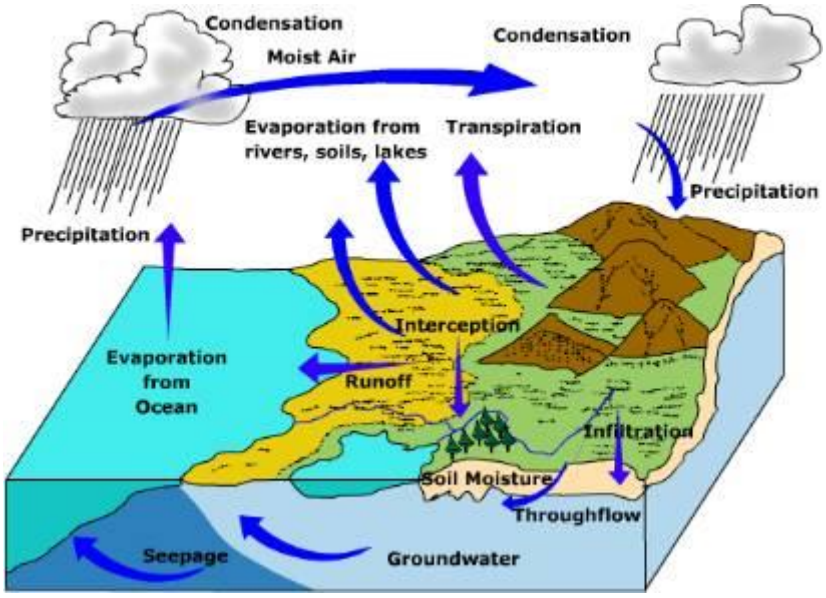
AGENDA AND AGENDA NOTES FOR THE 49th MEETING OF THE WORKING GROUP OF NIH

4 – 5 NOV., 2019
AT 1100 HRS



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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 49th MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

ITEM NO. 49.1 Opening Remarks by the Chairman

ITEM NO. 49.2 Confirmation of the minutes of 48th meeting of the Working Group

The 48th meeting of the Working Group was held during 2-3 May, 2019. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/WG/NIH-10 dated 28 May 2019**. No comments were received on the circulated minutes. A copy of the minutes of the 48th Working Group is given in **Annexure A(Page#4).**

The Working Group may please confirm the minutes.

ITEM NO. 49.3 Action taken on the decisions/ recommendations of the previous Working Group meeting

During the 48th 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. 49.4 Presentation and discussion on the status and progress of the work programme for the year 2019-20.

The approved Work Programme of the six Divisions of the Institute for the year 2019-20 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 2019-20**					
	New		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Environmental Hydrology	1	1	1	3	**06**	**-**
Ground Water Hydrology	-	-	2	13	**15**	**4**
Hydrologic Investigation	2	-	-	8	**10**	**5**
Surface Water Hydrology	-	-	8	2	**10**	**-**
Water Resources System	-	3	4	12	**19**	**-**
Research Management & Outreach	-	-	2	5	**7**	**-**
Total	**3**	**4**	**17**	**43**	**67**	**9**

During the present meeting, Division-wise progress and status of the work programme for the year 2019-20 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2019-20.

ITEM NO. 49.5: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 48th MEETING OF WORKING GROUP

MINUTES OF THE
48TH MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING 2-3 MAY 2019

The meeting was held under the Chairmanship of Dr. S K Jain, Director, NIH. The list of participants of the meeting is given in Annexure-I.

ITEM NO. 48.1: OPENING REMARKS BY THE CHAIRMAN

Chairman, WG, welcomed the WG members and the Scientists of NIH. He informed about the Foundation Day celebration of NIH in December 2018 and the special publications prepared by NIH. He mentioned about a NIH publication entitled 'Climate change and its impacts on water resources of India'. He requested the members to suggest topics for such publications in key areas, and indicate their willingness to collaborate with NIH in this endeavour. He informed about the organization of a conference in Hindi in December 2019, and requested the members to actively participate in it. Also, he desired frequent interaction of NIH scientists with the WG members on specific studies.

The Chairman then requested the WG members to give their general observations, suggestions and remarks on the scientific activities of the Institute. These are summarized below:

S N	Member	Suggestion(s)
1.	Sh. Wasim Ahmed	▪ Collaboration with NIH on spring rejuvenation program
2.	Dr. K V Singh	▪ Site tour of WG members on ongoing/completed studies
3.	Dr. R D Deshpande	▪ Objectives of some studies not carefully formulated ▪ Preparation of PPTs needs improvement ▪ Not all studies need to be presented in every meeting ▪ All NIH scientists should be present during the deliberations ▪ Data interpretation workshops should be organized among NIH groups with participation of concerned WG member(s) ▪ NIH may plan a new program on Hydromatics ▪ NIH may bring out a report on 'Hydrologic processes in Himalayas' ▪ NIH may organize an International Symposium on 'Advances in Hydrologic Research'
4.	Dr. S P Aggarwal	▪ NIH's may contribute more to solve real world water problems
5.	Dr. R K Goyal	▪ Need for time management in presenting studies ▪ Overlap of scientists in many studies ▪ Mentioned ICAR's guidelines on scientists involvement in studies
6.	Dr. Man Singh	▪ Emphasised on data availability
7.	Prof. A K Saraf	▪ Change detection is an important consideration in many studies
8.	Prof. M L Kansal	▪ Requested for active participation in Roorkee Water Conclave 2020
9.	Dr. S S Grewal	▪ Water recharge and allocation planning in industrial belt of Aravalli hills ▪ Drying of springs in Shiwaliks and Arvallis ▪ Lesser number of studies should be presented ▪ Pond rejuvenation work to be widely publicized
10.	Dr. Kaushal K. Garg	▪ Collaborative work with NIH on watershed interventions ▪ Consider Ecosystem Services as part of hydrology studies ▪ While working out climate change scenarios, include landuse changes along with precipitation and temperature
11.	Prof. Ramakar Jha	▪ Prepare e-books ▪ Work for patents

		▪ Sponsored projects need not be presented in detail
12.	Prof. A P Dimri	▪ Establishment of High Performance Computing Centre ▪ Avoid duplication of studies among Divisions of NIH ▪ Organize workshop on 'Statistical interpretation of hydrologic data' ▪ Organize national workshop on 'Rejuvenation of village ponds' ▪ Plan new programs on 'Hydrology for atmosphere-land-underground' and 'Hydrologic regimes of India' ▪ Understanding of processes is important while selecting a model ▪ Highlight societal aspects of NIH's work
13.	Dr. Sadhana Malhotra	▪ Success stories need to be documented and disseminated ▪ Presentation skills need improvement
14.	Sh. Sudhindra Mohan Sharma	▪ More training programs for field engineers ▪ More interaction with industry
15.	Dr. Anil Guatam	▪ Collaboration with NIH on spring rejuvenation program

Next, the Chairman asked the Member-Secretary to take up the agenda.

ITEM No. 48.2: CONFIRMATION OF THE MINUTES OF 47th MEETING OF THE WORKING GROUP

The 47th meeting of the Working group was held during 23-24 October 2018. The minutes of the meeting were circulated to all the members and invitees vide letter No. RMOD/WG/NIH-10 dated 04 December 2018. The members confirmed the minutes of the 47th Working Group meeting.

ITEM No. 48.3: 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 47th working group meeting.

ITEM Nos. 48.4 & 48.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2018-19 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2019-20.

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2018-19 and proposed work program for the year 2019-20. Accordingly, the progress of various studies and sponsored projects was presented by all Scientific Divisions during the two day deliberations of the Working Group. The Division wise minutes of each study/project presented during the meeting are given next.

ENVIRONMENTAL HYDROLOGY DIVISION

Dr. J.V. Tyagi, Scientist 'G' & Head of EHD presented a brief overview of the Division including scientific manpower, status of studies, consultancy projects, publications, and technology transfer activities. Thereafter the scientists of the Division presented the progress of their studies and the comments/suggestions received from the Working Group members are summarized below.

Progress of Work Program for 2018-19

SN	Study	Recommendations/Comments
	Internal Studies (Continuing)	
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows **Study Group:** Pradeep Kumar (PI) and C. K. Jain Duration: 3 Years (04/16-05/19)	Dr. Pradeep Kumar presented the study and there were no comments.
2.	Impact of Climate Change on Runoff and Sediment Yield for Puthimari Tributary of River Brahmaputra **Study Group:** Swapnali Barman (PI), J. V. Tyagi, & R.K. Bhattacharya (IITG) Duration: 3 Years (11/18-10/21)	Dr. Swapnali Barman presented the study and following suggestions were made. • Dr. A. P. Dimri suggested to calculate variations in % and use hybrid ANN-SWAT model. • Dr. A. K. Saraf suggested to use void free data. *Note: Due to transfer of PI to CFMS Guwahati, the study is transfered to CFMS Guwahati.*
	Sponsored Projects (Continuing)	
3.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin **Study Group:** C.K. Jain (PI), Manohar Arora, M. K. Sharma, Pradeep Kumar, R. Singh, & D. S. Malik (GKU) **Sponsored by:** DST (NMSHE) **Project Cost:** Rs. 2.25 Crore **Duration:** 5 Years (04/16-03/21)	Dr. M. K. Sharma presented the study and following suggestions were made: • Dr. Anil Gautam suggested to explore indexing of water quality based on biological parameters.
4.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures **Study Group:** M. K. Sharma (PI), C.K. Jain, Surjeet Singh, & Pradeep Kumar **Partner:** WRD, Raipur & CGWB, Raipur **Sponsored by:** NHP-PDS **Project Cost:** Rs. 25.4 Lakh **Duration:** 03 Years (09/17-08/20)	PI Dr. M. K. Sharma presented the study and following suggestions were made: • Dr. Deshpandey enquired about the criteria for selection of sampling sites considering the aquifer geometry. Dr. Sharma replied that the sampling sites were selected on the basis of wells connected to different aquifers, which are continuously being observed either by WRD, Raipur or CGWB. • Dr. Dimri wanted to know the causes of the dilution of water quality parameters. Dr. Sharma supplemented that rainfall and surface irrigation may be the causes of dilution. • Dr. Jha advised to use same colour combination for pre- and post-monsoon data presentation to have more visibility of dilution effect.
5.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their	PI Dr. Rajesh Singh presented the study and following suggestions were made:

	Possible Remedial Measures **Study Group:** Rajesh Singh (PI), Pradeep Kumar, M. K. Sharma, & Sumant Kumar **Partner:** Water Resources Organization, Punjab **Sponsored by:** NHP-PDS **Project Cost:** 65.6 Lakh **Duration:** 3 Years (09/17 – 08/20)	• Dr. S.S. Grewal suggested collecting the samples from the villages/locations in depressions.

