure	3,00,000	3,00,000	3,00,000	3,00,000
3.	Infrastructure/Equipment	30,000	-		-
4.	Experimental charges	-	-	-	-
5.	Misc. expenditure Hydro-meteorological Data and Satellite Data Miscellaneous	- -	5,00,000 - 1,00,000	5,00,000 -	- -
	Sub- Total:	4,05,000	9,75,000	8,75,000	3,75,000
	Grand Total	**26,30,000**			

Year: 2016-17

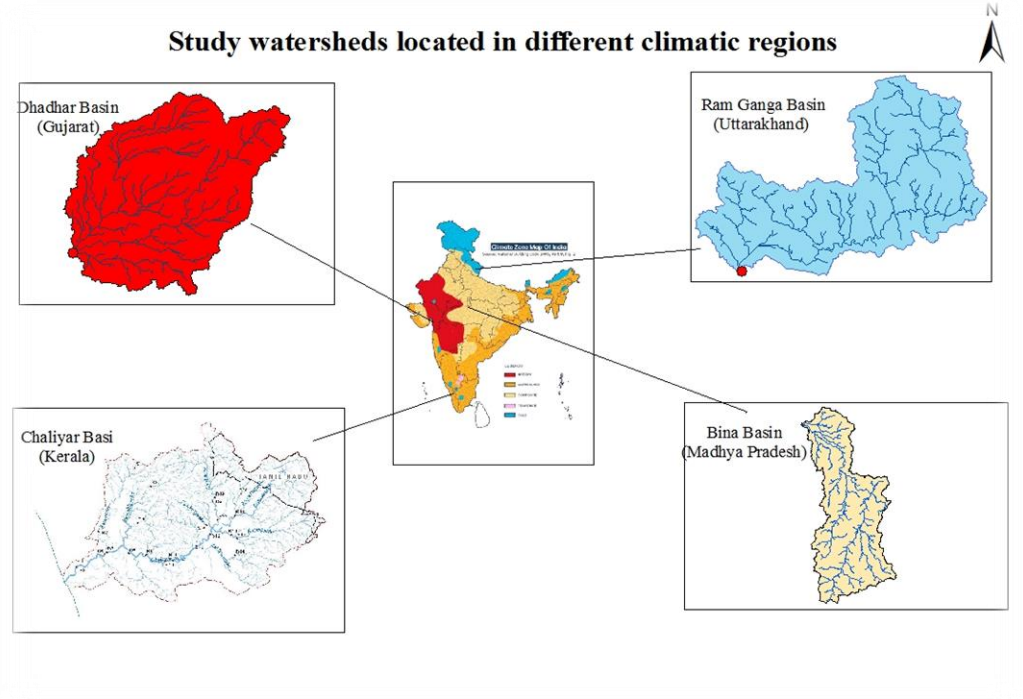
S.No.	Sub-head	Amount (in Rupees)			
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1.	Salary	75,000	75,000	75,000	75,000
2.	Travelling expenditure	2,00,000	2,00,000	1,00,000	
3.	Infrastructure/Equipment	-	-	-	-
4.	Experimental charges	-	-	-	-
5.	Misc. expenditure Hydro-meteorological Data and Satellite Data Miscellaneous	- - 1,00,000	- - -	- - 50,000	- - -
	Sub- Total:	3,75,000	2,75,000	2,25,000	75,000
	Grand Total	**9,50,000**			

9. Work Schedule:

a. Date of commencement of the project: April 2015
b. Duration of the project: 3 Years
c. Stages of work and milestone:

S. No.	Work Element	First Year	Second Year	Third Year
1.	Literature survey and Data collection, selection of watersheds	*		
2.	Processing and analysis of hydro-metereological data, GIS database development,	*	*	

S. No.	Work Element	First Year	Second Year	Third Year
3.	Assessment of variation in surface water		*	
4.	Ground water variation, Drought characterization		*	
6.	Climate change, Inter-comparison of water resources variability in selected basins and suggestions for IWRM.		*	*
7.	Preparation of Final report			*



6.	Climate change, Inter-comparison of water resources variability in selected basins and suggestions for IWRM.		*	*
7.	Preparation of Final report			*

10. Progress of Work

Four different watersheds located in different climatic regions namely Dhadhar river basin (Gujarat), Ramganga up to Kalagarh (Uttarakhand), Bina River basin (M.P) and Chaliyar river basin (Kerala) as shown in Figure 1. have been selected for the present study. The hydro-meteorological data pertaining to the three river basins namely Ramganga, Bina and Chaliyar basins have been processed to meet out different objectives of the study. The various inputs for the hydrological model such as dem, landuse/landcover soil map etc. have been prepared. The Processing and analysis of collected hydro-meteorological/Soil/Satellite data for the Dhadhar basin is in progress.

Figure 1: Study watersheds located in different climate regions of India

The downloaded and processed digital elevation model data of SRTM version 4.1 using ACGIS 9.3 software has been used for delineation of drainage networks and watershed boundaries for the four watersheds under the study. The parametric and non-parametric approaches have been applied to determine the trends in the time series data of rainfall. Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches for the Ramganga, Bina and Chaliyar river basins. Drought characterization using standard precipitation Index has been carried out for the Bina basin. Moreover, NAM and SWAT models have been calibrated and validated for these three basins.

10. Progress since last working group

- GIS data base development: Landuse/Land cover and soil map prepared for Chaliyar basin.
- Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches for the Ramganga, Bina and Chaliyar river basins.
- Drought characterization using standard precipitation Index for the Bina basin.
- Calibration and validation of NAM and SWAT hydrological model for the Ramganga, Bina and Chaliyar river basins.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/01

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**

Project Investigator	**:** Dr. R.J. Thayyen, Sci-D
Project Co-Investigators	**:** Dr. Farooq Azam, Inspire Faculty
	Dr. P.G. Jose, Sci-D, WHRC, Jammu
	Prof. A.P. Dimri, SES, JNU

3. **Title of the Project:** Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range
4. **Objectives:**
    1. Winter and Summer Mass Balance studies of Phuche and Khardung glaciers for building a long term mass balance data series.
    2. Energy balance studies for understanding the reasons of contrasting mass balance response of Phuche and Khardung glaciers.
    3. Improving regional climate downscaling for Ladakh region using ground observations and study of glacier –climate linkages.

5. Present state-of-the-art

Headwater runoff is sustaining life and livelihood in the cold-arid regions of Ladakh. Due to this reason mass balance response of the small glaciers in the Ladakh range raises considerable interest. Lack of mass balance studies across diverse glacio-hydrological regimes of the Himalaya limited our understanding of climate – glacier linkages across the Himalayan region. Considering these aspects, a long-term mass balance research programme was funded by SERB on Phuche glacier in the year 2010. Since then winter and summer mass balance data is being generated over the Phuche glacier. 5 years of mass balance studies have shown that the Phuche glacier have cumulatively lost about 900 mm w.e. during these period. A nearby glacier named Khardung glacier is also studied additionally for winter and summer balance during these period. This glacier is part of the six glaciers of Khardung glacier complex and separated from Phuche glacier by around 2.5 km. Both these glaciers have NE aspect and under similar climatological setup. Khardung glacier is in the Nubra side of the Ladakh range while Phuche glacier feed into River Indus. Even though these glaciers are under seemingly experiencing similar weather, mass balance study of Khardung glacier showed enormous mass loss of this glacier with a cumulative loss up to 2300mm w.e during these five years. Reasons for such a contrasting mass balance response need thorough investigation. All the instrumentation in the region is focused on the Phuche glacier catchment and prevailing weather condition or energy balance of Khardung glacier is unknown. Present project is formulated to undertake detailed study of these two glaciers to understand the contrasting mass balance behavior.

6. Methodology

1. Mass balance studies will be carried out by glaciological method including winter and summer balance with an aim to build up long-term mass balance series.
2. Monitoring of climate parameters of AWS installed at Phuche glacier near ELA (5600 m a.m.l). The energy balance study was carried out of the Phuche glacier.

3. Regional climate downscaling and parameterization

Use of regional climate model (RCM) outputs "without tuning" to evaluate hydrological and glacier responses to climate change in the Himalayan high mountains is still elusive (Yasunari et al., 2012). And thus it is imperative to assess the sensitivity of RCMs for hydrological and glaciological studies at basin level. Also, during winter, having an understanding of the liquid–solid precipitation ratio within the model framework is important for various hydrological and glaciological purposes. In present project statistical downscaling approach modifying dynamically downscaled outputs using Statistical Downscaling and Bias Correction (SDBC) method will be employed.

7. Research Outcome from the project:

Winter and summer mass balance of two glaciers, SEB data on two glaciers. Research papers with better understanding of climate forcing and factors controlling the glacier mass balance in the cold-arid system.

8. Cost Estimate : 65.14 lacs

Total cost of the project: Rs. 65.14 lakhs

b. Source of funding: SERB-DST

9. Work schedule

k	Year 1				Year 2				Year 3			
Acquisition of Equipment & logistics material	←	—	→									
Appointment of project staff	←	—	→									
Mass balance measurements	←	—	—	—	—	—	—	—	—	—	—	→
Meteorological monitoring by three existing AWS	←	—	—	—	—	—	—	—	—	—	—	→
SEB monitoring			←	—	—	—	—	—	—	—	—	→
Data Interpretation &Analysis					←	—	—	—	—	—	—	→
Report writing										←	—	→

10. Analysis and results

Winter and summer mass balance of Phuche and Khardung glacier of year 2015-2016

Winter mass balance measurements of Phuche glacier was carried out on May 16, 2016. The measured standing snow depth over the glacier was up to 1.52 meters and average snowpack density was 0.43 gm/cc. The snowpack density was used to calculate the point mass balance of each stakes and estimated glacier wide winter mass balance (B_w) was about 0.67 m w.e. The melting of snowpack thickness was monitored on 15-20 days interval. The sequential snowpack thickness measurement revealed that the snowpack melt on the glacier continued till mid of the July and major part of the glacier got exposed for melting during the last 15 days of July (after July 15, 2016). The estimated glacier wide annual (B_a) and summer (B_s) mass balance was (-) 0.73 m w.e. and (-) 1.41 m w.e. respectively. Whole of the glaciers was under melt regime with no accumulation occurring for the year.

Winter mass balance measurements of Khardung glacier was carried out on May 2016. Standing snow depth over the glacier was up to 1.3 meters and average snowpack

density measured was 0.53 gm/cc. The estimated glacier wide winter mass balance (B_w) was 0.62 m w.e. The sequential snowpack thickness measurement revealed that the snowpack melt on the glacier continued first week of July and major part of the glacier was exposed for melting mid of the July (after July 4, 2016). The estimated glacier wide annual (B_a) and summer (B_s) mass balance was (-) 1.51m w.e. and (-) 2.13 m w.e. respectively. The annual mass balance of both the glaciers hugely negative with record melting since the study started on these glaciers since 2010. Khardung glacier experienced two times more mass loss than the Phuche glacier as reported in the previous years.

Phuche meteorological data for surface energy balance model

To investigate glacier-climate interaction on Phuche glacier, one automatic weather station (AWS) has been installed at 5600m a.s.l. One year (1 October 2015 to 27 September 2016) data record without any gap was available from this station, the data sets is generated half-hourly includes global radiation (incoming and outgoing shortwave radiation), albedo, net radiation, air temperature, relative humidity and wind speed and direction. The minimum and maximum temperature was recorded in 24th December 2015 (-28.9 °C) and 5th August 2016 (14.2 °C). The coldest month of the period was January with a mean T_a of (-19.5 °C) and warmest month was July with mean T_a of 2.7 °C. The daily mean air temperature varying from -28.9 °C to +14.2 °C with a mean air temperature of -7.4 °C during period. The daily mean SWI ranges from about 173.5 Wm^{-2} in midwinter to about 971.8 Wm^{-2} in summer with a mean value of 577.9 W/m^2 and observed highest in the May 2016 with a mean value of 709.9 Wm^{-2} and lowest value in the month of December 2015 with a mean value of 442.6 Wm^{-2}. Similarly, the daily mean SWO is varying from 530.5 to 40.2 Wm^{-2} with a mean value of 284.5 Wm^{-2}. The daily mean value of net radiation varies from -62.4 to 175.4 wm^{-2} with a mean value of 26.9 wm^{-2}. The mean monthly minimum and maximum value of net radiation was observed in January (12.2wm^{-2}) and July (105.7wm^{-2}) of the study period. The variation of daily mean relative humidity (RH) observed from 21.2% to 99.9% with a mean value of 56.3%. The mean monthly minimum and maximum RH was observed in October (45.7%) and August (71.0%) of the study period. The daily mean wind speed was varying from 1.7 ms^{-1} to 9.8 wm^{-2} with a mean value of 4.4 wm^{-2}. The mean monthly minimum and maximum value of wind speed was observed in August (3.3 wm^{-2}) and February (5.5 wm^{-2}) of the period. The positive degree day (PDD) was observed 365.9 °C from 1 October 2015 to 27 September 2016 with a mean value 1.01 °C.

On the administrative side, glacier ice temperature profiler is purchased and procurement of automatic weather station is in the final stages.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/02
NMSHE STUDIES

1. Title - Development of a project website and hydrological database in Upper Ganga basin

2. Study team

1. Dr. M. K. Goel, Scientist 'G', NIH, Roorkee - PI
2. Dr. M. Arora, Scientist 'D', NIH, Roorkee – Co-PI
3. Dr. A. K. Lohani, Scientist 'G', NIH, Roorkee
4. Mr. D. S. Rathore, Scientist 'F', NIH, Roorkee
5. Mrs. D. Chalisgaonkar, Scientist 'F', NIH, Roorkee
6. Dr. A. R. S. Kumar, Scientist 'E', NIH, Roorkee
7. Dr. Surjeet Singh, Scientist 'E', NIH, Roorkee
8. Mr. P. Mani, Scientist 'D', NIH, CFMS, Patna
9. Dr. A. Sarkar, Scientist 'D', NIH, Roorkee
10. Mr. M. K. Nema, Scientist 'C', NIH, Roorkee
11. Smt. Suman Gurjar, Scientist 'C', NIH, Roorkee
12. Dr. P. K. Mishra, Scientist 'B', NIH, Roorkee

3. Objectives

The objectives of the project are:

a) Development of a coherent hydrological and hydro-meteorological database in Upper Ganga basin.
b) Processing and analysis of hydro-meteorological data in study area.
c) Assessment of adequacy of hydro-meteorological network in study area.
d) Investigation and referencing of available spatial database from various sources for use in water resources management.
e) Capacity building for use of hydrological data entry and processing software for maintaining hydrological database.
f) Development of interactive project web site for NIH projects under NMSHE including a web-based hydrological information system.

4. Sponsored by DST, New Delhi
5. Project Cost Rs.113.22 Lakh
6. Brief Background

The Himalayan region of our country is marked with steep mountains, which largely influence the climate and weather conditions of our country and is the main source of water supply for Indo-Gangetic plains from rainfall and snow/glacial melt.

The first important task in the whole gambit of hydrological analysis for a river basin is the collection of true, accurate and regular hydrological and hydro-meteorological data. In our country, a number of organizations are involved in collection of hydrologic and meteorological data. However, it is also important to integrate the data related to different hydrological variables (say, rainfall, snowfall, temperature, humidity, wind speed, sunshine, river flow, groundwater observations etc.) in a database so that comprehensive analysis and processing of hydrologic variables in a river basin can be made. In addition to the point observations, a number of satellite platforms (such as Resourcesat, Cartosat, MODIS, TRMM, APHRODITE etc.) are now providing spatial information in various observation

windows (or bands), some of which are on-line in public domain. This information can be referenced at a single platform for use in hydrological analysis for various purposes.

Data collected on hydrologic variables are generally raw which may not be used directly in most hydrologic analysis work. Processing of hydrological data has two major objectives: one to evaluate the data for its accuracy and the other to prepare the data in a form valuable to the users. The rapid advance in computer technology, in speed of operation and data storage capacity as well as the capability of hydrological software has greatly simplified the management of large quantities of hydrological data. All hydrological datasets can be maintained in well-defined computerized databases using standard database management system. Surface Water Data Entry System (SWDES), developed under Hydrology Project – I, and HYMOS software can be used for entry and processing of hydrological data in standardized format. This is essential for the long-term sustainability of the datasets in proper form and their dissemination to the end users. Both, raw and processed data sets are to be properly stored and archived to specified standards so that there is no loss of information. NIH has trained manpower on SWDES and HYMOS software which can be used entry and process the hydrological database for the Upper Ganga basin up to Rishikesh and to build capacity in other organizations dealing with hydrological data for their effective utilization.

For mountainous areas, significant variation in altitude, slope, aspect, soil, and land use characteristics over short distances requires high density of hydrometric networks for reliable assessment of hydrological variables. However, due to various operational problems such as approachability, low temperatures, snowfall, high velocity flows with boulders and sediments etc., hydro-meteorological information available in the mountainous regions is quite limited due to lack of proper observation network. There is an urgent need to properly design and upgrade automated hydro-meteorological networks suitable for the prevailing climate in the region for long-term monitoring and database development. It is envisaged to analyze the existing hydro-meteorological network in the study area and analyze its adequacy using different techniques.

There has been widespread concern over the global change in climate and its impact on various hydrological variables. This impact is not uniform globally and mountainous regions are considered to be more susceptible to climate change (IPCC, 2007). It is envisaged to carry out trend analysis of long-term data of hydrological variables to assess the possible impact of climate change on various hydrological processes. These findings can be used to analyze various scenarios of water availability and demand to develop strategies for proper management of water resources in future.

Finally, it is envisaged to develop the web-site of the project for online information about various studies and sub-projects being carried out and the intermediate dissemination of results. It is also planned to link the web-based hydrological information system with the site to show the summary/gist of processed data at various observation sites in the study area.

7. Present Progress

Spatial Data: Digital Elevation Models (ASTER/SRTM); Soil Map (FAO); Landuse Map (Bhuvan); Shape Files (Ganga River Basin Management Plan, IITD Server); Landsat Imageries (NASA Earth Explore/Bhuvan) have been downloaded from different free sources.

Temporal Data: Precipitation, minimum & maximum Temperature, relative humidity, sun-shine hours, wind speed, solar radiation, dew point, ground forest frequency, potential evapotranspiration, reference evapotranspiration, vapour pressure and wet day frequency have been downloaded from different free sources.

Satellite based Data: Satellite rainfall data i.e., TRMM (3B43) & APHRODITE have been downloaded for the study area(s) under NMSHE project.

Miscellaneous:

1) Study area has been demarcated/delineated up to Triveni Ghat using digital elevation model.
2) G&D sites are identified under the study area as per India WRIS web site under SP-1
3) Catchment area of the basin comes out to be 21,762 km^2. Catchment area is covered about 45 SoI Toposheets (1:50,000 scale) under SP-2. Daily observed rainfall data of 48 IMD stations have been collected in softcopy.
4) Study area map(s) have been finalized for all projects using the GIS techniques under SP-1&2
5) IMD 0.25 deg grids have been identified for data extraction.
6) Village level population data has been downloaded for study area.
7) Tentative website design has been prepared and its coding is in progress in HTML under SP-1&2.
8) Landsat data have been downloaded for Satluj, Beas & Chenab basin under SP-3.
9) Rainfall data has been imported in SWDES.
10) Efforts are underway to install the HYMOS system for detailed processing of hydro-meteorological data of the study area.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/03
NMSHE STUDIES

1. Title - Real-time snow cover information system for Upper Ganga basin

2. Study team

a) Project Investigator:	D. S. Rathore, Sc. "F"
b) Project Co- investigators:	Deepa Chalisgaonkar, Sc. "F"
	V.S. Jeyakanthan, Sc. "E"
	L.N. Thakural, Sc. "C"
c) Project Staff (JRF)	Abhilasha Dixit
	Reema Gupta

3. Objectives

The objectives of the project are:

a) Development of methodology for snow cover delineation in study basin using multispectral remotely sensed data.
b) Development of web-GIS application for real-time snow cover information in study basin.

4. Sponsored by DST, New Delhi

5. Project Cost Rs.77.992 Lakh

6. Statement of Problem

For obtaining snow depletion curve, high temporal resolution data are highly desirable for small basins. Availability of high temporal and spatial resolution has a trade off. In such case, error introduced due to mixed pixels may be important. Microwave data has good potential in study of snow water content. Spatial information obtained from multiple sources may be easily disseminated through web GIS applications. Web GIS has potential for interactive applications in addition to visualization.

7. Present state-of-art

MODIS snow cover data are available as daily, eight day composite, real time fractional snow etc. Products use global automatic processing for snow, fractional snow and grains extraction from MODIS data. MODIS snow cover cloud estimation technique maximizes cloud area. Texture products have been utilized snow and cloud. Several Web GIS software are available for creating web GIS services. Library and development tools are available for accessing web GIS services for visualization of spatial data on client machines.

8. Methodology

Snow cover, fractional snow cover, snow underneath cloud/ vegetation will be delineated using satellite remotely sensed data. Various techniques e.g. NDVI-NDSI regions for snow underneath forests, change detection/ image matching of cloud obscured images with reference images, comparing multi resolution images for fraction snow cover etc. will be employed. Snow cover maps will be published using Web GIS technologies e.g. Geoserver, Openlayers, GeoExt etc. Available web services of spatial data e.g. Open Street Maps etc. will also be utilized.

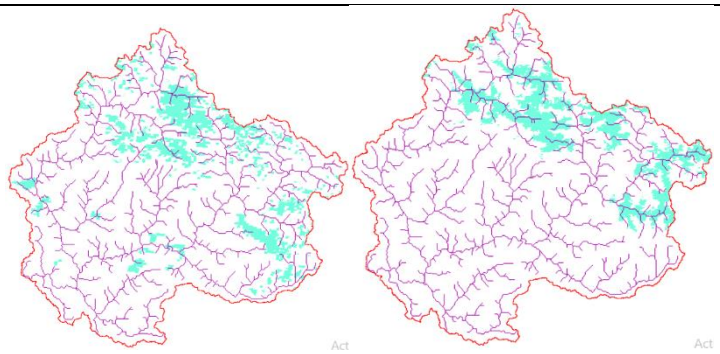
9. Approved action plan and time line

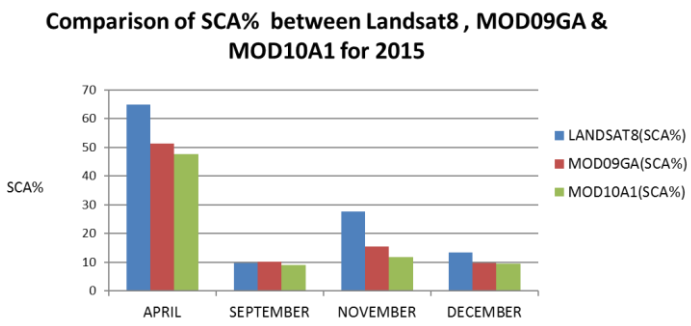
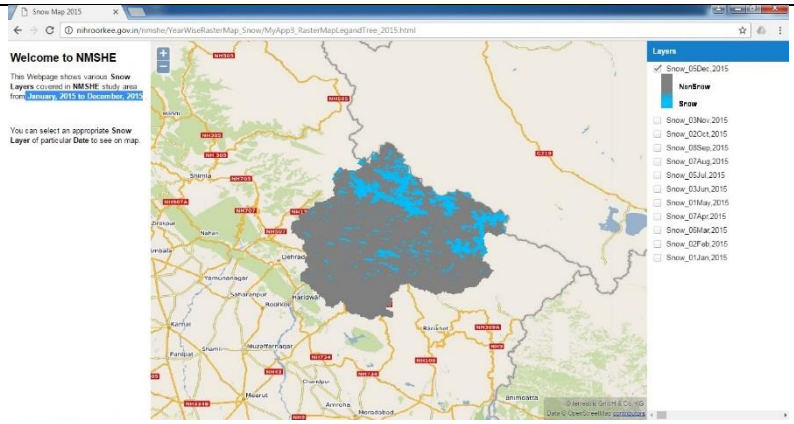
Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Processing of satellite data and GIS layers for delineation of snow	←	→								
Development of web GIS application for snow	←	→								
Field visit for ground truth and observations	←	→								
Preparation of interim/ final reports		↔		↔		↔		↔		↔

10. Recommendations / suggestions in previous WG

None.

11. Achievements

Year	Objectives	Achievements
2016-17	Snow mapping	  Fig. a. MOD10A1, b. MOD09GA, c. Landsat 8 clockwise from top left (November 7, 2015) Satellite data (Landsat 5, 7 and 8 for 2010, 2013 and 2015 respectively and corresponding date MOD09GA data) were processed for snow cover estimation and results were compared with MOD10A1 snow area. Snow area delineated from Landsat data was more than those from MODIS data.

		
2016-17	Web GIS application	 WMS layers were created for snow cover maps (2013- 2015) and maximum and minimum snow cover maps (2001- 2015). Web applications to depict snow cover in a year and maximum and minimum snow cover was developed using Openlayers and GeoExt. The maps were displayed along with Open Street Maps.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/04
NMSHE STUDIES

1. Title - Glacial Lakes and Glacial Lake Outburst Flood (GLOF) in Western Himalayan region

2. Study team

1. Dr. Sanjay K. Jain, Scientist 'F', NIH, Roorkee - PI
2. Dr. A. K. Lohani, Scientist 'F', NIH, Roorkee – Co-PI
3. Dr. Sudhir Kumar, Scientist 'G' & Head, HI Division, NIH, Roorkee
4. Dr. P. Thakur, Scientist 'D', IIRS, Dehradun

3. Objectives

The objectives of the project are:

1. To generate data base with regard to glaciers and glacial lakes in basins located in Western Himalayan region.
2. To define conditions of glacial lakes, moraine dams associated with mother glaciers attributing those with topographic features around lakes/moraine dams.
3. Analysis of the data to identify the potentially dangerous and vulnerable glacial lakes susceptible to out burst.
4. To define geometrical parameters (spread area, depth and volume of water etc.) of the vulnerable lakes and their further examination.
5. GLOF modeling using the hydro-dynamic mathematical modeling.
6. To disseminate the results and outputs among relevant oragnisations in the region that could make use of this information for GLOF hazard prevention and mitigation planning.

4. Sponsored by DST, New Delhi

5. Project Cost Rs. 41.796 Lakh

6. Brief Background

The climatic change/variability in recent decades has made considerable impacts on the glacier lifecycle in the Himalayan region. Warmer climates of the past have resulted in glacier retreat and the formation of glacial lakes in many mountain ranges. As the glaciers area retreating, some glacial lakes are formed behind the new exposed terminal moranins. Rapid accumulation of water in those lakes particularly in those adjacent to receding glaciers, can lead to a sudden breaching of the unstable dam behind which they have formed. The sudden discharge of large volumes of water with debris from these lakes potentially causes Glacial Lake Outburst Floods (GLOFs) in valleys downstream.

In order to assess the possible hazards from such lakes it is therefore essential to have a systematic inventory of all such lakes formed at the high altitudes. To identify the individual glaciers and glacial lakes, different image enhancement techniques are useful. Besides making a temporal inventory, a regular monitoring of these lakes is also required to assess the change in their nature and aerial extent. The criteria for identifying potentially dangerous glacial lakes are based on field observations, processes and records of past events, geo-morphological and geo-technical characteristics of the lake and surroundings, and other

physical conditions. Once the vulnerable lake is identified, Mathematical modeling of dam breach floods can be carried out by either one dimensional analysis or two dimensional analyses.

7. Methodology

The studies for outlined focused area would involve following work items:

(i) Collation of literature & reference documents, procurement Remote Sensing Data from appropriate agencies-national and though on line sources.

(ii) Formulation of data on Glacial Inventory of the Basins defining snow line, different glaciers, their attributes and classification.

(iii) Establishing Glacial Lake and Moraine Dam Inventory in the Basins and defining geometric parameters of lakes, possibility of their inter-connectivity, and geomorphic classification to work out their vulnerability status.

(iv) Analysis of Glacial Lake database to identify the vulnerable lakes and their possibility of out burst under different causative modes. Defining breach parameters to estimate the scale of hazard on incidence of the GLOF.