WORK PROGRAM FOR THE YEAR 2019-20

SN	Study	Study Team	Duration/Status
Internal Studies (Continuing)			
1.	Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows	Pradeep Kumar (PI)	3 Years (04/16-05/19)
Internal Studies (New)			
2.	Water Quality Assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh, J. V. Tyagi Pradeep Kumar	3 years (05/19-04/22)
Sponsored Projects (Continuing)			
3.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	M. K. Sharma (PI) Manohar Arora, Pradeep Kumar, Rajesh Singh D. S. Malik (GKU)	5 Years (04/16-03/21) Sponsored by: DST (NMSHE)
4.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) Surjeet Singh, Pradeep Kumar Partner: WRD, Raipur, CGWB, Raipur	3 Years (09/17-08/20) Sponsored by: NHP-PDS Project Cost: Rs. 25.4 Lakh Status: In-progress
5.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) Pradeep Kumar, M. K. Sharma, Sumant Kumar **Partner:** Water Resources Organisation, Punjab	3 Years (09/17-08/20) Sponsored by: NHP-PDS Project Cost: Rs. 65.6 Lakh Status: In-progress
Sponsored Projects (New)			
6.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi, M. K. Sharma, Nitesh Patidar **Partner:** CGWB (Delhi unit)	3 Years Project cost: Rs. 76.10 Lakh Status: PDS proposal submitted to NHP, yet to be approved by Review committee
7.	Study of Emerging Pollutants and Geochemical Processes Responsible for the Groundwater Contamination in and around Raipur Agglomerate, Chhattisgarh and Suggestive Ameliorative Measures	M. K. Sharma (PI) J. V. Tyagi Surjeet Singh Pradeep Kumar Rajesh Singh WRD, Raipur	3 Years Project cost: Rs. 77.32 Lakh Status: PDS proposal submitted to NHP, yet to be approved by Review committee

Proposed Training Programmes during 2019-20

SN	Topic	Duration	Place
1.	Hydrologic Modelling using SWAT (Coordinator: Dr. J. V. Tyagi)	Two weeks 20-31 May 2019	Roorkee
2.	Ground Water Quality Monitoring & Assessment under NHP-PDS (Coordinator: Dr. M. K. Sharma)	5 Days 3-7 June 2019	Roorkee
3.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days 17-21 June 2019	Roorkee
4.	Water Quality: Concepts and Analysis under NHP (Coordinator: Dr. Pradeep Kumar)	5 Days Oct. 2019	Roorkee

GROUND WATER HYDROLOGY DIVISION

Mr. C. P. Kumar, Scientist 'G' & Head presented a brief overview, status of studies and activities carried out by the division. He informed that one in-house R&D study and ten sponsored studies were approved for the year 2018-19. Out of these, the in-house R&D study was dropped due to various issues in customization because the designed system was not allowing the level of customization. He also informed that since suitable land could not be made available for the study "*Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water*", this study has been dropped. In addition, scientists of the division have a major role in activities of NHP such as coordinating the Purpose Driven Studies (PDS) of all implementing agencies of NHP, DSS planning and management in selected states, development of groundwater module for "*Integrated Hydrologic Model*" with IIT Kharagpur and procurement.

The study-wise progress was presented by respective Principal Investigators and emerged suggestions are given below.

1. Project Code: NIH/GWH/NIH/15-19: **Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply**

Dr. Surjeet Singh (PI) briefed about the study and progress made during the last six months. He informed that Phase-I works at the four sites; Agra and Mathura in U. P. along Yamuna river, Berhara village in Ara district in Bihar along the Ganga river, and Varaha river at Visakapatnam have been completed through respective state water supply departments. He informed that Phase-II works are partly completed for the Agra and Mathura sites involving the installation of submersible pumps, the establishment of a pump house, etc. For the other two sites, Ara and Visakapatnam, the Phase-II works are likely to start through the respective state government departments.

2. Project Code: NIH/GWH/BGS/17-20: **Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements**

Dr. Gopal Krishan presented the results for variation in water level indicating different times of fluctuation thereby ascertaining the relationship between deep and shallow aquifers and also indicated the recharge sources.

3. Project Code: NIH/GWH/NMSHE/16-20: **Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani**

Dr. Surjeet Singh presented the progress of the study during the last six months. He also described the status of installation of piezometers being developed, water sampling and analysis being carried out, future plans and presented the results of water quality and isotopic analysis.

4. Project Code: NIH/GWD/NIH/16-19: **Grey Water to Blue Water – Natural Treatment Techniques for Transforming Wastewater into Sustainable Useable Water**

This study was dropped.

5. Project Code: NIH/GWH/DST/18-20: **Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA**

Dr. Surjeet Singh presented the progress made so far. He informed that the project is of 4 x 4 consortium partner from each country and the Indian partners are NIH (Indian Lead); IIT Kharagpur; IIT Roorkee; and Mahavir Cancer Sansthan, Patna and UK partners are University of Manchester (UK Lead), British Geological Survey, Salford University; and University of Birmingham. While presenting the objectives and hypotheses to be tested in the project, he also explained the future plans.

6. Project Code: NIH/GWH/DST/18-20: **Impact of Rainwater Harvesting on Groundwater Quality in India with Specific reference to Fluoride and Micro-pollutants**

Dr. Anupma Sharma presented the research gaps, objectives of the study, and the work packages. The study sites in which field investigations are being conducted were discussed. It was informed that a few more sites besides Laporiya watershed are being surveyed that would be taken up for research investigations.

7. Project Code: NIH/GWH/PDS/17-21: **Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study**

Dr. Surjeet Singh presented the objectives, progress of work and future plans of the study. Dr. Ramakar Jha enquired about the selection of the Sot river catchment which was replied by Dr. Singh.

8. Project Code: NIH/GWH/PDS/17-21: **Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures**

Dr. Gopal Krishan presented the background, statement of the problem, objectives, methodology, progress and future plans of the study.

9. Project Code: NIH/GWH/PDS/17-20: **Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin**

Mr. Sumant Kumar presented the objectives, methodology, achievements and expected outcome of the study. The Chairman, Working Group suggested doing sampling in the other side of Ganga river to know the present situation of Arsenic contamination.

10. Project Code: NIH/GWH/CEHM/18-22: **Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi**

Dr. Anupma Sharma presented the special study taken up under the Centre of Excellence for Hydrologic Modeling in NHP. The project entails large data processing, field investigations and modeling pertaining to surface water and groundwater flows, contaminant transport and water resources management. The progress made in respect of data collection and processing, field experiments and hydrologic modeling was presented. It was informed that in view of the large study area, satellite data would be used to the extent possible. Field investigations and laboratory experiments are planned to build up the soil parameters database. The working group members expressed concern about the decline in groundwater levels in certain areas of the eastern and western Yamuna canal commands. It was informed that except in salinity affected areas, groundwater pumpage has increased during the last two decades. However, groundwater withdrawal data are not readily available and would be collected through field surveys.

11. Project Code: NIH/GWH/NIH/18-19: **Application for Conjunctive Use Management of Surface Water and Groundwater in Saryu Nahar Pariyojna, U.P. using "Strategic Basin Planning for Ganga River Basin"**

This study was dropped.

12. Project Code: NIH/GWD/NIH/19-21: **Assimilation and Application of Satellite Data Products for Water Resources Assessment of Inland River Basins of India**

Ms. Suman Gurjar presented the background, objectives, methodology, and expected outcome of the study. Dr. A. P. Dimri suggested changing the title of the study because the assimilation techniques are not being used in this study. Therefore, the title of the study has been changed as "*Application of Satellite Data Products for Water Resources Assessment*". He also suggested that to begin with, an area in the Ganga basin can be used as a study area. He also indicated that the estimation of the land surface temperature using satellite data can be a great output. Dr. S. P. Aggarwal suggested getting the basic information of satellites which are providing the data. He also suggested defining the methodology. The Chairman, WG suggested to start with the water balance equation and consider all major processes.

13. Project Code: NIH/GWH/NIH/19-22: **Integrated Hydrological Modelling to Investigate the Surface-Subsurface Water Interactions**

Mr. Nitesh Patidar presented the background, objectives, methodology, and expected outcome of the study. Dr. S. M. Sharma indicated that finding the information related to the aquifer geometry of the study area will be a complex task as it is dominated by basalt rocks.

The work program of the division for the year 2019-20, as recommended by the Working Group below:

WORK PROGRAM FOR THE YEAR 2019-20

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh, C. P. Kumar, P. K. Singh	2 years (05/19 - 04/21) *Status: In progress*	Internal Study
Sponsored Projects				
2. NIH/GWH/NIH/15-19	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply	Surjeet Singh (Lead), B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal	2.5 years (11/15–12/19) Extended till Dec. 2019 *Status: In progress*	Sponsored by MoWR, RD & GR under Plan Fund
3. NIH/GWH/NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8

4. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	3 years (12/17-11/20) *Status: In progress*	Sponsored by BGS, UK
5. NIH/GWH/PDS/17-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3 years (12/17-11/20) *Status: In progress*	Sponsored by NHP under PDS
6. NIH/GWH/PDS/17-21	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), Surjeet Singh, C. P. Kumar, S. K. Verma *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	3 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
7. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
8. NIH/GWH/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme

9. NIH/GWH/ DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants	Anupma Sharma (Indian Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Other Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* Cranfield University School of Water, Energy and Environment; Cranfield University *Project Partners:* Wells for India and Excellent Development, UK based NGOs together with their Indian offices and local NGO partners in Rajasthan	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme
10. NIH/GWH/ CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi.	Anupma Sharma (PI) Sanjay K. Jain, Archana Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Suman Gurjar, Vishal Singh, Nitesh Patidar *Partner Organization:* C.E, IWRD Haryana, Tech. Coord., GWD UP, S.E. YBO, CWC New Delhi	4 years (04/18-03/22) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)
11. NIH/GWH/ DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (Lead NIH), Nitesh Patidar (Lead: CAZRI Jodhpur, Partner: NIH)	4 years (03/19 - 02/23) *Status: In progress*	Sponsored by DST
12. NIH/GWH/ NMCG/19-20	Environmental Flow Assessment for Yamuna River from Hathnikund Barrage to Okhla Barrage	Anupma Sharma (PI), Sharad K. Jain, Manohar Arora, Pradeep Kumar, Rajesh Singh, Vishal Singh	1 year (04/19 - 03/20) *Status: In progress*	Sponsored by NMCG
13. NIH/GWH/ MoES/19-19	Improving our Understanding of the Aquifer Systems in Sunderbans	Gopal Krishan (PI), C. P. Kumar (Co-PI)	5 months (05/19 - 09/19) *Status: In progress*	Sponsored by India-UK Water Centre (MoES & NERC)
Other R & D Projects				
15.	Development of Groundwater Model for Integrated Hydrologic Model	Anupma Sharma, B Chakravorti, Surjeet Singh, Suman Gurjar, Sumant Kumar, Nitesh Patidar	3 years (08/18 -07/21) *Status: In progress*	CEHM, NHP
16.	DSS Planning & Management in Selected States	Anupma Sharma, D S Rathore and Team	6.5 years (06/19 -11/25) *Status: to start*	NHP

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr Sudhir Kumar, Scientist-G and Head of the H. I. Division presented the brief details of the Division including the scientific staff strength and infrastructure. He briefly introduced about the scientific work of the Division and the various studies being carried by the Division including the new proposals, along with details about the publications by the Division and analytical work carried out at the Nuclear Hydrology Laboratory. He also made a brief presentation on Hydrology for Disaster management wherein the case study related to NIH involvement and hydrological investigation for the management of mining disaster in Meghalaya was presented.

Table 1: Status of studies carried out by HI Division during 2018-19

Type of study/Project	***Completed during 2018-19***	***Continuing in 2019-20***	***Total***
Internal Studies	-	-	-
Sponsored Projects	0	6	6
Consultancy Projects	5	4	9
Total	5	10	15

Table 2: Training Courses/Workshops organised by HI Division during 2018-19

S.N.	**Title of Training Course/Workshop**	**Duration**	**Venue**
1.	Training Workshop on "Interpretation of Isotopic Data for Aquifer Mapping" for CGWB Officials	5 days 30 July-3 August, 2018	NIH Roorkee
2.	Training Workshop on "Interpretation of Isotopic Data for Aquifer Mapping" for CGWB Officials	5 days 27th August to 31st August, 2018	NIH Roorkee
3.	Training Workshop on "Environmental Isotopes for Climate Resiliency of Mountain Watersheds" Government Officials of Nepal.	5 days 22-26 October, 2018	NIH Roorkee
4	Training Workshop on "Coastal Zone Water resources: Challenges Investigation Techniques and Management"	11-15 February, 2019	NIH Roorkee

Table 3: Details of samples analysed by HI Division Labs during 2018-19

S.N.	Parameter analysed	No. of samples
1	$\delta^{2}H$ on DI-IRMS	6996
2	$\delta^{18}O$ on DI-IRMS	919
3	$\delta^{18}O$ on CF-IRMS	5653
4	Tritium	310
5	WQ samples on IC	950

Table 4: Details of Research Publications by HI Division during 2018-19

	Published	**Accepted**	**Communicated**
Books/Book Chapter	2	-	-
International Journals	8	4	8
National Journals	-	-	-
International Conferences	3	-	-
National Conferences	-	-	-

Table 5: Details of important instruments purchased by HI Division during 2018-19

S.N.	Name of Instruments	Approximate Cost
1	Normal Scintillation Counter	27 lakh
2	CHNS element analyser	47 lakh
3	DWLRs	5 lakh
4	WL Indicators	1.5 lakh

The progress of each individual study for the year 2018-19 was presented by the respective P.I. of the study. The comments/actions suggested by the working group for various studies are as follows:

INTERNAL STUDIES: Nil

SPONSORED PROJECTS:

SN	Project	Duration	Funding	Status	Comments/ Action(s) Suggested
1.	Understanding of hydrological processes in Upper Ganga basin using isotopic techniques	5 Years (04/16-03/21)	NMSHE Project	Continuing Study	i) Dr. R. D. Deshpande suggested that isotopic signatures may be correlated with meteorological data. ii) Dr. R. D. Deshpande suggested that efforts be made to measure discharge of some springs.
2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	3 Years (06/16 - 05/19)	Project with GBPIHE	Continuing Study	No specific action suggested
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	3 Years (06/16 - 05/19)	IAEA	Continuing Study	No specific action suggested
4.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	3 ½ year (1/18 – 6/21)	PDS under NHP	Continuing Study	No specific action suggested
5.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	3 ½year (1/18 – 6/21)	PDS under NHP	Continuing Study	No specific action suggested
6.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	3 Years (1/18 – 12/20)	PDS under NHP	Continuing Study	No specific action suggested
7.	Climate resilient conservation & data management of spring water sources by strengthening monitoring mechanisms in drought prone areas of Sikkim	6 months (11/18-4/19)	Proposed to be funded by UNDP	Had to be dropped due to delay in approval	--

Besides the progress of the studies for 2018-19, two new studies proposed under the work programme of the Division for the year 2019-20 were presented by the respective PIs. The comments/actions suggested by the working group for these studies are as follows:

SN	Project	Duration	Funding	Status	Comments/ Action(s) Suggested
1.	Integrated hydrological investigations of natural springs in lesser Himalaya, Uttarakhand	3 years (04/10-03/22)	Internal	New	Director, NIH suggested to include Dr. S.S. Grewal in the project and involve more area from Siwalik region
2.	Isotope fingerprinting of precipitation over Indian Region	3 years (04/10-03/22)	Internal	New	Dr. Dimri suggested to include Odisha like Bhubaneswar and Shimla may be included for monitoring.

APPROVED WORK PROGRAMME FOR 2019-20

SN.	Project Title	Study Team	Duration	Remarks
INTERNAL STUDIES:				
1	Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand	S M Pingale (PI), Sudhir Kumar, S. D. Khobragade, Soban Singh Rawat, Rajeev Gupta	3 years (04/19-03/22)	New Study
2	Isotope fingerprinting of precipitation over Indian Region	Nidhi Kalyani (PI) Sudhir Kumar, MS Rao; Scientists from RC's	3 years (04/19-03/22)	New Study
SPONSORED PROJECTS:				
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	Suhas Khobragade (PI), Sudhir Kumar, Rajesh Singh, M. Arora, R. J. Thayyen, S.K. Verma	5 Years (04/16-03/21)	Continuing Study under NMSHE Project
2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar (PI) S.K. Verma	3 Years (06/16 -05/19)	Continuing Study Project with GBPIHE
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	MSRao (PI) Sudhir Kumar, S.K. Verma	3 Years (06/16 -05/19) Extended till Dec. 2021	Continuing Study IAEA under CRP
4.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) M.K. Sharma, M. Someshwar Rao, S.K. Verma	3 ½ year (1/18 – 6/21)	Continuing Study PDS under NHP

5.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M. Someshwar (PI), Sudhir Kumar, S.K. Verma, Nidhi Kalyani, V. S. Jeyakanthan	3 ½year (1/18 – 6/21)	Continuing Study PDS under NHP
6.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Suhas Khobragade, Sudhir Kumar	3 Years (1/18 – 12/20)	Continuing Study PDS under NHP
7.	Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study	Sudhir Kumar, MS Rao, Nidhi Kalyani BK Purandra YRS Rao	1 year (04/19 – 03/20	MoES through NCESS

SURFACE WATER HYDROLOGY DIVISION

WORK PROGRAMME FOR THE YEAR 2019-20

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/ 17-20	Water efficient Irrigation by using SCADA system for medium irrigation Project (MIP) Shahnehar (PDS-NHP).	R.P. Pandey J.P. Patra Rajesh Singh N.K. Bhatnagar	3 years (Dec 2017 to Dec 2020)
2.NIH/SWHD/ 16-21	Hydrological modeling in Alaknanda basin and assessment of climate change impact (NMSHE).	A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	5 years (April 2016 to March 2021)
ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
3.NIH/SWHD/ 17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
4.NIH/SWHD/ 15-19	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	4 years (April 2015 to March 2019) extended up to March 2020
5.NIH/SWHD/ 17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P. Patra Rakesh Kumar Pankaj Mani Sanjay Kumar	3 years (April 2017 to March 2020)
6.NIH/SWHD/ 18-21	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario	Ashwini Ranade Archana Sarkar	3 years (April 2018 to March 2021)

7.NIH/SWHD/ 18-20	Assessment of climate change impact on water availability and agriculture in part of Banas basin.	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2 years (Nov 2018 to October 2020)
8.NIH/SWHD/ 18-21	Evaluation of the influence of low- frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent.	Sunil Gurrapu Ashwini Ranade J.P. Patra	3 years (Nov 2018 to March 2021)
9.NIH/SWHD/ 18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. Thakural	2 years (Oct 2018 to Sept. 2020)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
10.NIH/SWHD /19-22	Development of drought monitoring system for early warning and preparedness for a selected region in India	R.P. Pandey, D.S.Rathore, Ravi Galkate, Sunil Gurrapu	Proposal to be revised based on comments in the 48th Working Group meeting

S.N.	**Title of Project/ Study, Study Group, Start/ Completion Dates**	**Status and Recommendations/Suggestions**
	SPONSORED STUDIES	
1.	Water efficient irrigation by using SCADA system for medium irrigation project (MIP) Shahnehar (Ongoing) PDS under NHP. **StudyGroup:** R.P. Pandey J. P. Patra Rajesh Singh N.K. Bhatnagar **DOS:** Dec. 2017 **DOC:** Dec. 2020	Dr. R.P. Pandey (PI) presented progress of the study. He informed that the NIH team has conducted field investigations in the Shahnehar command area and three experimental sites identified as follows: (i) Lift Irrigation Scheme (LIS) at Sathana Vilage, Terrac Sub-Division, (ii) field plots in distributary-1 (D-1) command area – at Riyali village, Badukhar Sub-Division and (iii) distributary-2 (D-2) command area- at Kathghar village. Dr Man Singh suggested to consider suitable optimum size of furrow length or check basin in field water application. Dr. Amrish Tiwari, IISWC, suggested to monitor flows in canal system for precise assessment and quantification of losses. Dr SS Grewal informed that the land leveling and shaping is one of the very important components in irrigation water saving. Therefore, the farmers should be convinced level their fields to improve irrigation water use efficiencies. It was informed that the conveyance system in Shahnehar command areas are lined have high conveyance efficiency.
2.	Hydrological modeling in Alaknanda basin and assessment of climate change impact (Ongoing). **Study Group:** A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural **DOS:** Jan. 2016 **DOC:** Dec. 2020	Dr A.K. Lohani presented the progress of the study. He informed that all the required spatial and temporal data for the study have been prepared. Flow data of various gauging sites and meteorological data have been collected from CWC, and processing of the data is in progress. VIC model has been setup for the study basin and calibration and fine-tuning of the model with the available data is in progress. He mentioned that the climate projection data are required to project impact of climate change on river flow. Projection data is to be generated through another NMSHE study and utilized.