(v) Defining slope attributes of the river from vulnerable lake/lakes to project sites and cross sections of the river-valley which would carry the flood on incidence of GLOF; the parameters would be defined based on remote sensing data.

(vi) Hydrological studies on GLOF/ Moraine Dam Break Simulation and consequent lake breach flood using the hydro-dynamic mathematical modeling.

(vii) Recommendation for the establishment of a system for monitoring potential risk lakes.

(viii) Information to be given to relevant institutions regarding the results and potential risks, thereby increasing the capability to plan for and prevent or mitigate the risks.

8. Present progress

1. This project includes part of four study basins: Sutlej, Beas, Chenab and Ganga.
2. The Digital Elevation Models (ASTER/SRTM) of the four basins have been prepared and catchment maps have been delineated.
3. Landsat data have been downloaded for the study basins for the years 2000 and 2015.
4. The processing of the data for Sutlej basin has been carried out through ERDAS. The subset has been prepared and then mosaic of the data has been prepared. Finally the study basin for both the years has been extracted.

The NDSI map and slope map have been prepared. Using these maps, GLIMS maps and Google maps, delineation of the glaciers for the two years 2000 and 2015 have been completed. The satellite data of other year i.e. 1990 has also been downloaded for glacier area of the basin.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/05
NMSHE STUDIES

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
    1. Dr. R. J. Thayyen, Scientist 'D', NIH, Roorkee - PI
    2. Dr. Sanjay K. Jain, Scientist 'F', NIH, Roorkee – Co-PI
    3. Dr. Sharad K. Jain, Scientist 'G' & Head, WRS Div., NIH, Roorkee
    4. Dr. S. P. Rai, Scientist 'E', NIH, Roorkee
    5. Dr. P. K. Mishra, Scientist 'B', NIH, Roorkee
    6. Dr. M. Arora, Scientist 'D', NIH, Roorkee
    7. ***Collaborator: Dr. A. P. Dimri, Assoc. Professor, SES, JNU, New Delhi***
3. **Title of the Project:** Assessment of downstream impact of Gangotri glacier system at Maneri and Future runoff variations under climate change scenarios
4. **Objectives:**
    1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri
    2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri
    3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling.
    4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change.

5. Present state-of-art

River Ganga originates from the Gangotri glacier and fed by around 238 glaciers in the Bhagirathi catchment and 407 glaciers in the Alaknanda catchment covering around 1959 km^2 of the catchment area above Deoprayag. Discharge in these headwater tributaries of the Ganga is influenced by snow, rain and glacier melt. Melting glaciers of this region have raised serious concerns over the future trajectory of water availability in this crucial river system. There are conflicting viewpoints exists on the impact of glacier melt in the downstream flow regimes. IPCC 2007 report and many other studies in the Alpine systems suggested increased river flows during the early stages of glacier melt. However, Thayyen and Gergan (2010) distinguished between Alpine and Himalayan systems on the basis of annual precipitation distribution and flow regimes and pointed out that the runoff variations in the precipitation (Monsoon and winter snow) dominant systems such as Bhagirathi and Alaknanada basins are not dominated by the glacier discharge. Here precipitation variability plays the key role in runoff fluctuations with glacier melt helps to reduce the inter-annual runoff variability. Hence assessment of future runoff variation in this headwater streams required some robust future projections on precipitation and temperature. The impact of glacier melt dividend is found to be maximum for a basin with 20-30% glacier cover under the Alpine conditions. However, such assessment is non-existent in the Himalaya barring Dingad catchment, Garhwal Himalaya. As Gangotri is the largest glacier in the Ganga headwaters, extent and nature of its impact on downstream flow is critical issue for glacier resource management. The proposed project aims to understand this critical knowledge gap in the headwater regions of the Bhagirathi River at Maneri with 14.19% glacier cover. This catchment has 4205 km^2 area and 232 glaciers covering 596 km^2 (14.19%) The understanding

of climate forcing on river flow under a data free regime is challenging. Key knowledge gap are precipitation and temperature gradients in the higher altitude regions. This knowledge gap will be addressed with collaborations with Jawaharlal Nehru University on atmospheric process modeling. Future runoff will be modelled using the future climate projections from this sub project.

6. Methodology

A) Discharge data of Maneri will be collected from the state agencies and inter-annual variations and long-term trends will be assessed.

B) Weather monitoring near Harsil: Weather data at the high altitude Himalayan region is very sparse. Hence orographic processes of the Himalayan slopes are poorly understood. Recent studies have shown that the orography is a key factor controlling the weather variables in the Himalaya. A full-fledged automatic weather station with four component radiometer, precipitation gauge and soil heat flux sensors will be installed near Harsil. Data from this weather station will be used for runoff modelling and climate downscaling.

C) Runoff modelling by SNOWMOD: Runoff modelling will be carried out by the established in-house model SNOWMOD. SNOWMOD is capable of providing snow, glacier, rainfall and base flow components separately. The glacier melt component in the discharge will be derived through modelling exercise. Glacier change in the Bhagirathi catchment during the past three decades will be estimated and correlations will be established between temperature/precipitation variations in the catchment with that of glacier change with the help of reanalysis data. Future glacier area change will be determined by using the inputs from the climate downscaling exercise and future runoff and glacier component will be modelled.

D) Climate downscaling and future predictions: Climate of the region is dominated by Indian winter monsoon and Indian summer Monsoon. Keeping such broad scale flow in mind climate downscaling will be done in conjuncture with the study of interaction of large scale monsoonal flow with existing variable topography and to study land surface processes in association with hydrological balance over the region of study with existing CORDEX simulation (from IITM, Pune), downscaling over the catchment region and modelling experiments. As it is understood that the region of study is of complex topography and hence such topography will not be truly represented within the model domain and hence dynamical downscaling will be used to established the atmospheric-topographic interaction in defining primarily precipitation forming processes. Statistical downscaling methods will be used to overcome the coarser horizontal model resolution problem and establish moisture-temperature interplay processes.

7. Research Outcome from the project:

Understanding of the downstream impact of Gangotri glacier system with glacier, snow & rainfall component and its probable future variability.

8. Cost Estimate:

a. Total cost of the project:	Rs. 153.716 lakhs
NIH	Rs. 80.42
JNU	Rs.73.296
b. Source of funding:	NMSHE-DST

9. Progress of the project

1) To initiate the project a research associate (RA-1) has been recruited in May 2016. Discharge data of Maneri dam site is collected for 2000-2016 period. Catchment boundary delineation and glacier cover delineation has carried out. MODIS Tera (MOD) and Aqua (MYD) data was download and after product pre-processing number of steps have been implemented to generate the cloud free snow cover extent and depletion 16 years from 2000 to 2016. Snow cover area is computed for each Elevation Zone (Hypsometry) and analysis of the snow cover variability for mountain hydrological years were carried for 16 years. Maximum snow cover in the basin is observed in the month of March/February and minimum in August/September. During the observation period, no significant long term trend in the snow cover distribution observed in the basin. However, there is significant inter-annual variations do occur. The impact of snow cover variations is better represented in snow cover days. Annual snow cover days have been estimated for each 500m elevation band in the basin. The result show a significant reducing trend of annual snow cover days in the elevation band of 4000-4500 m a.s.l. Above and below this altitude band no discerning trend is visible during the pat one and a half decade. These are glacier elevations and this imply that the lower elevations of the glaciers are getting exposed early and could be factor in the enhanced melting of the glaciers in the region. For undertaking the runoff modeling, temperature and precipitation data in the catchment and nearby region is awaited.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/07
NMSHE STUDIES

1. **Thrust Area:** Himalayan Hydrology

2. **Project Team**

Project Investigator	**:**	Dr. Sharad K. Jain, Scientist 'G'
Co-Project Investigator	**:**	Dr. R. J. Thayyen, Scientist 'D'
Project Co-Investigators	**:**	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. S. P. Rai, Scientist 'F'
	:	Dr. Surjeet Singh, Scientist 'E'
	:	Mr. M. K. Nema, Scientist 'C'
	:	Dr. P. K. Singh, Scientist 'C'
	:	Dr. P. K. Mishra, Scientist 'B'
	:	Mr. P. K. Agarwal, Scientist 'B'
	:	Dr. A. P. Dimri, Professor, JNU
Research Associate	**:**	Dr. Pravin RangraoPatil

3. **Title of the Project:** Observation and Modelling of Various Hydrological Processes in a Small Watershed in Upper Ganga Basin

4. **Objectives:**

   1. To establish relationship between climatic and hydrologic variables and their seasonal variations in Himalayan environment.
   2. To study the atmospheric dynamics including seasonal variations in atmospheric water budget, land-surface flux, orographic interactions during Indian summer and winter monsoon.
   3. To develop the understanding of the hydrological processes in the watershed though isotope geochemistry.
   4. To study the ground water dynamics in a lesser Himalayan watershed.
   5. To study the soil erosion characteristics and sediment routing of the watershed.
   6. To model various water balance components for a small watershed.

5. **Present State-of-the-Art**

   Climate – Hydrology interaction in the mountain areas is complex due to closer and dynamic land-atmospheric exchange on account of orographic updraft and drainage winds. Indian Summer Monsoon (ISM) and Indian Winter Monsoon (IWM) is a major factor controlling climate of the Himalaya (Thayyen and Dimri, 2014). Hence, understanding the atmospheric, land surface and hydrological processes and its linkages is key to our understanding of climate change forcing on the Himalayan hydrological system. We did not succeed in attributing the regional climate change to the anthropogenic forcing till date. There is a clear need to move beyond the status quo and expand from this narrow hydrological perspective to generate hypotheses governing general behaviour across places and scales, with the ultimate aim to advance our understanding of the mountain hydrological processes. The project is envisaged to cover major components and processes of the water cycle; starting from the seasonal atmospheric water budgeting, atmosphere-land surface interaction and feedback, surface water balance, soil moisutre-soil temperature-sediment and water quality responses, groundwater dynamics and hydrological process studies and atmospheric moisture source assessment by stable isotope measurement.

6. Methodology

Study Area: The small Himalayan watersheds (Henval & Jijali) in the upper Ganga basin in Tehri Garhwal district of the state of Uttarakhand are proposed for the study.

i. Analysis of factors influencing local weather, land surface flux including soil temperature and diurnal & seasonal forcing at AWS site.

ii. Application of updated Regional Climate Model-RegCM4 (Giorgi et al. 2012) for atmospheric modelling along with CORDEX and subgrid land surface parameterization using mosaic-type scheme of the RegCM 3 (Giorgi et al. 2003).

iii. Water and sediment sampling for water quality investigations and modelling with advance use of isotopes.

iv. Develop understanding of the groundwater dynamics or interactions and recharge through installation of piezometer's longitudinally along the river, modeling and isotopic analysis.

v. Water balance modelling using field experiment based input data to understand the components of the hydrological cycle.

vi. Quantitative assessment of soil erosion and spatial distribution using USLE, RUSLE and MMF, RSSYM, WERM, SWAT Models with GIS and Remote Sensing in order to plan soil conservation measures.

7. Research Outcome from the Project:

Enhanced understanding of the Lesser Himalayan hydrology-atmospheric interactions and climate change forcing aiding water resources management.

8. Cost Estimate: 134.32 lakhs

Total cost of the project	:	Rs. 134.32 lakhs
Source of funding	:	NMSHE-DST

9. Work schedule:

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Development of procedure for scientific work										
Recruitment and deployment of Project Personnel										
Purchase of instruments and experimental setup										
Data generation and acquisition										
Data analysis and modelling (Isotopic analysis / Sediment Modelling)										
Atmospheric Dynamics (water budgeting / Land Surface Flux)										
Watershed water balance and budgeting										
Ground Water Dynamics										
Final Reporting										

10. Progress of Work:

i. **Manpower Recruitment:** A Research Associate (RA) has been recruited under this project.

ii. **Field Visits:** The NIH personnel's are working tirelessly over both the Lesser-Himalayan watersheds. It involves frequent field visits to survey, sampling, assess the concerns as well as progress of instrumentation within the watershed in order to monitor performance against the proposed work plan.

iii. **Field Work:** Fieldwork is undertaken for installation of discharge site and AWS. Sediment sampling was also done at the outlet of Henval stream during monsoon season in order to find out the soil texture and sediment concentration. Undisturbed

and disturbed soil samples (of different depths) were collected using auger-hole method for bulk density and soil type estimation. Infiltration tests have been conducted with double ring infiltrometer.

iv. **Watershed Instrumentation & Site Selection:** An AWS has been installed in the Henval valley (through NIH in-house project fund) to continuously monitor various climatic, radiation & soil variables on 30-min basis. The site selection for another AWS setup through the present project (NMSHE-5) fund has been done in the Jijali catchment. Sensors mounted and placed in the vicinity of the Henval AWS are: Wind speed & direction at different height, Four component radiometer, Air temperature, RH, Tipping bucket rain gauge, Barometric pressure, Soil moisture & temperature at different soil depths, Soil heat flux.

v. **Stream Gauging for Water Balance Study:** Henval & Jijali streams are continuously gauged by using rectangular weirs constructed at their outlets. Staff gauges have also been installed to monitor the water levels. An automatic water level recorder (AWLR) is installed on the Henval stream just upstream of the weir. The procurement of another AWLR for Jijali stream is under process. pH meters and digital thermometer have been procured.

vi. **Manual Weather Station:** The instruments required for manual weather station setup (ordinary rain gauges, pan evaporimeter) have been procured.

vii. **Piezometer Installation:** The possible locations for installation of piezometer were identified by visiting the upper reach of Henval valley and tendering process is on.

viii. **Factors Influencing Local Weather:** The timing of daily extremes (min. & max.), magnitudes and amplitudes of factors influencing local weather and land-atmospheric exchange i.e. solar radiation; air, skin and subsoil temperatures at different depths; wind speed at different heights were estimated and their behaviour has been analyzed for the Himalayan region on diurnal basis. Role of wind systems (upslope and downslope winds, up-valley and down-valley winds) was found more significant over mountain terrain. Wind direction behaves accordingly to these wind systems and affects the land-surface interactions. Variations in vol. water content (VWC) at different depths w.r.t. monsoon rainfall have been analyzed. Skin temperature has been estimated using Stefan-Boltzmann Law. Radiation data correction (considering a cut-off point of 5 W/m^2) results in accurate estimation of albedo and net short-wave radiation. The analysis of time to peak reveals that after solar radiation peak, skin and air temperature peak occurs subsequently whereas; the sub-soil (at 2 cm) temperature peaks lastly. It is found that minimum skin and air temperature typically occur close to sunrise, with air temperature minimum occurring slightly after skin temperature minimum. This reflects that soil heats up during day, cools at night very fast than air. Generally the magnitude of the soil temperature dampens with the depth whereas; in post monsoon months (Oct-Jan) the reverse trend was observed. During monsoon months the estimated amplitudes of air, sub-soil & skin temperatures are found quite closer.