	INTERNAL STUDIES	
3.	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f) (Ongoing). **Study Group:** Sanjay Kumar Rakesh Kumar J. P. Patra Pankaj Mani **DOS:** April 2017 **DOC:** March 2021	Dr. Sanjay Kumar presented the study and stated that the study specifically focuses on developing design flood estimation methods for ungauged regions based on the concept of regionalization using L-moments approach. He stated that at site frequency analysis based on L-moments approach for eleven sites (for GEV distribution) has been completed. The results of NAM model calibration for one sub-basin and its applicability in other (ungauged) sub-basins using calibrated NAM parameters were also reported based on the use of IMD gridded rainfall data. Limitation of using gridded rainfall data in the un-gauged basins was highlighted. Chairman suggested to examine the use of area weighted NAM parameters in un-gauged basins for possible improvements.
4.	Study of hydrological changes in selected watersheds in view of climate change in India (Ongoing). **Study Group:** L.N. Thakural S. Rathore Surjeet Singh Sanjay Kumar Jain Shard Kumar Jain **DOS:** April 2015 **DOC:** March 2020	Dr. Thakural presented the GIS database created to meet out the objectives of the study using Digital Elevation Model (DEM) and satellite imagery for flow accumulation, stream network, watershed boundary, Land use/Land cover thematic maps in addition to soil map for the four watersheds. Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches for the Ramganga, Bina and Chaliyar river basins were also presented. The outcomes/results of hydrological models (NAM and SWAT) were presented. To study the impact of climate change, gridded rainfall and temperature data, historical NCEP/NCAR reanalysis data (observed predictors) and GCM Predictor grid boxes for the four river basins processed to generate RCP2.6 RCP 4.5, RCP 6 and RCP 8.5 using statistical downscaling model (SDSM) were presented. The model calibration and validation for the rainfall and temperature using NCEP reanalysis data for the RCP 2.6, 4.5, 8.5 were also presented. Members inquired about the gridded data being used. Dr. Thakural mentioned that these data were obtained from various national and international sources available in public domain. Dr. Thakural also requested to allow extension of one year for the study to further investigate the impact of climate change which was agreed.
5.	Development of regional methods for design flood estimation in Uttarakhand (Ongoing). **Study Group:** J.P. Patra Rakesh Kumar Pankaj Mani Sanjay Kumar **DOS:** April 2017 **DOC:** March 2020	Mr. Jagadish Prasad Patra, presented the objectives and need of the study with brief methodology. The progress made for at-site flood frequency analysis using L-moments approach for annual maximum peak flood series data obtained from CWC were presented. The relationships developed to estimate design flood for various return periods with catchment area were also presented. The progress made in Nonstationary Extreme Value Analysis considering the aspect of non-stationary in the data series was presented for one of the sites. The effect of Tehri dam operation for moderation of flood peaks at Rishikesh, Haridwar etc. as well as the hypothetical dam at Alaknanda river were explained.
6.	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario (Ongoing). **Study Group:** Ashwini Ranade Archana Sarkar	Dr. Ashwini Ranade presented important results from the first objective. Working Group noted the work on updation of eleven major and nine independent minor river basin rainfall series and the results obtained from trend analysis for understanding the recent changes in rainfall pattern across India.

	DOS: April 2018 **DOC:** March 2021	
7.	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin. **Study Group:** Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu **DOS:** Dec. 2018 **DOC:** Dec. 2020	Dr Archana Sarkar presented the background and objectives of the study. She informed that the Banas river basin up to Bisalpur dam and the irrigation command are located in the State of Rajasthan in western India has been selected as the study area. Trend analysis of the historical & future patterns of rainfall and temperature time series in Banas basin and command area is being carried out using modified Mann-Kendall's technique and Sen's Slope method and presented the preliminary results. The future time series data is being taken from the GCM downscaled data of the Copernicus website which consists of data of 19 GCMs under two RCPs (RCP4.5 & RCP 8.5). Dr R.K. Goyal advised not to use the CROPWAT software due to huge data requirements and use simple methods for the same. Dr. S.S. Grewal advised to carry out the trend analysis of rainfall events producing runoff using historical data of rainfall.
8.	Evaluation of the influence of low-frequency-atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent. **Study Group:** Sunil Gurrapu Ashwini Ranade J.P. Patra **DOS:** Dec. 2018 **DOC:** Dec. 2021	Mr. Sunil Gurrapu, Scientist C and PI of the study was on official tour, hence Mr. Jagadish Prasad Patra, presented the progress of the study and explained that the Narmada basin and Godavari basin are identified for evaluating influence of various low-frequency atmosphere-ocean oscillations on flood magnitude and frequency. It was informed that the data of 31 gauging sites have been collected and PDO indices, Southern Oscillation Index (SOI), Dipole Mode Index (DMI), etc. are being collected from various international agencies. During the presentation, committee members suggested to include name of the basin in the title of the study.
9.	Evaluation of Water Quality of Government Schools in Roorkee Block, District Haridwar. **Study Group:** N. K. Bhatnagar M. K. Sharma L. N. Thakural Reena Rathore **DOS:** Dec. 2018 **DOC:** Dec. 2020	Sri NK Bhatnagar presented the objectives of the study and progress. Dr Ramakar Jha inquired whether sampling could be done on weekly instead of pre-monsoon and post-monsoon basis as it is being done in CGWB. Dr. Mukesh Sharma replied that water quality sampling is done during pre and post-monsoon only. Dr. Sudheendra Sharma inquired whether water samples are collected from hand pumps of Schools. It was informed that the samples will be collected as suggested by the Working Group members.

NEW STUDIES(INTERNAL)		
10.	Development of drought monitoring system for early warning and preparedness for a selected region in India **Study Group:** R.P. Pandey D.S. Rathore Ravi Galkate Sunil Gurrapu Suman Gurjar **DOS:** May 2019 **DOC:** March 2022	Dr. R.P. Pandey informed that the primary purpose of the proposed project is to develop a scientific tool for regular drought monitoring and early warning system (EWS) for preparedness in drought affected Bundelkhand region. Chairman WG suggested to recast some the objectives of the study. Accordingly, objectives of the study have been revised as: 1. Identification and evaluation of key hydro-meteorological indicators/indices for monitoring and assessment of drought and severe water scarcity condition. 2. Development of base maps showing demarcation of areas vulnerable to drought using physiographic, climatic and social factors including demarcation of rainfed and irrigated areas. 3. Development of systematic database setup and computation programs for different drought indices/techniques.

		4. Development of composite program and dashboard with menu driven generic system for various drought indicators/ indices linked with common data base. 5. Customization of drought monitoring system for district/sub-district level assessment. 6. Evaluation and result verification with field observations. 7. Hosting of the EWS/drought monitoring system on the NIH website. Dr Dimri suggested to explore possibility to include soil heat flux index as one of the early warning indicator. Dr S.P. Agrawal suggested to contact MNCFC and NRSC to obtain input and support for the proposed monitoring and early warning system. Dr Man Singh informed that IARI is working with the University of Nabraska, USA to develop a composite index for drought monitoring. He suggested to share the proposal with him for providing suitable inputs. Director, NIH suggested to send the proposal to IARI seeking comments and input for the proposed study, and to include Dr. T. Thomas, Sc D, RC Bhopal in the study team.

WATER RESOURCES SYSTEMS DIVISION

SUGGESTION/ COMMENTS RECEIVED FROM MEMBERS DURING 48th WORKING GROUP MEETING

Dr. Sanjay K Jain, Sc. G and Head, presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Thereafter scientists of the division presented their studies. Following are the comments received from working group on the presentations of the various studies:

PI: Dr. Renoj J Thayyen (RJT), Scientist "E"

1. ***Catchment scale evaluation of cold-arid cryospheric system Hydrology, Ganglass catchment, Ladakh (Completed)***

RJT presented this completed project which established the characteristics of the Himalayan permafrost for the first time. He elaborated on the field monitoring of GST in the Ganglass catchment Ladakh and modelling of soil temperature upto 10m using the measured GST distributed at 12 plots between 4727 -5610 m a.s.l. Core permafrost characteristics such as Surface offset, thermal offset, active layer thickness variations, Mean Annual Ait Temperature (MAAT) are discussed. He has shown that the site at 4727 m a.s.l. did not show the permafrost signatures while the site at 4900 m a.s.l. has strong permafrost presence. Active layer thickness in the catchment vary between 4.3 m to 0.3 cm at higher elevation regions. The spatial distribution of permafrost is assessed by regression models and suggest around 95% permafrost cover in the catchment. RJT acknowledged the collaboration and assistance with Carleton University, Ottawa, Canada and ICIMOD, Nepal.

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

1. Hydrological Processes and Characterization of Lesser Himalayan Catchments (Ongoing)

The progress of the study was presented by MKN. It was informed that all proposed instrumentation have been installed in the experimental catchment and data is being received at NIH, Roorkee. Soil monitoring station (COSMOS) has also been established at project site. Analysis and time series graphs of few of the meteorological, hydrological and lithological variable were presented. The results of the evapotranspiration (ET) estimated by Eddy-covariance (EC) flux tower were compared with the ET estimates by Penman-Monteith method.

PI: Deepa Chalisgaonkar, Scientist "G"

1. ***Development of window based software for hydrological data processing and Unit Hydrograph Analysis (Ongoing)***

Mrs. Deepa presented the progress of the project. She informed that a user friendly software in vb.net platform has been developed for hydrological data processing and unit hydrograph analysis for the estimation of flood for gauged as well as ungauged catchments of small and medium size catchments. Online help for the software is available and the package is capable of displaying the results in tabular and/or graphical form.

2. ***Development of window based software for Flood Estimation (New)***

Mrs Deepa presented the proposed study. She informed that this software will be used for the flood estimation of large catchments. At the later stage, the unit hydrograph package can be merged into this package so that a comprehensive software for flood estimation and small, medium and large catchments will be developed.

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

1. Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework (Ongoing)

PKS presented the ongoing study and relevance of global data used in WA+ as input, before presenting the results on Sheet 2 and Sheet 3 on evapotranspiration from the basin and land and water productivity respectively. He also discussed on the data biasness in global rainfall data particularly CHIRPS and TRMM products w.r.t the IMD rainfall data. Dr. R. K. Goyal from CAZRI desired to organize a training programme as well as execute a research project work on WA+ for the basins of Rajasthan with the scientists from NIH. Dr. Ambrish Kumar, Principal Scientists, IISWC, Dehradun also evinced his interest to deliver lectures on WA+ at IISWC for which he will soon communicate.

PI: Dr. Vishal Singh (VS), Scientist "C"

1. Real time flood modelling using HEC-RTS modelling framework (Ongoing)

VS presented study on Real time flood modelling using HEC-RTS framework in Periyar river basin. He briefly presented the different components under HEC-RTS. He also shared the preliminary findings of flood modelling. Few members suggested the following:

- Use of different rainfall dataset which has less bias.
- Use of WRF model for the prediction of more accurate rainfalls for the flood event.
- Revisiting the reservoir rules for Mullaperiyar dam.
- Use of High resolution DEM for flood inundation modeling and mapping the flood extent.

PI: D. S. Rathore, Scientist "F"

1. ***Design and development of DSS (H) platform for Neeranchal National Watershed Project (Ongoing)***

The study was not presented since it was dropped by the sponsoring agency.

2. ***Investigating water stress using hydro-meteorological and remote sensing data (Ongoing study under NHP-PDS)***

Mr D.S. Rathore informed that various data e.g. precipitation, and groundwater level data, technical reports etc. were collected from Water Resources Department and State Groundwater Board. The validation of the data is in progress. Missing daily precipitation data were observed and gap filling will be carried out. Declining trend in groundwater was observed in both pre and post groundwater levels. For last 15- 20 years, several wells and piezometers remain dry in summer. Nearly 2.5 MCM storage is created by small and medium size water harvesting structures in the basin. Procurement of equipment namely soil moisture profile probe and digital tipping bucket raingauge with datalogger is initiated. Satellite data products were browsed for initiating their purchase. R script was written for

data filling using linear/ multiple linear regression technique. For spatio- temporal analysis, bfastspatial R-package was selected and was applied to sample data.

PI: Dr. M. Arora (MA), Scientist "D"

1. Modeling of Gangotri Glacier melt runoff and simulation of stream flow variation under different climate scenarios (Ongoing study)
MA presented the progress of the study. No specific comments were received from the members.

PI: Dr. M. K. Goel (MKG), Scientist "G"

1. Study title: National Mission for Sustaining the Himalayan Ecosystem (NMSHE) (Ongoing)
MKG initiated the combined presentation on NMSHE sub-projects where-in six presentations for six sub-projects of NMSHE (in which Scientists of WRS Division are involved) were made.

Sub-project – 1: Development of a project website and hydrological database in Upper Ganga Basin (PI-Dr. M. K. Goel, Sc-G)

No specific comments were received from the members.
Sub-project – 2: Real-time snow cover information system for Upper Ganga basin (PI-Mr. D. S. Rathore, Sc-F)

The study was presented by Dr. M.K. Goel. It was informed that post processing procedure (with altitude mask and temporal filter) was implemented in R-software as a semi-automated method. The method was applied to Upper Ganga and Subansiri and adjoining basins. The script will further be modified to calculate zone wise area. Dr S.P Aggarwal inquired whether topographic aspect was considered in applying the altitude based masking in post processing. Mr. Rathore replied that aspect was not considered in this post processing procedure of altitude mask. Present method will provide initial snow cover estimates and will be useful as an input in hydrological models.

Sub-project – 3: Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region (PI-Dr. Sanjay K. Jain, Sc-G)

No specific comments were received from members.

Sub-project – 4: Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios (PI-Dr. Renoj J. Thayyen, Sc-D)

No specific comments were received from members.

Sub-project – 5: Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin (PI-Dr. Sharad K. Jain, Sc-G)
No specific comments were received from members.

Sub-project – 11: Water Census and Hotspot analysis in selected villages in Upper Ganga basin (PI-Dr. P. K. Mishra, Sc-C)
No specific comments were received from members.

WORK PROGRAMME FOR THE YEAR 2019-2020

SN	Title	Study Team	Duration	Funding (Rs. in Lakhs)
Ongoing Internal Studies				
1.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain, Sanjay K. Jain, Renoj J.Thayyen, P. K. Mishra	5 years (12/14-12/19)	
2.	Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework	P. K. Singh P. K. Mishra, M. K. Goel, Suman Gurjar	2 years 2018-2020	

3.	Real time flood modelling using HEC-RTS framework	Vishal Kumar A. K. Lohani, Sanjay K. Jain	2 years 2018-2020	
Ongoing Sponsored Studies				
1.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel M. Arora, A. K. Lohani, D. S. Rathore, D. Chalisgaonkar, P. Mani, P. K. Mishra	5 years (01/16-12/20)	DST (52.15)
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar, V. S. Jeyakanthan, L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
3.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain A. K. Lohani, Sudhir Kumar, P. Thakur (IIRS)	5 years (01/16-12/20)	DST (36.79)
4.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	Renoj J.Thayyen Sanjay K. Jain, Sharad K. Jain, P. K. Mishra, M. Arora, AP Dimri (JNU)	5 years (01/16-12/20)	DST 51.43 (NIH) + 28.29 (JNU)
5.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	Sharad K. Jain Renoj J.Thayyen, Sanjay K. Jain, Surjeet Singh, M. K. Nema , P. K. Mishra, P. K. Agarwal, AP Dimri (JNU)	5 years (01/16-12/20)	DST (54.07)
6.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra M. K. Nema, Renoj J. Thayyen, P. K. Sachan	5 years (01/16-12/20)	DST (90.99)
7.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya	Renoj J.Thayyen P. K. Mishra	3 years (03/17-03/19)	NMHS-MoEF (58.76 lakh)
8.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema Renoj J. Thayyen, Sharad K. Jain, Sanjay K. Jain, P. K. Mishra, AP Dimri (JNU)	3 years (2016-19)	MOES (Rs. 98 Lakh)
9.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)	Sanjay K. Jain (PI) Sharad K. Jain CSP Ojha (PI, IITR)	3 years (2016-2019)	MOES-NERC, Newton-Bhabha project (11.59 Lakh)
10.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore L. N. Thakural, Sanjay Kumar, B. Venkatesh, M. K. Jose, T. Chandramohan	3 years 2017-2020	PDS under NHP
11.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Deepak Singh Bisht, Sanjay K. Jain	3 years 2018-2021	NIH
New Internal Studies				
1	Development of windows based software for Flood Estimation	D. Chalisgaonkar A. K. Lohani, M. K. Goel	1 year (04/19-03/20)	

SN	Title of Project/Study, Study Team	Status and Recommendations/Suggestions
1.	**Study on effect of climate change on sediment yield to Pong reservoir.** **Team:** A. R. Senthil kumar, J. V. Tyagi, S. D. Khobragade and Manohar Arora DOS: Apr 2015, DOC: June 2019	Dr Senthil kumar (PI) presernted the discharge and sediment yield at Nadaun Brdige (Pong reservoir) simulated using SWAT with data from ERA INTERIM. The downscaling of rainfall, maximum and minmum temperature for the sceanrios RCP2.6, 4.5 and 8.5 were carried using SDSM from CanESM2 using IMD gridded data from 1961 to 2005 and bias corrected by the probability of exceedence method. The discharge and sediment yield were simulated using IMD data of rainfall, maximum and minimum temperature for data from 1987 to 2005. The discharge was well simulated but sediment yield was poorly simulated. Prof Dimri suggested to find reason behind poor simulation of sediment yield and if not improved, the same may be reported in final report. The Chairman suggested all team members to try to fix the problem and complete the study by June 2019.
2.	**Bathymetric survey and water quality monitoring of selected ponds in Bundelkhand region for development of water management plan.** **Team:** Digambar Singh**,** Omkar Singh, Subhash Kichlu, Rajesh Kumar Nema, Hukum Singh and N R Allaka DOS: Apr 2018, DOC: March 2020	The study could not be presented due to paucity of time.
3.	**Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system** **Team:** Omkar Singh, V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, Rakesh Goel & N R Allaka **Partern Organization:** Prof. Laurence Carvalho & Team, Centre for Ecology & Hydrology (UK). DOS: Apr 2018, DOC: March 2020	Sh. Omkar Singh (PI) infomed that weekly/ quarterly water and wastewater sampling is going on from both ponds (CW-NTS pond at Ibrahimpur Masahi and control pond at Masahi Kala). CEH-UK team is also visiting periodically to collect samples from the both ponds and providing data on GHG emissions and biota. Dr. Sadhana Malhotra desired to know about maintenance of CW-NTS at village pond. The PI & Co-PI replied their queries.
4.	**Vulnerability Assessment to Climate Change in Chhattisgarh** **Team:** Dr Jyoti P Patil, Scientist C and Ms Meeta Gupta, JRF DOS: July 2017, DOC: June 2019	This study was taken up under NNWP but is now converted to internal study due to closure of NNWP. Accordingly, title of the study is also changed. The objectives, brief methodology and results of the study were presented by Dr Jyoti Patil. The scheduled date of completion of this study is June 30, 2019 and analysis for two districts in Chhattisgarh is completed.
5.	**Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact** **Team:** A R Senthil kumar, J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora and Digambar Singh	Dr. Senthil kumar (PI) mentioned that the discharge and sediment yield at Tehri dam was simulated using SWAT by considering the parameters randomly initially and input data obtained/generated from different sources. The discharge was simulated fairly good and the sediment yield was poorly simulated. The Chairman suggested to discuss with team members to