ix. **Soil heat flux** (Oke, 1987) effectively couples surface energy balance & soil thermal regime. The surface SHF is calculated by adding the measured flux at a fixed depth (8 cm) to the energy stored within the layer (0-8 cm) above the heat flux plates (obtained using the soil temperature-soil moisture data & soil-water properties). The SHF at a particular depth (6 cm) has been estimated using Fourier's law. The available energy at the ground surface decreases with depth causes amplitude damping and time lag (peak shift) with increasing depth. Here, we observe the same phenomenon with increasing depth from 6 to 8 cm. This justifies the accurate estimation of SHF at 6 cm depth. The storage within the layer (0-6 cm) estimated similarly & added to SHF at 6 cm to obtain surface SHF. *The surface SHF estimated by both these ways are analogous reflects that the soil properties (ρ_b*

= soil bulk density = 2000 Kg/m3, C_d= specific heat capacity of dry mineral soil = 840 J/KgK) used in the analysis are accurate and representative of the region. Here, volumetric heat capacity of the moist soil C_s varies from 1941625 to 3789744 J/m^3K.

x. **Soil Thermal Regime/Profile** (Jury et al., 1991) has been estimated considering the soil temperature oscillates as a pure harmonic/sinusoidal function of time about some mean value of surface soil temperature. Here observed mean daily air temperature & its amplitude have been used to serve the purpose. Upper reach (2-30 cm) of the soil profile is considered for estimation of thermal diffusivity and damping depth. The diurnal fluctuations of soil temperature in most soils do not penetrate below 50 cm and the assumption of constant temperature T_{avg} at infinite depth $z = \infty$ is no longer valid for greater depths. Hence, the thermal profile at 90 cm depth has not been evaluated. The overall average Nash-Sutcliffe efficiency (NSE) obtained for the top 4 layers (2, 6, 15, 30 cm) is 79.48%. The results have been improved (NSE=82.92%) by using mean & amplitude of estimated skin temp instead of air temperature. Further, more realistic results have been obtained (NSE=89.26%) with the combine use of amplitude of air temperature and mean values of skin temperature. *The thermal diffusivity estimated in this way is representative of the region with an average value 0.11 m^2/hr.*

xi. **Lifting Condensation Level (LCL)** has also been estimated using daily mean RH and air temperature data. The LCL is found to be the lowest in monsoon period (June-Sept) and increases in post monsoon period. It varies between 0.05 km (17th July 2016) to 2.24 km (26th April 2016).

xii. **Particle Size Analysis** of sediment samples using an instrument "Mastersizer" reveals that soil is of silt loam type. Sediment concentrations (gm/l) have been estimated with the help of vacuum pump filtration apparatus and oven drying method in laboratory.

xiii. **Quantitative Assessment of Soil Erosion** and its spatial variation is very important for designing effective erosion control measures for any watershed. In this study, three popular erosion prediction models, i.e., Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation (RUSLE) and Morgan-Morgan and Finney (MMF) models coupled with GIS and Remote Sensing were utilized at a spatial grid of 30 m x 30 m for quantifying the average annual soil loss and its spatial variation in Henval watershed (area = 75.593 km^2, elevation = 998-2686 m). Digitized LULC maps, soil map, slope map and other maps were developed to generate input maps of various parameters of all the three models. The IMD gridded data of 0.25^0 x 0.25^0 and observed rainfall data at Henval watershed was used for erosion modeling. As per USLE estimates it was found that about 31% of watershed area has average annual soil loss in the range of 30-40 t/ha/year and about 32% area has > 50 t/ha/year, which can be classified under very high to severe erosion zones. As per RUSLE estimates about 35% of the watershed area was found to have erosion rates >30 t/ha/year and 40% area with 15-20 t/ha/year, which can be classified under very high-severe and high erosion zones as per Singh (1992) classification. However, as per MMF estimates, the average annual soil loss was found to be comparatively less than the USLE and RUSLE models and about 49% area was found to be under moderate erosion zone and 41% area under slight erosion zone. The lower rates of erosion prediction due to MMF could be attributed to the reason as only one year data of rainfall was available and accurate estimates of soil physical and hydraulic properties as well as data on ET_t and ET_0 will be revised accordingly. Daily data on watershed sediment yield will also be required to validate the results of all the three models and choose the best model to describe the process of soil erosion within the Henval watershed.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2017/07
NMSHE STUDIES

1. Title - Water Census and Hotspot analysis in selected villages in Upper Ganga basin

2. Study team

1. Dr. P. K. Mishra, Scientist 'B', NIH, Roorkee - PI
2. Dr. R. J. Thayyen, Scientist 'D', NIH, Roorkee
3. Er. M. K. Nema, Scientist 'C', NIH, Roorkee
4. Dr. P. K. Sachan, Scientist 'C', NIH, Roorkee
5. Swagatam Das (JRF)
6. Minakshi Dutta (JRF)
7. Sanjay Kumar (PA)
8. Pankaj Kumar (PA)
9. Vishal (PA)

3. Objectives

The objectives of the project are:

a) To map water use pattern and livelihood linkages.
b) To map potential water hazard zones in the catchment.
c) To identify hotspot matrix components, hotspots analysis and adaptation strategies.

4. Sponsored by DST, New Delhi

5. Project Cost Rs. 90.99 Lakh

6. Brief Background

Himalaya is called the water tower of Asia. Himalayan rivers gather melt water from glaciers, snow and rainfall and deliver it to the millions living in the nearby plains across the Shivaliks. But the paradox lies in the fact this pristine water flowing in the Himalayan gorges have little use for the mountain people living on its slopes. Their livelihood is solely sustained by the springs and small rivulets as well as the rain and snowfall. The issues of the mountain people is often neglected in the Himalayan climate change discourse. This project is framed with the strong conviction that the sustainable Himalayan ecosystem is a mirage without addressing burning issues of the mountain people. Flash floods and landslides triggered by the frequent extreme events is becoming a regular feature for the mountain people. Reducing winter snowfall/extent/duration in consonant with the increase in winter temperature has already impacted the mountain hydrological regime as evident in the changing spring flow characteristics. The prime objective of the water census is to identify the water sources of the mountain villages and habitat, their issues and concerns, their habits and water use pattern. This fundamental understanding is necessary for evaluating the climate change impact on the mountain habitat and structuring and implementing adaptive strategies for sustaining the Himalayan ecosystem.

Water accounting, otherwise known as 'water census' is as important as other census activities for population, livestock, etc. carried out by the Government every decade. The Water Census is an emerging concept vital for creating Decision Support Capacity for water management agencies and policy makers. This provide a detailed accounting of water availability and use in a region. The main aim of the Water Census is to integrate diverse research on water availability and use as well as enhancing the understanding of relationship between water quality and water availability. Further, water census can be an umbrella platform in the hands of the stakeholders working in the field of water resources with

information on water availability, water uses, potential water hazards, and most importantly the livelihood linkages. Livelihood- water linkage is core to sustaining the Himalayan ecosystem for the mountain people. Water disasters are increasingly become a threat to the mountain habitat and economic development under changing climate. Identification and management of potential water disaster zones are also key to sustaining Himalayan eco-system.
Considering these issues, this project is aimed to map and develop the water census (preliminary) for the Upper Ganga basin with information at micro (village) level on water availability, water use pattern and livelihood linkage, potential water threat, water structures not only for the major streams but also for tributary streams and rivulets close to habitat. It is also envisaged to identify the hot spot matrix components and its analysis to identify the most vulnerable sites (villages). This can only be accomplished by extensive survey at micro-level (village). The project could become a platform to integrate input from all other studies and information aiding policy formulation and strategic planning. Methodology developed and refined through this project can be replicated across the Himalayan region in subsequent stages of this mission.

An inter-linked approach to water resources management is envisaged in this project with following key components of water governance.

- Consider all water resources
- Address water demand as well as water supply
- Address wastewater management as well as water supply
- Involve all sectors and civil society stakeholders
- Promote access and gender equality
- Recognize the economic (livelihood), social, and environmental value of water.
- Recognize the water related threat and hazards for preventive measures (adaptation and mitigation strategies)

7. Methodology

The project will be executed as per the following roadmap:

Sampling

The study requires extensive survey work of two distinct nature, one is to develop water census of at least 100 selected villages distributed across the altitudes of the upper Ganga basin and another is of engineering survey of selected water structures/ sites. The engineering survey will capture L-section, X-section and other design flood parameters of selected bridges and culverts in the area.

The upper Ganga is divided into two major zones comprising of Alaknanda basin and Bhagirathi basin. Each of this major zones will be sub-divided into five sub-zones based on the elevation (altitude), climate etc. At least 10 villages will be screened from each sub-zones through scientific assessment and field visit as well as with discussion with other stakeholders.

Water census will be carried out by developing an elaborative matrix to capture various WRM components. A structured questionnaire and field mapping will be done to gather the information. An engineering survey will include mapping of the water structures, bridges, culverts etc. Landslide and earth quake hazard zonation maps will be integrated in the engineering survey.

Road map/ work components:

1. Preparation of GIS layers and Base line data collection
2. Selection of villages
3. Training of Resource Persons
4. Launch workshop
5. Stage I survey
    a. Attributes for water census
6. Mid-term Workshop
7. Diagnostics report
8. Stage II survey
9. Finalisation of Hotspot analysis
10. Development of adaptive strategies
11. Concluding workshop
12. Report preparation and submission

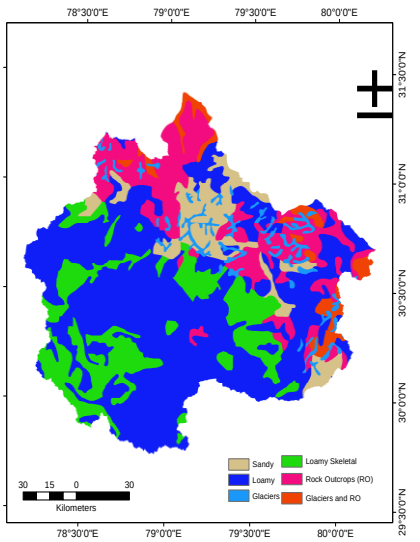
Activity chart (5 years)

Activity	1st year		2nd year		3rd year		4th year		5th year	
Selection of project personnel										
Preparation of GIS layers and Base line data collection										
Selection of villages										
Training of Resource Persons										
Stage I survey										
Mid-term workshop										
Diagnostics report										
Stage II survey										
Finalization of Hotspot Analysis										
Development of adaptive strategies										
Concluding workshop										
Report preparation and submission										

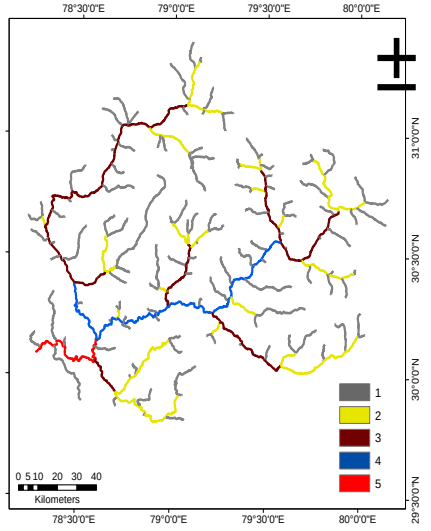
9. Present progress

- Preparation GIS layers and collection of baseline data, mainly from secondary sources is going on. Few thematic maps of the study area is provided separately.
- Process for identification and selection of villages is under progress.
- The rainfall induced extreme events (monsoon periods) for the last 10 years were followed in newspaper clippings for the study area. The year-wise extreme events are then plotted to investigate the pattern of occurrence. About 20% of the villages (out of 100) to be identified based on this.
- Collection and archiving geographical information of the study area carried out through various sources available online
- 10 nos. of Hand-held GPS and 02 nos. of Hand-held current has been already been procured to be used during field survey.
- Rainfall variability map has been prepared using 0.25x0.25 degree IMD data.

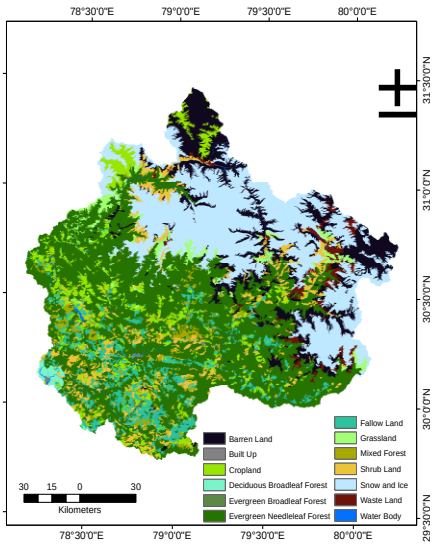
- About 7000 villages (as per Census 2011) has been browsed and identified their location (latitude, longitude, elevation) from Google Earth. The identified villages has been mapped using ArcGIS to identify the villages based on different criteria.



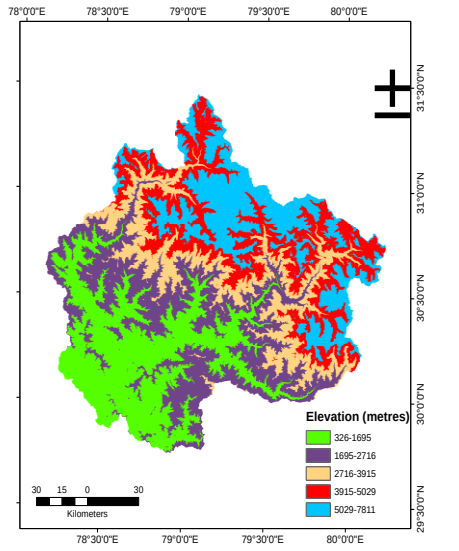
Soil map



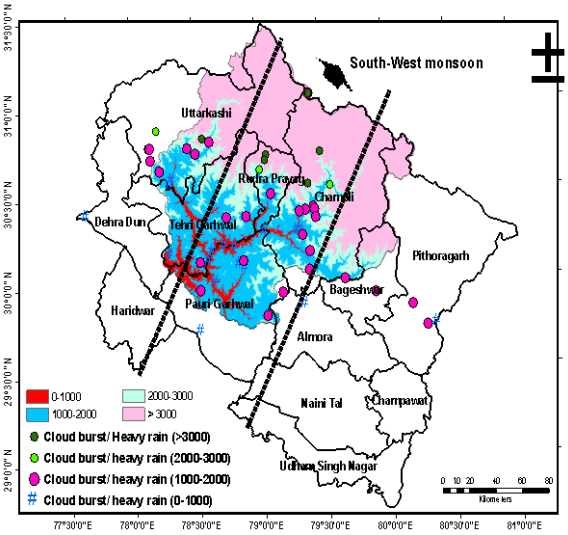
Stream order

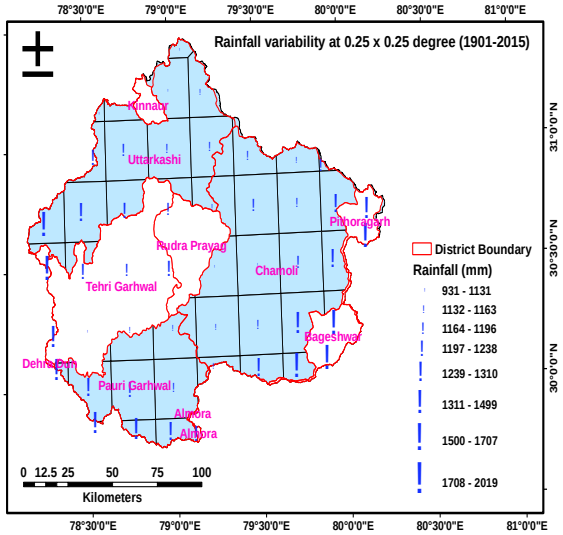


LULC



DEM


South-West monsoon
Uttarkashi
Rudra Prayag
Chamoli
Dehra Dun
Tehri Garhwal
Pithoragarh
Bageshwar
Haridwar
Pauri Garhwal
Almora
Naini Tal
Champawat
Udham Singh Nagar
0-1000
2000-3000
1000-2000
> 3000
Cloud burst/ Heavy rain (>3000)
Cloud burst/ heavy rain (2000-3000)
Cloud burst/ heavy rain (1000-2000)
Cloud burst/ heavy rain (0-1000)
0 10 20 40 60 80
Kilometers
77°30'0"E
78°0'0"E
78°30'0"E
79°0'0"E
79°30'0"E
80°0'0"E
80°30'0"E
81°0'0"E
29°30'0"N
30°0'0"N
30°30'0"N
31°0'0"N


Rainfall variability at 0.25 x 0.25 degree (1901-2015)
Kinnaur
Uttarkashi
Rudra Prayag
Chamoli
Pithoragarh
Tehri Garhwal
Bageshwar
Dehra Dun
Pauri Garhwal
Almora
Almora
District Boundary
Rainfall (mm)
931 - 1131
1132 - 1163
1164 - 1196
1197 - 1238
1239 - 1310
1311 - 1499
1500 - 1707
1708 - 2019
0 12.5 25 50 75 100
Kilometers
78°30'0"E
79°0'0"E
79°30'0"E
80°0'0"E
80°30'0"E
81°0'0"E
30°0'0"N
30°30'0"N
31°0'0"N

NEW STUDIES

SPONSORED RESEARCH PROJECT: NIH/WRS/2017/01

National Mission on Himalayan Studies (NMHS) Project

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

   National Lead: Prof. A.P Dimri, SES JNU, New Delhi

2. Project Team

   National Team

   Lead: Prof. A. P. Dimri, SES, Jawaharlal Nehru University, New Delhi, India
   Co-Lead: Dr. R. Thayyen, National Institute of Hydrology, Roorkee, Uttarakhand, India

Institutional PI's

Dr. Subimal Ghosh (Indian Institute of Technology, Mumbai, Maharashtra, India)
Dr. Renoj Thayyen (National Institute of Hydrology, Roorkee, Uttarakhand, India)
Dr. P. K. Mishra (National Institute of Hydrology, Roorkee, Uttarakhand, India)
Dr. Sarat Kar (National Center for Medium Range Weather Forecasting, Noida, UP, India)
Dr. Soumya Prasad (Jawaharlal Nehru University, New Delhi, India)
Dr. Sumanta Bagchi (Indian Institute of Science, Bangalore, India)
Dr. Raman Kumar (Nature Conservation Foundation, Mysore, Karnataka, India)
Prof. A. P. Dimri (Jawaharlal Nehru University, New Delhi, India)

3. **Title of the Project:** Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya

4. **Objectives:**

   The proposed project will address the following objectives, in particular for the Ganges and Indus within the western Himalayan Region, spanning select states:

   1. *Develop database for climate* and ecological processes across the elevation gradients
   2. Regional climate modeling with sub-grid orographic forcing, extreme hydrological events, biodiversity dynamics for the present (1970-2010)
   3. Regional climate model simulations for climate change scenarios (up to ~ 2100)
   4. Identify ecological restoration strategies to adapt to future climatic scenarios
   5. Communicate findings to stakeholders

5. **Present state-of-art**

Developing a clear understanding of climate change impacts on Himalayan snow cover, glaciers, water storage and associated rivers, forest and ecosystems are key scientific questions which need to be assessed as these affect large a proportion of the Indian population living along the southern rim of the Himalayas. To address these issues we need a comprehensive understanding of climatic and ecological process for the Himalayan region. Due to limitations imposed by availability of climatic and ecological data layers, we have a limited understanding of impacts of future climates on ecological, hydrological and climate regimes in the Indian Himalayan Region.

The Himalayan region consists of many glaciers and major north Indian rivers are fed from snow and glacier ice melt. About 90 % glacier area lay between 4000 to 6500 m a.s.l. The total glacier area decreased by around 20% between 1970 to 2010. Around 17 % of the Indian

Himalayan Region (WESTERN HIMALAYAS) is under permanent cover of Ice and snow and have more than 9200 glaciers and high altitude fresh water lakes. These data indicate the importance of climate on snow and ice melt in water resources management in the high altitude ungauged river basins of India. This is main reason that South Asia is thought to be the most vulnerable region is the possible impacts of climate change on water resources(Brun et al. 2015). The water resources from the main Himalayan region drain through Indus, Ganges and Brahmaputra rivers. The most widely reported impact of climate change in this region is the retreat of glaciers which has profound future implications for downstream water resources. Appreciable changes in the volume and/or timing of river flows are likely, but there is great uncertainty about the rate, and even the direction, of these changes(Dutta et al. 2015). This uncertainty in the rate and direction of hydrological changes in the Himalayan region places a major limitation on our ability to understand impact of climate change on Himalayan ecology and society.

The Himalayan region consists of diverse ecosystems, and encompasses a global biodiversity hotspot, and several Important Bird Areas. They span alpine, temperate, tropical non-monsoonal and monsoonal forest habitats, with heterogeneous topographic and landuse characteristics. As the world warms, several species and communities in mountain ecosystems have been documented to be moving to higher altitudes to keep track of suitable habitats. Faced with changing climates, species can (a) evolve adaptations to new climatic conditions, (b) adapt to new climatic conditions if they have pre-existing adaptations, (c) migrate to suitable habitats which have climatic conditions that match the species requirements or (d) go extinct if the species cannot evolve, adapt or migrate in response to changing climates (Corlett 2009). Anthropogenic climate change has already influenced biodiversity and ecological processes, and this is certain to increase in the coming decades. Changes in the distribution of species has been well documented in the temperate regions in the recent decades (Walther et al. 2002; Parmesan and Yohe 2003). There is limited baseline data to document such range shifts for the Himalayan region, and it has been forecast that a vast majority of species will display changes in distributions along rainfall and temperature gradients (Colwell et al. 2008; XU et al. 2009; Joshi et al. 2012)).

There is an urgent need to fill these major knowledge gaps in climate and ecological databases and models for the Indian Himalayan Region in order to provide policy makers with knowledge upon which well informed decisions can be made for natural resource management in the Indian Himalayan Region (WESTERN HIMALAYAS). Therefore, a collaborative study, encompassing monitoring, mapping and modeling of both ecological and climatic variables in the selected major river basins of the Himalayas, i.e., Ganges and Indus is proposed in this project.

6. Methodology (NIH)

Objective 1: Databases for tree, bird and mammal species diversity along altitudinal gradients in the selected river basins will be developed, by combining existing records, field surveys by research teams and citizen science. Phenological changes in vegetation during recent decades will be examined by satellite imageries and citizen science approaches. Landuse-landcover maps will be prepared, and patterns of habitat fragmentation examined. ***Database of temperature and relative humidity from 50 stations across the western Himalaya, especially from the data sparse regions and precipitation data from 10 stations will be established***.

Objective 2: Climate data will be upended with IMD station data and mathematical formulations for temperature and precipitation gradients will be derived. This will provide better insights on the orographic processes controlling these variables. Climate envelope –

biodiversity distribution relationships will be examined using niche models, including Maxium Entrophy models.

7. Research Outcome from the project:

Deliverables (NIH): Fine resolution temperature data from 50 AT/RH stations and 10 precipitation stations for at least 3years. Regional slope environmental lapse rate of temperature and precipitation gradients.

8. Cost Estimate:

a. Total cost of the project:	Rs. 2.1 Crore
NIH	Rs. 58.76 Lakh
b. Source of funding:	NMHS-MoEF

9. Progress of the project

To initiate the project an MoU between NIH and JNU has signed and the amount first instalment is transferred to NIH in February 2017. Recruitment of JRF has been completed and the procurement of 50 AT/RH and 10 rainfall stations are initiated and the tenders are received at the institute. It is expected to complete the installations of 60 stations by July 2017. Investigation of Slope lapse rate of temperature were carried out in Sutlej/Beas and Upper Ganga basin under monsoon regime. Two distinct temperature lapse rates, one constrained at higher altitude and one valley scale has been identified. Monsoon lowering is identified as a regional phenomenon. It is also suggested that the SELR variations linked with regional liquid condensation Level (LCL) in in turn linked with the meso- scale climate systems. The study also suggests that the higher altitude SELR has higher inter-annual variability as compared to valley scale lapse rate. Hence it is suggested to use valley scale lapse rate for modeling purpose.

NEW STUDIES

SPONSORED RESEARCH PROJECT: NIH/WRS/2017/02

National Hydrology Project (NHP)

1.1	**Project Title:**	Suspended sediment dynamics and sediment potential assessment in parts of Upper Ganga Basin (UGB) of Lesser Himalayan region through modeling techniques
1.2	**Lead Research Organization:**	
	Name of the organization	National Institute of Hydrology, Ministry of Water Resources, River Development & Ganga Rejuvenation, Roorkee, Uttarakhand
1.3	**Principal Investigator (PI) and Co-PI from Lead Organization:**	
		Dr. Pushpendra K. Singh, Scientist 'C'
		Dr. Sharad K. Jain, Scientist 'G'& Head, WRS Division
		Dr. Sanjay K. Jain, Scientist 'G'
		Dr. M. K. Goel, Scientist 'G'
		Dr. Renoj. Thayyen, Scientist 'D'
		Er. Suman Gurjar, Scientist 'C'
		Er. M. K. Nema, Scientist 'C'
1.5	**Partner Organization (if any)**	
	Name of the organization	Uttarakhand Irrigation Department
1.6	**Principal Investigator (PI) from Partner Organization**	
	Name & Designation	Er. Anubhav Nautiyal
	Address	Irrigation Design Organization, Roorkee, Haridwar, Uttarakhand - 247667
1.7	**Collaborators**	
1:	Name and Designation	Dr. Navratil Oldrich
	Address:	UMR-CNRS 5600 "Environment, City, Society" (EVS) Université of Lyon, School of "Environment and society. Study of the human past" 5 av. P. Mendès France, bâtiment Europe 69676 Bron cedex France
2:	Name & Designation	Er. Deepak K. Singh, Scientist
	Address	Land & Water Management Engineering, Division of Hydrology & Engineering, ICAR-Indian Institute of Soil and Water Conservation, Dehradun

NEW STUDIES

SPONSORED RESEARCH PROJECT: NIH/WRS/2017/03

National Hydrology Project (NHP)

10. Purpose Driven study (PDS)

11. Project team:

a. Project Investigator	Dr. L. N. Thakural, Sc C, PI
b. Co-PI Project Co-Investigator(s)	Dr Sanjay Kumar Jain, Sc G
	Er. D. S. Rathore, Sc F
	Dr. A. K Lohani, Sc G
	Dr. Renoj Thayyen, Sc D
	Dr. C. K Jain, Sc G
	Dr. S. P Rai, Sc F
	Dr. M. K. Sharma, Sc D

3. Title of the Project - HYDROLOGICAL MONITORING AND MODELLING OF A HIMALAYAN BASIN

4. Objectives

- Augmentation of the existing network by new instrumentation in the study area.
- Spatial and temporal analysis of the hydro-meteorological data.
- Snowmelt runoff modelling for the Tons River.
- Study major Ion chemistry in melt water in the river flows.
- Study the composition of stable isotopes in the river flows.

5. Present state-of-art

A hydrological network is an organized system for collection of information of specific kinds such as precipitation, run off, water quality, sedimentation and other climate parameters. The accuracy in the decision making in the water project design depends on how much information are available for the region concerned. Having enough relevant and accurate hydrologic information reduces the chances of under-design or overdesign and thus minimizes the economic losses, which leads to the overall increase in the benefit/ cost ratio. There are several ways to define the objectives of the hydrological network design, but the fundamental theme, in most cases, is the selection of an optimum number of stations and their optimum locations.

A complete network design answers the following questions pertaining to the collection of hydrological data:

(a) What hydrological variables need to be observed?