	DOS: July 2016, DOC: June 2021 (**NMSHE**)	sort out the problem.
6.	**Development of water allocation plan of watershed in Kanker district, Chhattisgarh** **Team:** A. R. Senthil kumar, Jyoti P Patil, T R Nayak and Rajesh Agarwal DOS: Apr 2018, DOC: March 2020	Dr. A. R. Senthil kumar (PI) mentioned that the WEAP model was setup for micro watersheds IWMP14 and IWMP15 of Kanker Districts Chhattisgarh. Results such as water demand, runoff generated, demand site inflows and outflows, unmet demand, reliability of demand met were presented for the base period (2015). The same output for reference period from 2016 to 2050 were being extracted from the results.
7	**Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts** **Investigators:** V C Goyal, Omkar Singh, Rajesh Singh, Digambar Singh **Scientific/Technical Staff:** Subhash Kichlu, Rajesh Agarwal, Rakesh Goel, N. R. Allaka DOS: April 2017, DOC: March 2020	The technical progress of the study was presented by Er. Omkar Singh, Sc. F. The status regarding onsite rejuvenation work of 12 ponds as carried out by the NPCC, which is in an advanced stage, was also presented.
8	Rejuvenation of Village Ponds in Identified Villages of Baghpat, Ghaziabad and Meerut Districts of Uttar Pradesh **Investigators:** Omkar Singh, Rajesh Singh, V. C. Goyal, Digambar Singh **Scientific/Technical Staff:** Subhash Kichlu, Rajesh Agarwal, Rakesh Goel, N. R. Allaka DOS: Jan. 2018, DOC: Dec. 2020	The technical progress of the study was presented by Er. Omkar Singh, Sc. F. The status regarding onsite rejuvenation work of 9 ponds as carried out by the NPCC, which is in the advanced stage was also presented. There were no specific comments from working group members.
9	**Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)** **Team:** V.C. Goyal (PI) **Partners:** NIH, NIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad DOS: Apr 2019, DOC: Mar 2024	The overview of the project was given by Dr. V. C. Goyal, Sc. G & Head (PI). The PI informed that an Inception cum-Need Assesment workshop is scheduled during 24-25 June 2019 at NIH Roorkee

WORK PROGRAMME FOR THE YEAR 2019-20

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar (PI) J V Tyagi, S D Khobragade , Manohar Arora	Apr 2015-Mar 2018 (extended up to June 2019)	On-going
2	Bathymetric survey of identified ponds in the districts of Muzaffarnagar, Meerut, Ghaziabad and Baghpat (UP) for development of water management plan	NIH	Digambar Singh (PI) Omkar Singh Rajesh K.Nema Hukam Singh N R Allaka	Apr 2018-Mar 2020	On-going
3	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural	NIH,CEH (UK)	**NIH**: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh,	Apr 2018-Mar 2020	On-going

	treatment system		Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka **CEH-UK**: Prof. Laurence Carvalho & Team		
4	Development of DSS for Watershed Hydrology	NIH	V C Goyal (PI) Jyoti Patil, Rohit Sambare	May 2019-Aug 2019	New
	Sponsored Projects				
1	Vulnerability assessment of identified watersheds in Chhatisgarh	NNWP (under NIH scheme)	Jyoti P Patil (PI)	Jul 2017- Jun 2019	On-going
2	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	DST (under NMSHE)	A R Senthil kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora	Mar 2016-Mar 2021	On-going
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts of UP	MoWR-funded project-Through INCSW	V C Goyal (PI) Omkar Singh, Digambar Singh, Rajesh Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Apr 2017-Mar 2020	On-going
4	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoWR-funded project (through Scheme funds)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Apr 2017-Mar 2020	On-going
5	Development of water allocation plan for identified watersheds in Kanker district (Chhattisgarh)	NNWP (under Scheme funds)	A R Senthil kumar (PI) T R Nayak, Jyoti P Patil, Rajesh Agarwal	Apr 2018-Mar 2020	On-going
	New Sponsored Project				
6	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)- establishment and operation of 'Live Laboratory' in a rural setting near Roorkee	DST (GoI), Cost: Rs. 5.1 Crore	Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Rohit Sambare	Jun 2019-Mar 2024	New Project

Proposed Trainings/Workshop/Activities:

S.No.	**Name of activity**	Funding	Team/Div.	Period	Venue
1	Inception cum-Need Assessment of IC-EcoWS Project	DST (GoI)	V.C. Goyal (PI), Omkar Singh, Jyoti Patil, Rajesh Singh, Rohit Sambare	24-25 Jun, 2019	NIH Roorkee/MNIT Jaipur
2	Networking Project on Rejuvenation of Ponds-Review Meeting	DST (GoI)	T. Thomas (PI), Jyoti Patil	14-15 Jun, 2019	NIH Roorkee
3	National Workshop on Scientometrics	NIH	V C Goyal (PI), Archana Sarkar, Rohit Sambare, Furqan Ullah, Charu Mishra	Feb 2020	NIH Roorkee

Expected Outreach Activities:

S.No.	**Name of activity**	Funding	Team/Div.	Period	Venue
1	India Water Week	NIH	RMOD	24-28 Sep 2019	Vigyan Bhawan, New Delhi
2	India International Trade Fair	NIH	RMOD	14-27 Nov 2019	New Delhi
3	Indian Science Congress	NIH	RMOD	3-7 Jan 2020	UAS, Bangalore
4	Any other Outreach activity on demand/assigned	NIH	RMOD		

List of activities proposed under INC-IHP during 2019-20

Meetings to be organised/ attended

1. Meeting of INC-IHP, during May/June 2019, after obtaining approval on re-constitution of committee from the Ministry
2. 24th session of the InterGovernmental Council (IGC) of the International Hydrological Programme of UNESCO, Paris, France
3. 27th meeting of the IHP Regional Steering Committee for Asia and the Pacific, to be held at Myanmar in 2019
4. Participation in Asian GWADI meeting
5. Participation of Indian nominees in various UNESCO meetings

Thematic Trainings:

1. Training course on 'Water Security Assessment' during July 2019 (Location: New Delhi/ Roorkee)
2. Training course on 'Water Education- Key for Water Security' during March 2020 (Location: New Delhi/ Roorkee)

Brainstorming sessions/ exhibitions during conferences/ summits

Sl. No.	**INC-IHP proposed event**	**Conference/ Summit**	**Host Organisation**	**Location**	**Date**
1.	Exhibition on R&D in Hydrology, Wastewater treatment	3rd World Water Summit 2019	Energy and Environment foundation	New Delhi	21-23 Aug, 2019
2.	Brainstorming session on Theme-V 'Ecohydrology-Engineering Harmony for a Sustainable World'	Water future Conference	IISc, Bengaluru	Bengaluru	24-27 Sep, 2019
3.	Session on 'Enhancing sustainable groundwater resources management'	8th Int. Groundwater Conference on Sustainable Management of Soil-Water Resources	IIT-Roorkee	Roorkee	21-24 Oct, 2019

4.	Theme- Water-related Disasters and Hydrological Changes	Int. Conf. on Soil and Water Resources Management for Climate Smart Agriculture, Global Food and Livelihood Security	Soil Cons. Society of India (SCSI), New Delhi	New Delhi	5-9 Nov, 2019
5.	Theme- Game-changing approaches and technologies	Int. Conference on Future Cities	IIT-Roorkee	Roorkee	11-13 Dec, 2019
6.	Theme- Promoting innovative tools for safety of water supplies and controlling pollution	HYDRO-2019 (Hydraulics, Water Resources and Coastal Engineering)	Osmania University, Hyderabad	Hyderabad	18-20 Dec, 2019
7.	Theme- Water Education-Key for Water Security	Roorkee Water Conclave 2020	IIT-Roorkee and NIH	Roorkee	26-28 Feb, 2020
8.	Celebration of World Water Day		NIH, jointly with UNESCO New Delhi	New Delhi	22 Mar 2020

Dr. V C Goyal thanked the members for their valuable contributions during deliberations in the Working Group meeting. The WG members desired to form a Whatsapp group of WG members.

The meeting ended with vote of thanks to the Chair.

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ANNEXURE-I

List of Working Group Members who attended the 48th WG meeting

1.	Dr. S.K. Jain, Director, NIH	Chairman
2.	Sh. Wasim Ahmed, CGWB, Dehradun	Member
3.	Dr. K V Singh, IMD, New Delhi	Member
4.	Dr. Ambrish Kumar, ICAR-IISWC, Dehradun	Member
5.	Dr. R D Deshpande, PRL, Ahmedabad	Member
6.	Dr. S P Aggarwal, IIRS, Dehradun	Member
7.	Dr. R K Goyal, ICAR-CAZRI, Jodhpur	Member
8.	Sh. Man Singh, WTC, ICAR-IARI, New Delhi	Member
9.	Prof. A K Saraf, IIT, Roorkee	Member
10.	Prof. M L Kansal, IIT, Roorkee	Member
11.	Dr. S S Grewal, Chandigarh	Member
12.	Dr. Kaushal K. Garg, ICRISAT, Hyderabad	Member
13.	Prof. Ramakar Jha, NIT, Patna	Member
14.	Prof. A P Dimri, JNU, New Delhi	Member
15.	Dr. Sadhana Malhotra, Mindspace, Dehradun	Member
16.	Sh. Sudhindra Mohan Sharma, Indore	Member
17.	Dr. Anil Guatam, PSI, Dehradun	Member
18.	Dr. Rakesh Kumar, Sc. G & Head SWH Division, NIH	Member
19.	Dr. J V Tyagi, Sc.G & Head EH Division, NIH	Member
20.	Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH	Member
21.	Er. C P Kumar, Sc.G & Head GWH Division, NIH	Member
22.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
23.	Dr. V C Goyal, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from National Institute of Hydrology