(b) Where do they need to be observed?

(c) How often do they need to be observed?

(d) What is the duration of the observation programme? and

(e) How accurate should the observations be?

6. Methodology-

Network Design: A monitoring network should be based upon two main boundary conditions, namely the monitoring objectives and the physical aspects of the system to be monitored. The identification of the monitoring objectives is perhaps the most important step in the design of monitoring systems, and also a very difficult one. It further complicated by the fact that various users of the network may have different objectives. Moreover, the physical basis of the variability of the relevant processes must be known as

this strongly determines the optimal sampling frequencies and densities. The central concept in this regard is the concept of effectiveness of the monitoring network. The level of effectiveness indicates the degree to which the information obtained from the network meets the network objectives. Therefore, the effectiveness can only be at a high level if the data collection and data analysis are optimally tuned to the objectives.

Field observation and laboratory testing: Installation of instruments in the field and collection of field data such as precipitation, temperature and stream flow etc. from field organizations. Winter snow samples will be collected in the month of May from different altitudes of the catchment to determine ion speciation and therefore, groundwater characterization. Water samples will be collected various locations on bimonthly basis by dip (or grab) sampling method. The samples will be collected at a depth of 15 cm to avoid introduction of floating particles.

Spatial and temporal analysis of the hydro-meteorological data: Spatio-temporal analysis will be carried out for various available hydro meteorological parameters namely rainfall, temperature, and discharge data using parametric (linear regression) and non-parametric (Mann-Kendall and Sen's slope Estimator) approaches.

Identification of moisture sources of snow hydrograph separation using isotopic studies: Physico-chemical parameters include pH, EC, temperature and dissolved oxygen will be analyzed in the field for of all type of samples (precipitation, river, spring, snow and ice etc.). It is essential to measure these parameters in the field since values readily change due to interaction with the atmosphere, and reliable measurements are required to determine ion speciation and therefore, groundwater characterization. The detailed parameters will be carried out at the laboratory. O & H isotopes: Oxygen and hydrogen isotopes are invaluable to hydrological studies as these are part of the water molecule itself. δ18O and δ2 H values may be used to assess evaporation during recharge, steam – aquifer interconnectivity, and mixing between different bodies of water within the basin. Similarity of δ18O and δ2H values between stream and aquifer may indicate interconnectivity, whereas isolated aquifers may contain waters with different δ18O and δ2 H values. Stable isotope systematic of waters around surface water bodies may be used to trace movement of seepage into / from nearby groundwater systems. The use of stable isotopes for hydrograph separation relies on the assumed conservative behavior of stable isotopes in water during flow through a catchment.

Major Ion Chemistry and Metal Contamination in Tons River: Water samples will be collected various locations on bimonthly basis by dip (or grab) sampling method. All the samples will be collected at a depth of 15 cm to avoid introduction of floating particles. Some parameters like pH, electrical conductance, temperature and dissolved oxygen will be measured on the spot by means of portable meters. For other parameters, samples will be preserved by adding an appropriate reagent and will be brought to the laboratory in sampling kits maintained at 4oC for detailed chemical analysis. Physico-chemical analysis of the collected samples will be conducted following standard methods.

Hydrological Modelling: Estimation of Snow Cover Area (SCA): In the present study, estimate of SCA will be made using IRS-WiFS images, NOAA-AVHRR images and MODIS SCA data product.

Assessment of lapse rate: In snowmelt runoff studies, air temperature is an important component. In rugged terrain like Himalayas, meteorological stations collecting air temperature are very sparsely located. Therefore, the observations being point data are not representative for the whole terrain. Land Surface Temperature (LST) is a key parameter for snowmelt runoff studies in the Himalayan region. Besides, air temperature is manually

measured and hence it is susceptible to errors. In such conditions, LST maps prepared from satellite images are an attractive and logical alternative. LST maps are a continuous dataset. These are prepared from satellite data, which automatically measures radiance value making it free from human errors, provided an accurate radiometric calibration of the sensor channels be achieved. In this study, LST will be measured for the Tons river basin using split-window algorithm. A number of studies have been carried out which gives good

7. Research outcome from the project

Stream flow including snowmelt runoff from the basin will be modeled using a snowmelt model. During April to June when the major component of stream flow is from snowmelt, prediction of stream flow is very beneficial for reservoir operation. Also this estimate is very much required for hydropower projects which are coming up in the Himalayan region.

8. Cost estimate:

a) Total cost of the project : Rs. 76.63 lakhs
b) Source of funding : NIH internal funds
c) Sub Head wise abstract of the cost

S. No.	Head	Amount (Rs.)
1	Remuneration/Emoluments for Manpower	2913000
2	Travelling Expenditure	800000
3	Infrastructure and equipment	2550000
4	Experimental Charges/Field work/Consumables	600000
5	Capacity building/Technology transfer	400000
6	Contingency	400000
	Total	7663000

10. Work Schedule:

a. Probable date of commencement of the project: 2017
b. Duration of the project: 4 Years (2017 to March 2021)
c. Stages of work and milestone:

Activity	Year 1	Year 2	Year 3	Year 4
Reconnaissance surveys, Data collection	←			
Problem conceptualization	→			
Meetings with participating agency	←	→		
Appointment of project staff	←			
Procurement of data, equipment, software	←	→		
Database development and instrumentation	→	→	→	→
Field visits for sample collection, glacier	←	→	→	→

expedition																
Applications of conceptual model					←								→			
Model calibration & Validation							←							→		
Report writing														←	→	

RESEARCH MANAGEMENT AND OUTREACH DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. V C Goyal	Scientist G & Head
2	Er. Omkar Singh	Scientist F
3	Dr. (Mrs.) Jyoti Patil	Scientist C (LCU)
4	Sri Subhash Kichlu	PRA
5	Sri Rajesh Agarwal	SRA
6	Dr. Dinesh Kumar	Res. Person (S)

RESEARCH MANAGEMENT & OUTREACH DIVISION (RMOD)

APPROVED WORK PROGRAMME FOR 2016-17

SN	Title of Project/Study	Study Team	Duration	Funding
	Internal Studies			
1.	**Study- 1 (RMOD/2015-16/TS-1)** Water Conservation and Management in Ibrahimpur Masahi Village of Hardwar District (Uttarakhand)	Omkar Singh (PI), V C Goyal, Dinesh Kumar	DOS: Apr 2013 DOC: March 2016 (extended upto Sep 2016)	NIH
2.	**Study-2 (RMOD/2015-16/TS-3)** WEAP Model set up for four sub-basins under Pilot Basin Studies (PBS) Programme, jointly with the RCs/CFMSs	**NIH HQs:** Jyoti Patil (PI), V C Goyal **NIH RCs/CFMSs:** Chandramohan T (Belgaum), Y R S Rao (Kakinada), T R Nayak (Bhopal), B Chakravorty (Patna), R V Kale (Jammu)	DOS: Apr 2015 DOC: Mar 2017 (Ongoing study)	NIH
	Sponsored Projects			
3.	Integrating hydrology, climate change and IWRM with livelihood issues: Development of methodology and a DSS for water-scarce Bundelkhand region in India- preparation of final report	V C Goyal (PI), T Thomas, Jyoti Patil, Rajesh Agrawal	DOS: Aug 2013 DOC: Jul 2016	TIFAC (Rs 56.64 lakh)
4.	IWRM Based Development Plan for Water Security in Four Districts of Bundelkhand Region in India	V C Goyal (PI), Omkar Singh, Jyoti Patil, T R Nayak, Ravi Galkate, T Thomas, R K Jaiswal, Shashi P Indwar, Subhash Kichlu, Rajesh Agrawal, Dinesh Kumar	DOS: Apr 2016 DOC: Dec 2016	MoWR, RD & GR (Rs 299.4 lakh)
5.	Development of a DSS (Hydrology) for Watershed Management in Neeranchal Project	V C Goyal (PI)	DOS: May 2016* DOC: Mar 2021	DoLR (GoI)

*Final approval from the DoLR (GoI) is awaited.

WORK PROGRAMME FOR 2017-18

SN	Title of Project/Study	Source of Fund	Study Team	Duration
1	WEAP Model set up for four sub-basins under Pilot Basin Studies (PBS) Programme **(Completed)**	Internal study	Jyoti P Patil + RCs	Apr 2015-Mar 2017
2	Development of IWRM Plan for Ibrahim-Masahi village (Haridwar district) **(Ongoing)**	Internal study	Omkar Singh (PI), V C Goyal, Dinesh Kumar	Apr 2013-Sep 2016; Extn. Sought upto Sep 2017
	Sponsored Projects			
3	Development of IWRM Plan for identified watersheds in Jhansi, Lalitpur and Chhatarpur districts **(Ongoing)**	MoWR-funded Bundelkhand-4 district project	**NIH:** V C Goyal (PI), Jyoti Patil **MPCST:** Sandeep Goyal, Rajesh Saxena **UP-RSAC:** Rajiva Mohan, Sudhakar Shukla	Apr 2016- Dec 2016; Extn. Sought upto Mar 2018
4	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts **(New Study)**	MoWR-funded project	V C Goyal (PI), Dinesh Kumar, Omkar Singh	Apr 2017- Mar 2020
5	Vulnerability assessment of identified watersheds in Neeranchal Project States **(New Study)**	Neeranchal Project	Jyoti P Patil + RCs	Jul 2017- Jun 2019

Study- 1 (RMOD/2015-16/TS-4)

Internal Study (Completed)

1. **Title of the Study:** WEAP Model set up for four sub-basins under Pilot Basin Studies (PBS) Programme
2. **Project team:**
    a. Project Investigator: Jyoti P Patil
    b. Project Co-Investigator(s): V C Goyal (PBS leader); Chandramohan T (RC-Belgaum), Y R S Rao (RC-Kakinada), T R Nayak (RC-Bhopal), B Chakravorty (CFMS-Patna), R V Kale (RCJ)
3. **Type of Study:** Internal
4. **Date of start:** 01.04.2015
5. **Scheduled date of completion:** 31.03.2017
6. **Duration of the Study:** 2 Years
7. **Study Objectives:**

    The main objective of the study is to set up the WEAP model for 5 sub-basins under the PBS Programme (Bina in MP; Zuari in Goa; Yerakalva in AP, Tawi in Jammu and Mahi in Bihar).

8. **Statement of the Problem:**

    The Water Evaluation and Planning System (WEAP) contain components that allow the appraisal of water management strategies at basin level with economic values. It has been developed by the Stockholm Environmental Institute (SEI) as a decision support tool for water resources management (www.weap21.org). It is being applied particularly in regions, which are characterized by water scarcity and increasing demands. In many basins, the groundwater extractions exceed the natural recharge resulting in a deterioration of the water qualities and worsening the water shortage. The application of integrated water management strategies (IWRM), including water reuse, artificial ground water recharge, use of brackish water, storage of natural and reclaimed water, demand measures and improved water allocation among competing water uses, becomes increasingly necessary.

    WEAP was applied successfully to model the hydrological features and water management strategies at many basins and it is being developed further. An example is the co-operation between the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and the German Federal Institute for Geosciences and Natural Resources (BGR) (www.acsad-bgr.org). A further example is the research project 'Integrated Water Resource Management in the Lower Jordan Rift Valley (SMART)', funded by the German Ministry of Education and Research (BMBF) (www.iwrm-smart.org).

9. **Methodology**

    Customization of the WEAP model will be carried out for the respective sub-basins on a daily/monthly time step. First, a database will be prepared covering the required hydrologic, demographic and socio-cultural data, to be used with the model. Then, a draft schematic of the WEAP model will be prepared defining the demand and supply nodes, etc. The draft WEAP schematic will be discussed with the local stakeholders, and their views will be incorporated in the final model set up. Results from the WEAP model

analysis will be used to prepare an integrated water management plan for the 4 sub-basins. Next, the integrated water management plan will be shared with the local stakeholders in the form of a training workshop.

10. **Timeline**:

S. N.	Work Element/ Milestone	2015-16				2016-2017			
		1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
1	Creation of database	√	√						
2	Draft WEAP model set up			√	√				
3	Stakeholders' meeting				√	√			
4	Finalization of WEAP model set up						√	√	
5	Training workshop								√

11. **Objective and achievement during last six months:**

Objective	Achievement
Draft WEAP model set up	Completed for Bina basin

12. **Recommendation / Suggestion:** No Specific comments

13. **Analysis & Results:** Draft model has been set up for Bina basin, MP

14. **End Users / Beneficiaries of the study:** Water Resources Planners of the respective sub-basins

15. **Deliverables:** Training workshop for the stakeholders

16. **Major items of equipment procured:** Nil

17. **Lab facilities used during the study:** Nil

18. **Data procured or generated during the study:** None

19. **Study Benefits / Impacts:** Outputs of the study will be used in preparation of integrated water management plans for each sub-basin

20. **Involvement of end users/beneficiaries:** Local stakeholders

21. **Specific linkage with Institution and /or end users/beneficiaries:** Various line departments (KVKs, Irrigation, WRD, Agriculture, Industry)

22. **Shortcoming/Difficulties:** Classified data of Mahi basin is difficult to access. Belgaum centre needs training to set up the model.

23. **Future Plan:**

WEAP model will be set up for Bina basin and results of the model will be used for formulating water management plan of the area.

Study– 2
Internal Study (Ongoing)

1. **Title of the Study:** Water Conservation and Management in Ibrahimpur Masahi Village of Haridwar District (Uttarakhand)

2. **Study Group:**

Investigators: Omkar Singh (PI), V.C. Goyal, Dinesh Kumar
Scientific/Technical Staff Subhash Kichlu, Rajesh Agarwal

3. **Type of Study**: Internal
4. **Date of Start:** April, 2013
5. **Re-Scheduled Date of Completion:** Oct., 2016 with extension
   (requires extension upto March 2018 due to delay in field execution of civil works*)
6. **Duration of the Study:** 3.5 years
7. **Study Objectives:**
   - Assessment of water demand in the study area.
   - Assessment of water availability in the study area.
   - Assessment of water quality in the study area & eutrophication status of ponds.
   - Preparation of water conservation plan for the study area.
   - *Rejuvenation of village pond/s by establishing a CW-based Natural Treatment System (NTS) and assessment of its performance by monitoring relevant water quality parameters.
   - Mass Awareness Activities.