	EH Division		**SWH Division**
1	Dr. M.K. Sharma, Sc.D	23	Dr. A.K. Lohani, Sc.G
2	Dr. Rajesh Singh, Sc.C	24	Dr. R.P. Pandey, Sc.G
3	Dr. Pradeep Kumar, Sc.C	25	Dr. Sanjay Kumar, Sc.E
4	Dr. Swapnali Barman, Sc.C	26	Dr. Archana Sarkar, Sc.D
5	Sh. Rajesh K. Nema, Sc.B	27	Dr. L.N. Thakural, Sc.C
	GWH Division	28	Sh. J.P. Patra, Sc.C
6	Dr. Anupama Sharma, Sc.E	29	Dr. Ashwini A. Ranade, Sc.C
7	Dr. Surjeet Singh, Sc.E	30	Sh. N K Bhatnagar, Sc.B
8	Er. Sumant Kumar, Sc.C		**WRS Division**
9	Mrs. Suman Gurjar, Sc.C	31	Dr. M.K. Goel, Sc.G
10	Dr. Gopal Krishan, Sc.C	32	Smt. Deepa Chalisgaonkar, Sc. G
11	Sh. Nitesh Patidar, Sc.B	33	Er. D.S. Rathore, Sc.F
	HI Division	34	Dr. Renoj J. Thayyen, Sc.E
12	Dr. Suhas Khobragade, Sc.F	35	Dr. Manohar Arora, Sc.D
13	Dr. M.S. Rao, Sc.E	36	Dr. P K Singh, Sc.D
14	Sh. S.K. Verma, Sc.D	37	Er. Manish Nema, Sc.C
15	Dr. Santosh M Pingale, Sc.C	38	Dr. P K Mishra, Sc.C
16	Sh. Hukam Singh, Sc.B	39	Dr. Vishal Singh, Sc.C
17	Ms. Nidhi Kalyani, Sc.B	40	Sh. P K Agarwal, Sc.B
	RMO Division	41	Sh. Deepak Singh Bisht, Sc.B
18	Er. Omkar Singh, Sc.F		
19	Dr. A R Senthil Kumar, Sc.F		
20	Sh. Digamber Singh, Sc.C		
21	Dr.(Mrs) Jyoti P. Patil, Sc.C		
22	Sh. Rohit Sampatrao Sambare, Sc.B		

ANNEXURE – B

Division-wise Work Programme

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. J V Tyagi	Scientist G & Head
2	Dr. M K Sharma	Scientist D
3	Dr. Rajesh Singh	Scientist C
4	Dr. Pradeep Kumar	Scientist C
5	Sh. Rajesh K. Nema	Scientist B
6	Ms. Anjali	Scientist B
7	Smt. Babita Sharma	RA
8	Smt. Bina Prasad	RA

Work Programme for the Year 2019-20

SN	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	M. K. Sharma (PI) Manohar Arora Pradeep Kumar Rajesh Singh D. S. Malik (GKU)	5 Years (04/16-03/21) **Sponsored by**: DST (NMSHE) **Project Cost**: Rs. 2.25 Crore **Status:** In-progress
2.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur, CGWB, Raipur	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 25.4 Lakh **Status:** In-progress
3.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) Pradeep Kumar M. K. Sharma Sumant Kumar **Partner:** Irrigation Department, Punjab	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** In-progress
Internal Study (Ongoing)			
4.	Water quality assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh J. V. Tyagi Pradeep Kumar	3 years (05/19-04/22) **Project cost:** 17.10 lakh **Status:** In-progress
Sponsored Projects (New)			
5.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar J. V. Tyagi M. K. Sharma Nitesh Patidar **Partner:** CGWB (Delhi unit)	3 Years **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** New PDS approved
Internal Study (New)			
6.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema	4 years (11/19-10/23) **Project cost:** 43.02 lakh

Training Programmes

SN	Topic	Duration	Place
1.	Hydrologic Modelling using SWAT (Coordinator: Dr. J. V. Tyagi)	Two weeks 20-31 May 2019	Roorkee
2.	Ground Water Quality Monitoring & Assessment under NHP-PDS (Coordinator: Dr. M. K. Sharma)	5 Days 3-7 June 2019	Roorkee
3.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days 17-21 June 2019	Roorkee
4.	Water Quality: Concepts and Analysis under NHP (Coordinator: Dr. Pradeep Kumar)	5 Days 2-6 Dec. 2019	Roorkee

Publications:

i) Gupta S. K., Tyagi J.V., Sharma G., Jetho, A. S., Singh P. K. (2019) An Event-Based Sediment Yield and Runoff Modeling Using Soil Moisture Balance/Budgeting (SMB) Method. Water Resources Management, 33(11):3721–3741.

ii) Sharma, M. K., Kumar, Pradeep, Prajapati, Parul and Bhanot, Kunarika (2019) Hydro-chemical Characteristics of Upper Ganga Basin, India, VIII International Groundwater Conference (IGWC – 2019) at IIT, Roorke during 21-25 Oct. 2019.

iii) Sharma, M. K., Malik, D. S., Tomar, Garima and Wadhwa, Udita (2019) Ecological and biodiversity study of Upper Ganga Basin, India, VIII International Groundwater Conference (IGWC – 2019) at IIT, Roorke during 21-25 Oct. 2019.

iv) Sharma, M. K., Kumar, Pradeep, Singh, Surjeet, Kumar, Mohit and Shukla, A. K. (2019) Source Identification of Sulphate Contamination using Hydrogeochemical Investigation: A Case Study of District Bemetara, Chhattisgarh, India, VIII International Groundwater Conference (IGWC – 2019) at IIT, Roorke during 21-25 Oct. 2019.

v) Anjali, Singh, S. and Malik, A. (2019) Ecological risk assessment of oil spill and Bio-remediation Measures, VIII International Groundwater Conference (IGWC – 2019) at IIT, Roorke during 21-25 Oct. 2019.

vi) Kumar, S. Kumar, A., Singh, S., Malyan, S. K., Baram, S., Sharma, J., Singh, R. and Pugazhendhi, A. (2020) Industrial wastes: Fly ash, steel slag and phosphogypsum- Potential candidates to mitigate greenhouse gas emissions from paddy fields. Chemosphere, 241: 124824.

vii) Malyan**,** S. K., Singh, R., Rawat, M., Kumar, M., Pugazhendhi, A., Kumar, A., Kumar, V. and Kumar, S. S. (2019) An overview of carcinogenic pollutants in groundwater of India. Biocatalysis and Agricultural Biotechnology, https://doi.org/10.1016/j.bcab.2019.101288.

viii) Sundriyal, Shipika and Singh, Rajesh Singh (2019) Contemporary rate of Chemical Denudation in meltwater emerging from Gangotri Glacier, Central Himalaya, India, VIII International Groundwater Conference (IGWC – 2019) at IIT, Roorke during 21-25 Oct. 2019.

Study - 1 (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. M. K. Sharma, Sc. 'D' Dr. Manohar Arora, Sc. 'D'
Co-Investigator Dr. Pradeep Kumar, Sc. 'C' Dr. Rajesh Singh, Sc 'C'
Scientific/Technical Staff Smt. Babita Sharma, RA Smt. Beena Prasad, RA 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

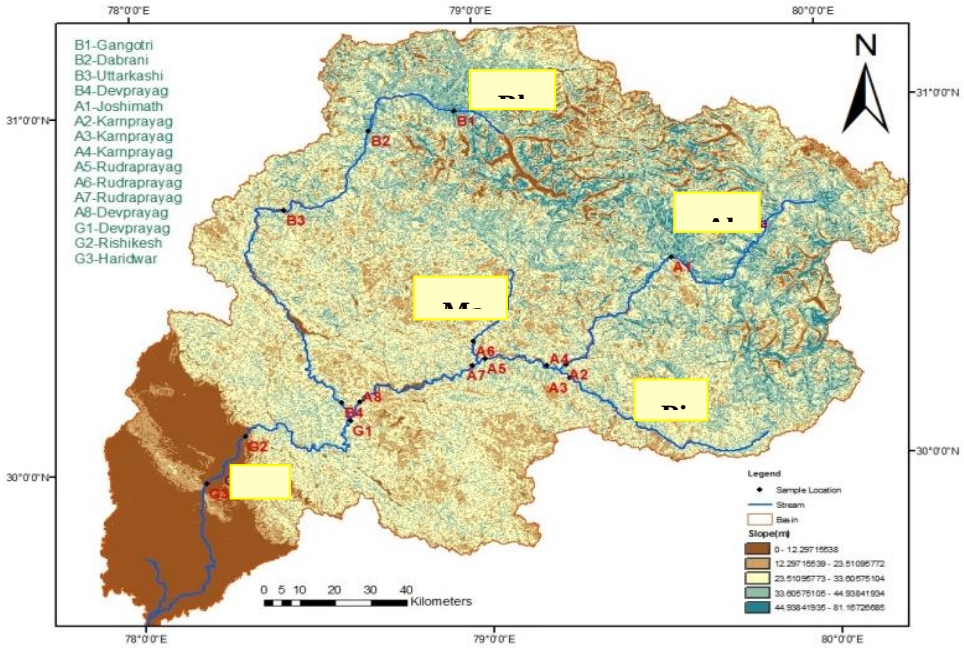
8. Study Objectives:

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. Statement of the Problem:

The States which share the Himalayas are also its principal sentinels. Adaptation to Climate Change must become an integral part of their development strategies. The special vulnerabilities of this ecologically fragile region need to be recognized, as much as its rich natural resources in terms of forests, water wealth, biodiversity and tourism potential. While a number of long-term measures are under consideration as part of the National Action Plan on Climate Change, several key and urgent interventions may be considered to prevent the further degradation of the Himalayan Ecology and to preserve their life-sustaining role for millions of our citizens. This not only includes those residing in this region, but also in the entire Indo-Gangetic Plain.

The cities in the Himalayan mountainous zones are increasing in size and in numbers. They are displaying the same degradation that plagues our cities in the plains – growing dumps of garbage and plastic, untreated sewerage, chronic water shortages, unplanned urban growth and heavy pollution from increasing vehicular traffic. This phenomenon will only exacerbate the impact from climate change.



Study area: Upper Ganga Basin

Ecologically sensitive mountainous areas, like the Himalaya, are prone to adverse impacts of global climate changes on account of both natural causes and anthropogenic emissions in other parts of the world as well as those arising out of unplanned developmental activities in the region. Himalayan Ecosystem resources are critical on the face of natural disturbances, anthropogenic activities and climate change. It has important implications for formulation of management strategies and sustenance of dependent human societies. Some of the significant consequences arising out of the global warming on the Himalayan region could relate to a) variability in the volumetric flow of water in the rivers, b) loss in biodiversity, c) unsustainable changes in ecology, d) glacier recession, e) deforestation and degradation, f) conditions for impending natural disasters and g) dislocation of traditional societies dependent vulnerably on the Himalayan ecosystem.