8. **Statement of the Problem:**

In our country, most of the traditional sources of water (i.e. ponds) in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and face severe eutrophication mainly due to untreated input of wastewater in the ponds. The ponds located in the Haridwar District are also suffering from various hydrological problems and are at the verge of extinction, which require immediate intervention to restore for various uses. Rain water harvesting is a popular technique of developing surface water resources that can be used to provide water for livestock, domestic use and irrigation purposes. The purpose of rain water harvesting is to either augment existing water supplies or to provide water where other sources are not available. It also aims to provide water in sufficient quantity and of suitable quality for the intended use. Therefore, water conservation and its management of village ponds is essential for proper utilizing the water for beneficial use in the society. The water conservation and rain harvesting may be helpful for improving the livelihood of the peoples. The present study has been taken for Ibrahimpur Masahi revenue village, lying under Shipla Nadi-Halzora Nadi watershed (a tributary of Solani River), District Haridwar (Uttarakhand). The area of Ibrahimpur Masahi revenue village is 14.26 km^2. The Ibrahimpur Masahi revenue village consists of 5 five sub-villages under its jurisdiction, namely- Ibrahimpur, Masahi, Belki, Inayatpur and Halzora.

9. Methodology:

In this study, the necessary data from different sources was obtained for human population, cattle and crop acreage and types in the area. The village level data on demography, dwelling amenities, public buildings, etc. was also collected door to door during surveys. Field investigations were carried out to study soil characteristics (infiltration, soil texture and soil moisture, etc.) under different land uses. The surface and ground water quality monitoring and analysis was carried out as per standard procedures (APHA 1989; Jain and Bhatia, 1987). The water quality was evaluated for drinking (BIS-2012) and agriculture purposes (BIS-1987/2001; USDA 1954). Eutrophication of ponds was assessed using Carlson's Trophic State Index (Carlson, 1977) and to suggest rejuvenation of the ponds. Rainfall data for 27 years (1987 to 2013) was used to decipher dependable rainfall at 50% and 75% frequency levels based on data of nearest hydro-meteorological observatory at Roorkee. The rainwater harvesting potential of the sub-villages covering roof top water structures (school & Govt. building) would assessed using Ghisi et. al. (2006). The planning of wastewater management vis-vis rejuvenation of existing ponds using environmentally hazards free CW-based Natural Treatment System (NTS) is also proposed in the study. The brief methodology is given below:

Estimation of Domestic Water Requirement (Human Needs): In this study, the quantity of domestic water (m^3) per capita per day (DWR_d), per month (DWR_m), and per annum (DWR_a) was estimated as follows (based on vision of M/o DW&S, GoI):

$$DWR_d\ (m^3/day) = (P_{rural} \times 70 + P_{urban} \times 135) \times 10^{-3}$$
$$DWR_m(m^3/month) = (P_{rural} \times 70 + P_{urban} \times 135) \times 10^{-3} \times 30$$
$$DWR_a(m^3/annum) = (P_{rural} \times 70 + P_{urban} \times 135) \times 10^{-3} \times 365$$

Livestock Water Requirement: Livestock Water requirement (LWR) refers to the quantity of water required for drinking and animal hygiene conditions (animal and place washing). The water required for livestock rearing depends on the number of animals and consumptive use per head (Amarasinghe *et al.*, 2004). The total livestock water requirement daily (LWR_d, m^3/day), monthly (LWR_m, m^3/month) and annually (LWR_a, m^3/annum) were estimated by adding water required for all domestic animals such as- cattle (cow family), buffaloes, bovines (cow family)/yak, sheep, goat, swine, and poultry (Frasier and Hyers, 1983):

$$LWR_d\ (m^3/day) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \times 10^{-3}$$
$$LWR_m\ (m^3/month) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \times 10^{-3} \times 30$$
$$LWR_a\ (m^3/yr) = \{C \times 85 + B \times 85 + B_o \times 85 + S \times 10 + G \times 10 + S_W \times 15 + P \times 0.40\} \times 10^{-3} \times 365$$

Where, C is number of Cattles, B is number Buffaloes, B_o is number of Bovines/yalk, S is number of Sheep, G is number of Goats, S_W is number of Swines, P is no. of birds (poultry).

Crop Water Requirement: Crop water requirement was estimated broadly using Inductive method based on standard crop deltas (Varshney, et. al, 1983; Garg, 2005). Accordingly, the quantity of water requirements (IWR, m^3) is the product of cropped area (CA, m^2) and standard delta (Δ, m) of respective crops during different seasons as given below:

$$CWR\ (m^3) = CA\ (m^2) \times \Delta\ (m)$$

Typical values of standard deltas (S_Δ) are adopted from Table (Varshney, et. al, 1983).

Probability Analysis of Rainfall Data: The analysis of rainfall trend for the study area was carried out using 27 years monthly rainfall data pertaining to Hydro-meteorological

Observatory of NIH Roorkee. The monthly data was arranged in descending order of their magnitude. The recurrence interval T (return period) of a particular magnitude was determined using Kimball's method (Weibull, 1939) as below:

$$T = (n + 1)/m$$

Where, T= recurrence interval (return period), n= total number of items data series, m= order number or rank of any particular storm value after arranging in descending order of their magnitude. The frequency F (expressed as percent of time) of that storm magnitude (having recurrence interval, T) is given by:

$$F\ (\%) = (1/T)100$$

In the present study, frequency curve (Precipitation P or I v/s F%) were developed for monthly rainfall data of the Roorkee using 27 years rainfall data.

Eutrophication Assessment of Ponds: Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977) based on Secchi disk transparency, phosphate concentration and chlorophyll content. The equations are given below:

TSI (TP) = 14.42 ln (TP) + 4.15 .....(Eq. 1)
TSI (SD) = 60 - 14.41 ln (SD) …..(Eq.2)
TSI (CHL) = 9.81 ln (CHL) + 30.6 .....(Eq. 3)

Preparation of Water Conservation Plan: The water conservation plan in the sub villages consist of following steps:

Step 1: Estimation of rainwater harvesting potential in sub-Villages: The volume of rainwater that could be harvested per household per month was estimated as per Eq. given by Ghisi et al., 2006, as below (Aladenola and Adeboye, 2010; Ishaku, et al., 2013):

$$VR = \frac{R.HRA.RC}{1000}$$

Where, VR= monthly volume of rainwater per household (m^3), R= monthly rainfall depth (mm), HRA= household roof area (m^2), and RC= runoff coefficient (dimensionless). The basic monthly balance would be estimated by subtracting monthly water demand from collected monthly rainwater and is expressed as below:

$$Wa = Iv + Vc - Vu$$

Where, Wa= water available, Iv=initial volume in storage, Vc=volume collected and Vu= volume used.

The analysis will include estimation of:

- Household monthly harvested rainwater & balance after flushing
- Household monthly harvested rainwater & balance after flushing & laundry (combined)

Apart from above, the following analysis will also be carried out:

- Rainwater harvesting potential of village ponds
- Monthly roof top water harvesting potential of schools/govt. buildings

Step 2: Planning for Wastewater Management of Village ponds: The ponds are generally used as sink for all wastewater as well as for solid waste generated in the villages. Accordingly, village ponds are going to vanish due to the entry of sewage causing eutrophication. Therefore, it is proposed to rejuvenate pond (s) through establishment of a

CW based Natural Treatment System (NTS) for treating village wastewater entering in the ponds and developing ponds for increasing rainwater harvesting potential for the benefit of local peoples.

10. Timeline:

S. N.	Major Activities	2013-14			2014-15			2015-16			2016-17		2017-18	
		Q1	Q 2	Q3-Q4	Q1-Q2	Q3	Q4	Q1-Q2	Q 3	Q 4	Q1-Q2	Q3-Q4	Q1-Q2	Q3-Q4
1	Review of literature													
2	Reconnaissance survey of the study area													
3	Procurement/Collection of necessary data													
4	Field investigations (WQ, survey of ponds													
5	Analysis of data for assessment of water demand, availability, WQ													
6	Door to door survey for village level data/ bathymetric survey of pond/eutrophication assessment													
7	Preparation of water conservation plan													
8	Rejuvenation of Village Pond/s by Establishing CW-based NTS & its Performance evaluation, Mass awareness activities													
9	Report/s preparation													

11. Objectives and achievements:

Objectives	Achievements
i) Assessment of water demand in Ibrahimpur Masahi Revenue Village of the Haridwar District.	• Estimation of water demand for domestic, livestock and agriculture has been completed based on data obtained from various sources. (June, 14).
ii) Assessment of water availability in Ibrahimpur Masahi Revenue Village of the Haridwar District.	• Frequency analysis of monthly rainfall data pertaining to Roorkee for 27 Years (1987-2013) was carried out and deciphered dependable rainfall at F=50% and F=75%, respectively. Accordingly, Rain Water Availability at village and watershed level was carried out. (June, 14).
	• Measurement of cross section, water level and velocity data (Sept., 2014) of Shipla-Halzora Nadi was monitored at Imlikhera. The data was analysed to estimate the discharge of the river for Sept., 2014(March, 2015). • The soil texture and soil moisture data was analysed for the study area (March, 2015). • Drainage pattern was prepared using DEM (March, 2015). • Landuse/Landcover map of Ibrahimpur Masahi village was prepared using google earth images.

	• Groundwater utilization data pertaining to Hand pumps and Tub wells used for drinking and irrigation purposes was collected in the study area.
iii) Assessment of Water Quality Status & Eutrophication of Ponds in Ibrahimpur Masahi Revenue Village of the Haridwar District.	• Water quality sampling from River, Ponds, Hand Pumps/Tubewells, etc. was carried out in the study area and data was analyzed (March, 2015). • Water quality parameters necessary for Eutrophication analysis (Secchi depth, phosphate, Blue Green Algae, Chlorophyll, etc.) of ponds was monitored (Dec. 2015).
iv) Preparation of water conservation plan for the identified village (s)	• Bathymetric survey of village pond at Masahi was completed (Dec. 2015). • A door to door survey was conducted in the sub-villages to collect necessary data pertaining to demography, dwelling amenities, public buildings, etc. for preparation of water conservation plan in the study. • Capacity estimation of village ponds was completed for RWH potential of ponds using depth data of bathymetric survey. • Estimated monthly rainwater harvesting potential of 5 sub villages based on door to door survey.
v) Rejuvenation of village pond/s by establishing a CW-based Natural Treatment System (NTS) and assessment of its performance by monitoring water quality parameters	• The works related to rejuvenation of pond (viz. de-weeding/de-silting) at village Ibrahimpur Masahi have been initiated during Nov./Dec. 2016 and remaining works are in progress. • Establishment of a CW-based NTS in pond located at village Ibrahimpur Masahi is also in progress.
vi) Mass Awareness Activities	**(i)** Conducted a villager's meet to interact with selected Farmers along with Gram Pradhan on dated 8/10/2016 at NIH, Roorkee regarding IWRM Plan. **(ii) Activities on NIH Foundation Day in Villages involving Scientists/staff of NIH (16/12/2016):** • Rally/Prabhat Feri and oath taking by children (Sankalp) in different Schools of 5 Sub Villages of by involving their respective school teachers for creating awareness amongst children and villagers. • Plantation in different schools of the Ibrahimpur Masahi revenue sub villages in association of ATHAK Foundation, Roorkee. • General awareness program on water and cleanliness issues (bhajan/Lokgeet, etc.) for villagers through hiring services of Rashtriya Jagriti Dal (Village Banjarewala, Dist. Haridwar). • Screening of water related films/activities on Bioscope for school children (through Delhi based Agency) • Theater Program on water related issues by local School children (through a Delhi based Agency) (iii) Soil Testing using PUSA-STFR Meter at selected farmers field, preparation/distribution of Soil Health Card to selected Farmers in the study area. (iv) The Division has coordinated Pond Cleaning work through involvement of Scientists/staff of all Divisions of the Institute under Swachh Bharat Abhiyan of GoI/MoWR during 16-31 March, 2017 at Village Masahi in the study area.

12. Recommendation / Suggestion:

Recommendation / Suggestion/Queries	Action Taken
-	-

- **13. Analysis & Results:** The water demand for domestic, livestock and agricultural uses has already been estimated for the Ibrahimpur Masahi Revenue Village. Water quality monitoring & analysis of different sources, delineation of drainage pattern, soil moisture, soil health card, textural analysis of soil and measurement of discharge of Shipla-Haljora nadi was also completed. The bathymetric survey of Masahi pond, Capacity estimation of RWH potential of ponds, monthly rainwater harvesting potential of 5 sub villages based on door to door survey. The latest progress includes: preparation of a draft water management plan, soil testing using Pusa STFR meter, preparation of soil health cards for farmers and mass awareness activities including cleaning of village ponds.

14. End Users/Beneficiaries of the Study: Village Panchayats and Dist. Administration
15. Deliverables: Technical report, papers and establishment of CW-based NTS in pond/s
16. Major items of equipment procured: -
17. Lab facilities used during the study: Soil & GW Lab, WQ Lab
18. Data procured or generated during the study: Soil Characteristics, Water Quality, Discharge
19. Study Benefits / Impacts: Helpful for improving the livelihood of the local people
20. Involvement of end users/beneficiaries: Local people
21. Specific linkage with Institution and /or end users / beneficiaries: Village Panchayats
22. Shortcoming/Difficulties: Observed initial difficulties of executing civil works in the pond for establishing NTS in the field.
23. Future Plan: The future Plan of the study is given below:

- Rejuvenation of village pond/s by establishing a CW-based Natural Treatment System (NTS) and assessment of its performance by monitoring relevant water quality parameters.
- Mass Awareness Activities.

Study- 3

Sponsored Project (Ongoing)

1. **Title of the Study:** Development of IWRM Plan for Jhansi, Lalitpur and Chhatarpur districts (MoWR-funded Bundelkhand-4 district project)
2. **Project team:**
    d) Principal Investigator: Dr V C. Goyal
    e) Project Co-Investigator(s): Dr Jyoti Patil (NIH)
    Dr Sandeep Goyal and Dr Rajesh Saxena (MPCST, Bhopal)
    S/Sri Rajiva Mohan and Sudhakar Shukla (UP-RSAC, Lucknow)
3. **Type of Study:** Action research
4. **Date of start:** 01.04.2016
5. **Scheduled date of completion:** 31.07.2017 (Extn sought from MoWR upto Mar 2018)
6. **Duration of the Study:**
7. **Study Objectives:**
    The main objective of the study is to develop IWRM plan for three watersheds of Bundelkhand region
8. **Statement of the Problem:**
    Bundelkhand is witnessing fluctuations between extremes in weather conditions– long drought spell and intense monsoon rainfall. For most part of the year, the residents of Bundelkhand region experience acute scarcity of water for domestic, agricultural and industrial use. Water sources are varied and often seasonal, ranging from ponds, tanks, lakes and streams to open wells, bore wells and irrigation canals radiating out from large-scale dams. Most agriculture is single-crop and rainfed with supplementary water from open wells. Thus, large numbers of farmers are highly dependent on the monsoon rains to recharge these wells.

    To improve the water situation in the region, it is felt that an integrated approach to water management has to be undertaken. The water management approach has to be built around the concept of efficient management and sustainability (quality and quantity), and building of livelihood systems at village level for community based management of water challenges.
9. **Methodology**

    The methodology of the study includes conducting a rapid vulnerability assessment using IPCC approach, and working out water budgeting in the three watersheds using secondary data. Finally an IWRM Plan will be developed to introduce an integrated approach of water management linked with the concept of livelihood in the identified three watersheds of Bundelkhand region. The IWRM Plan will have three sections- (i) Water management, (ii) crop management, and (iii) livelihood management.

    With a view to address the scarcity of water availability in the study region, establishment of demonstration rainwater harvesting systems is planned at few identified village sites (mainly school buildings). With the help of MPCST, Bhopal, demonstration and training of stakeholders on livelihood activities is being taken up in few identified villages.

Experiences of such demonstrations provide useful inputs in preparing the "Livelihood Management" section of IWRM Plan.

Maps have been prepared showing suitable water harvesting sites in the three watersheds. Field verification of these suggested sites will be undertaken for finalization of the suitable sites based on the local site conditions. Also, a number of ponds are available in the three watersheds. Bathymetry survey and water quality assessment of these ponds is planned after the monsoon is over. Both these surveys will provide useful inputs for the "Water Management" section of the IWRM Plan.

For the "Crop Management" section, the secondary data from KVKs and the results from the Focused Group Discussions (FGD) conducted at few field sites will be used.

The draft IWRM Plans will be discussed with the stakeholders in the respective watersheds by organizing Stakeholders' workshops. After incorporating the feedback and suggestions of the stakeholders, final IWRM Plan will be handed over to the district authorities in the respective watersheds.

10. **Timeline**:

S. N.	Work Element/ Milestone	2016-17				2017-18			
		I	II	III	IV	I	II	III	IV
	Collection of data from secondary sources in UP & MP								
	Water balance estimation								
	First stakeholders' workshop								
1	Vulnerability assessment								
2	Establishment of demonstration rainwater harvesting systems at identified sites								
3	Demonstration/training of stakeholders on livelihood activities in identified villages								
4	Field verification of suitable water harvesting sites								
5	Bathymetry survey and water quality assessment of ponds								
6	Preparation of draft IWRM plan								
7	Stakeholders' feedback workshop on draft IWRM plan								
8	Submission of IWRM plan to district authorities								

11. **Objective and achievement during last six months:** To be presented.
12. **Analysis & Results:** To be presented.
13. **End Users / Beneficiaries of the study:** Water Resources Planners of respective district
14. **Deliverables:** IWRM Plan. Awareness on the water situation and management through training workshop for the stakeholders
15. **Major items of equipment procured:** Remote survey boat
16. **Lab facilities used during the study:** Nil
17. **Data procured or generated during the study: -**
18. **Study Benefits / Impacts:** Outputs of the study will be used in preparation of District Irrigation Plans and District Agricultural Plans by the respective line departments

Study-4

Sponsored Project (New)

1. Title: Rejuvenation of Village Ponds for Identified Villages in Muzaffarnagar and Meerut Districts of western U.P.

2. Study Group:

Investigators: V.C. Goyal, Dinesh Kumar and Omkar Singh
Scientific/Technical Staff Subhash Kichlu, Rajesh Agarwal, Staff of Soil Water Lab

3. Nature of Study: Action research

4. Date of start: April, 2017
5. Expected date of completion: March, 2020

6. Weather externally funded or not: MoWR sponsored project

7. Objectives:

- Rejuvenation of identified village ponds by carrying out de-weeding, de-silting and strengthening of the embankments,
- Establishment of appropriate Natural Treatment System (NTS) technology for treatment of wastewater entering into these ponds,
- Pilot demonstrations on the use of treated wastewater from ponds for agricultural purposes,
- Assessment of the impact of the rejuvenation of ponds by monitoring relevant water quality parameters and groundwater levels,
- Mass Awareness Activities.

8. Statement of the Problem

Presently, ponds in the villages of western UP are in a very bad shape. Ponds are generally used as sink for all wastewater as well as for solid waste generated in the villages leading to the deposition of solid wastes and growth of weeds. Capacity of these ponds has been reduced drastically as removal of silt is not taken up on regular basis. Encroachment of the catchment area has added to the dismal state of such ponds in the rural and per-urban areas.

Through the proposed action research study, it is proposed to rejuvenate the identified ponds in a retrofitting mode by carrying out de-weeding, de-silting and strengthening of the embankments. Also, it is proposed to establish an appropriate Natural Treatment System (NTS) technology, such as Waste Stabilization Ponds (WSP), Constructed Wetlands (CW), for treatment of the wastewater entering into these ponds. The rejuvenated ponds with treated wastewater shall then be used for groundwater recharge, limited agricultural use, as well as for livelihood activities such as fishery.

The project aims to develop a model for rejuvenation of village ponds, which will facilitate the practice of water conservation and management in the selected villages in totality for water security and sustainability, which is also expected to be a role model for the Gram Panchayats in other part of the UP/country.

9. Study Area

The study is a part of western Uttar Pradesh. The villages have been selected in Muzaffarnagar and Meerut Districts, respectively.

Table 1: Villages selected in the project area

S. N.	Village	Block/Tehsil	District
1.	Bhora Kalan	Shahpur,	M.Nagar
2.	Bhora Khurd	Shahpur	M.Nagar
3.	Siwaya Jamalullapur	Sardhana	Meerut
4.	Antwara	Khatauli	M.Nagar
5.	Pavli Khas	Daurala	Meerut
6.	Munawwarpur Khurd	Khatauli	M.Nagar
7.	Roni Hazipur	M.Nagar	M.Nagar
8.	Khera Mastan (to be replaced by) Mohammadpur Modern Budhana & Itawa	M.Nagar Baghra, M.Nagar Budhana, M.Nagar	M.Nagar
9.	Biral	Budhana	M.Nagar

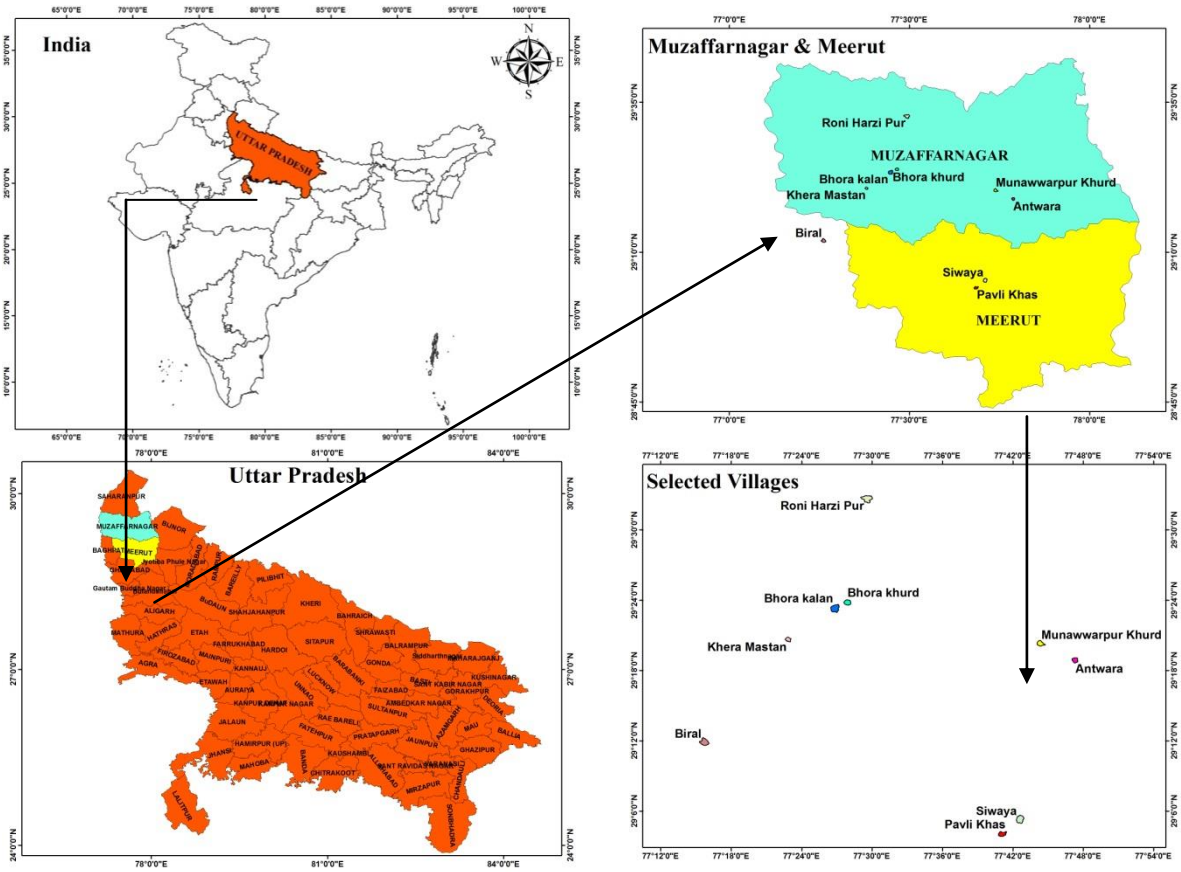


Figure 1: Selected area for action research on IWRM plan for water security in identified villages of western Uttar Pradesh

10. Brief methodology:

After field measurement of the dimensions of the ponds, DPRs will be prepared for estimation of the civil works, etc. involved in the pond rejuvenation related works. Execution of the pond rejuvenation works will be carried out by awarding contract to an identified agency.

In the next phase, an appropriate NTS technology will be established in the identified ponds for treatment of the wastewater entering into these ponds. Side walls/embankments of the ponds will be strengthened and a small pathway will be made on the periphery of the ponds.

S. N.	Work Element/ Milestone	2017-18				2018-19				2019-20			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Preparation of DPR for rejuvenation related works												
2	Field execution of rejuvenation related works												
3	Establishment of NTS technology												
4	Pilot demonstration on use of treated wastewater for agricultural purposes												
5	Monitoring of water quality parameters and groundwater level												
6	Mass awareness activities												

11. Mile Stones and Expected Outcome/Output:

- Rejuvenated village ponds
- Field manual for rejuvenation of village ponds
- Technical report(s) and publications

Study- 5

Sponsored Project (New)

1. **Title of the Study:** Vulnerability assessment of identified watersheds in Neeranchal Project States
2. **Project team:**

   Dr Jyoti P Patil and nodal scientists from Regional centres (Bhopal, Patna, Kakinada, Belgaum)
3. **Type of Study:** Sponsored- Neeranchal National Watershed Programme (NNWP)
4. **Date of start:** 01.07.2017
5. **Scheduled date of completion:** 30.06.2019
6. **Duration of the Study:** Two years
7. **Study Objectives:**

The aim of the study is to assess the vulnerability to climate change for the identified watersheds of 9 Neeranchal Project States.

8. **Statement of the Problem:**

Assessing vulnerabilities is the process of identifying, quantifying, and prioritising the vulnerabilities in a system. Vulnerabilities from the perspective of climate change means assessing the threats from potential hazards to population, infrastructure, development goals etc. VAs can help to improve adaptation-planning, allocation of resources and raising awareness about climate change at different levels. Vulnerabilities cannot be measured directly; it has to be inferred with the help of various variables.

9. **Methodology**

Focus of this study has been on generating Livelihood Vulnerability Index (LVI) by IPCC approach for watersheds under NNWP. The IPCC-LVI approach would facilitate the identification of areas, which are vulnerable to climate change and need special attention towards adaptation. The socio-economic, environmental, agriculture, water resource, health, climate and forest indicators of vulnerability will employed and classified into adaptive capacity (A), sensitivity (S), and exposure (E). Identification and classification of indicators for vulnerability assessment is always subjective keeping in view the importance of indicators in the spatial context, availability of quantitative/measurable data, time series availability of data and to some extent any indicator having proxy representation. They will be classified manually as it is not possible to carry out such a classification statistically. Statistics is based on numbers and do not take into account the physical nature of the indicator.

10. **Timeline**:

S. N.	Work Element/ Milestone	2017-18			
		I	II	III	IV
1	Select a set of indicators to assess the vulnerability of people, livelihoods and ecosystem				
2	Collection of data from secondary sources				
3	Calculate Livelihood Vulnerability Index using the IPCC approach				
4	Highlight areas that are most vulnerable and need to be protected as well as the areas that need improvement				
5	Suggest measures/ strategies to cope up with climate change events in future				

11. **Objective and achievement during last six months: NA**
12. **Recommendation / Suggestion:** NA
13. **Analysis & Results:** NA
14. **End Users / Beneficiaries of the study:** Integrated Watershed Management Programme
15. **Deliverables:** Areas which are most vulnerable to climate change and need further attention will be highlighted
16. **Major items of equipment procured:** Nil
17. **Lab facilities used during the study:** Nil
18. **Data procured or generated during the study:** -
19. **Study Benefits / Impacts:** Outputs of the study will be used in the development of DSS(Hydrology), and later on for preparation of DIP/ DPR by the respective line departments
20. **Involvement of end users/beneficiaries:** IWMP
21. **Specific linkage with Institution and /or end users/beneficiaries:** Various line departments (KVKs, Irrigation, WRD, Agriculture, Industry)