Ganges, Brahmaputra, Yamuna, and other major river systems originate in the Himalayas. Any changes in the Himalayan glacier dynamics and melting are expected to severely affect about 1.3 billions of people. Water quality assessment and studies of in-stream reactions and sediment dynamics play an important role in this context. There are several reasons for this. Because of substantial efforts to reduce point pollution sources the relative effect of non-point pollution has increased. This has increased the need to identify major sources of nutrients and trace elements deposited within the river system.

10. 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

11. 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										

12. Objectives and achievement during last six months:

Objectives	Achievements
Adsorption characteristics	Experiments of Adsorption of metal Cd, Cr, Zn and Pb on bed sediment of River Bhagirathi at Gangotri for different operating variables are under progress.
Habitat characteristics	Habitat characteristics data of 8 selected zones is under progress.
Aquatic biodiversity	• Processed relative abundant species of aquatic biodiversity. • Processed ecology and biodiversity data for the Biodiversity Index (Shanon – Weiner Index, Simpson Index, Evenness Index) of 8 zones.
Environmental flow estimations	• Discharge data of 11 different sites of 47 years have been processed through consistency and gap filling. • Probability Analysis was performed to identify the minimum, maximum and average flows for dry, wet and normal years for all the sites.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Dr. Gautam suggested to evaluate the Ganga river quality using Biological Water Quality Index using the generated biological data.	Processed ecology and biodiversity data for the Biodiversity Index (Shanon – Weiner Index, Simpson Index, Evenness Index) of 8 selected zones.

14. Analysis & Results:

i) Processed the hydro-chemical data for spatial and temporal variations.
ii) Experiments of Adsorption of metal Cd, Cr, Zn and Pb on bed sediment of River Bhagirathi at Gangotri for different operating variables are under progress.

iii) Processed relative abundant species of aquatic biodiversity viz; phytoplankton, zooplankton, macro-benthos and piscine fauna of different eight study zones of Upper Ganga basin of the samples collected.

iv) Discharge data of different sites viz. Deoprayag Bhagirathi, Deoprayag Ganga, Joshimath, Karnprayag, Rishikesh, Rudraprayag Alaknanda, Rudraprayag Mandakini, Rudraprayag Conf, Koteshwar and Uttarkashi from 1971-2018 (47 years) have been processed through consistency and gap filling. Probability Analysis was performed to identify the minimum, maximum and average flows for dry, wet and normal years for all the sites.

v) Processed ecology and biodiversity data for the Biodiversity Index (Shanon – Weiner Index, Simpson Index, Evenness Index) of 8 zones viz. Upper Alaknanda river, Upper Bhagirathi river, Upper Bhilangana river,Lower Bhagirathi river, Alaknanda Bhagirathi Conf, Upper Ganga river stretches, Middle Ganga river stretches and Lower Ganga river stretches from January 2017-December 2018.

Table 1. Hydro-chemical data of River Bhagirathi, River Alaknanda and River Ganga

Parameter	River Bhagirathi			River Alaknanda			River Ganga		
	Min	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Water temp ^{o}C	1.0	20	10.04	5	22	13.7	8	29	18.1
TSS, mg/L	0.2	2837	167.8	0.08	1953.8	98.97	0.26	743.8	79.9
TDS, mg/L	40.8	145.9	88.5	40.06	156.8	112.8	66.8	172.8	109.7
pH	6.3	8.6	7.5	6.8	8.3	7.9	7.3	8.9	8.0
EC, µS/cm	63.7	228	138.2	63	245	176	104	270	171.3
DO, mg/L	7	11.3	9.8	8	12.9	9.79	8.1	11.5	9.5
BOD, mg/L	0.3	2.2	1.2	0.3	3.4	1.41	0.5	3.2	1.36
COD, mg/L	2.1	45.7	12.8	2.08	41.1	12.83	2.1	36.96	12.74
HCO_3, mg/L	8.8	78.7	39.7	32.3	102.04	74.9	41.4	115.1	72.1
Cl, mg/L	0.1	2.8	1.1	0.115	6.33	1.22	0.050	4.003	1.603
NO_3, mg/L	0.02	3.8	0.9	0.261	2.501	1.135	.011	3.84	1.427
SO_4, mg/L	12	56.7	29.3	3.7	41.2	20.7	8.7	31.5	20.2
Na, mg/L	0.9	5.2	2.8	0.84	7.37	2.9	1.19	5.65	3.17
K, mg/L	0.01	3.5	2.3	1.37	4.07	2.39	1.22	4.02	2.32
Ca, mg/L	6.3	30	17	9.79	31.32	23.1	14.23	33.15	22.33
Mg, mg/L	1.4	7.2	3.8	1.09	8.32	5.53	2.47	10.71	5.41

15. End Users / Beneficiaries of the Study: Policy makers and planners of Central and State Government.

16. Deliverables: Technical report and research papers:

i) Sharma, M.K., Kumar, Pradeep, Prajapati, Parul and Bhanot, Kunarika (2019) Hydro-chemical Characteristics of Upper Ganga Basin, India, Submitted for Int. Conf. IGWC-2019 at IIT, Roorke during 21-25 Oct. 2019

ii) Sharma, M.K., Malik, D. S., Tomar, Garima and Wadhwa, Udita (2019) Ecological and biodiversity studyof Upper Ganga Basin, India, Submitted for Int. Conf. IGWC-2019 at IIT, Roorke during 21-25 Oct. 2019

17. Major items of equipment procured: Multi-Parameter Kit,

18. Lab facilities used during the study: Water Quality Laboratory (NIH)

19. Data procured or generated during the study: Discharge data and Hydro-chemical data

20. Study Benefits / Impacts:

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.

21. Involvement of end users / beneficiaries:

22. Specific linkage with Institution and /or end users / beneficiaries: GKV, Haridwar

23. Shortcoming/Difficulties: No

24. Future Plan:

- Processing of hydro-chemical data
- Processing of discharge data for Environmental flow requirement.
- Processing of Habitat parameter data.
- Experiments of Adsorption on bed sediments.

Study - 2 (Sponsored Project)

1. **Title of the Study:** Groundwater Quality Assessment with special reference to Sulphate contamination in Bemetara District of Chhattisgarh State and ameliorative measures

2. Study Group:

NIH	**WRD, Raipur**	**CGWB, NCCR, Raipur**
Project Investigator: Dr. M. K. Sharma, Sc. 'D'	**Project Investigator:** Mr. A. K. Shukla, Sr. Geohydrologist	**Project Investigator:** Mr. A. K. Patre, Scientist D
Co-Investigator Dr. Surjeet Singh, Sc. 'E' Dr. Pradeep Kumar, Sc. 'C'	**Co-Investigator** Mr. Ashok Verma, Asstt. Geohydrologist Mr. P. C. Das, Asstt. Geohydrologist	-

3. Type of Study: Sponsored project by NHP (PDS), Budget: Rs 25,39,600/-

4. Nature of Study: Applied Research

5. Date of start: 1 September, 2017

6. Scheduled date of completion: 31 August 2020

7. Duration of the Study: 3 Years

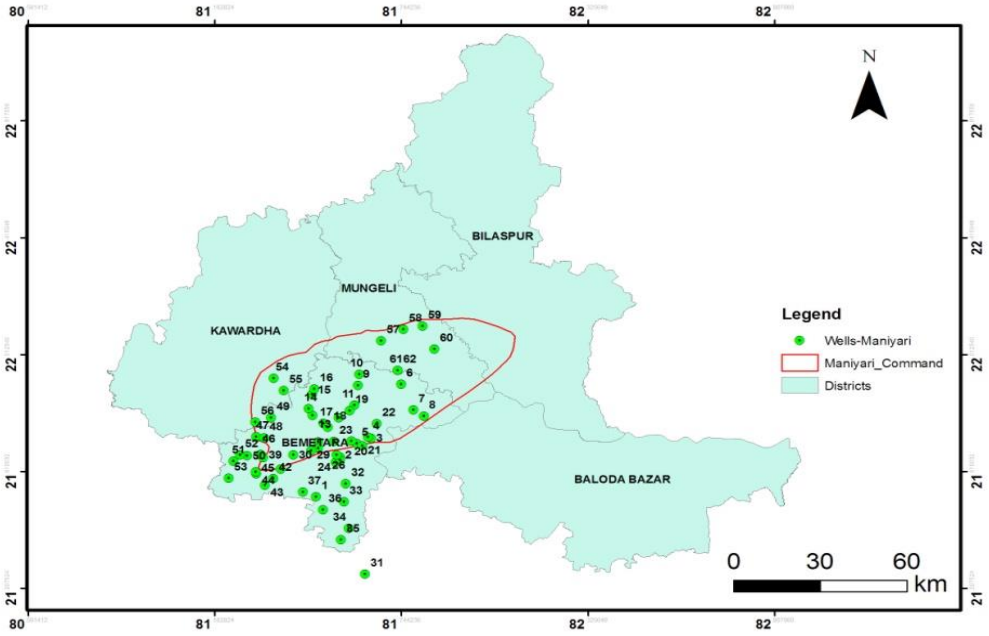
8. Study Objectives:

i) Groundwater quality monitoring in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.
ii) To map degraded ground water quality zones and possible sources of pollution and identify specific parameters not conforming to drinking/ & irrigation water quality standards.
iii) To investigate the important geochemical processes responsible for the groundwater contamination.
iv) Modelling flow and transport of sulphate contamination using MODFLOW & MT3D
v) To suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking/ & irrigation purpose by investigating the hydro-geology of the area.
vi) Dissemination of knowledge and findings to field engineers/scientists and common people through preparation of manual, leaflets, booklets and by organizing workshops/training.

9. Statement of the Problem:

Groundwater is one of the vital resources, which meets the requirements of daily livelihood especially in rural areas of India. Growing demand of water in various sectors viz; agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the groundwater resource, continuously declining groundwater levels, sea water ingress in coastal areas, and groundwater pollution in different parts of the country. Geo-environmental conditions have a marked influence on the groundwater quality. Hydrogeochemical studies relevant to the water quality explain the relationship of water chemistry to aquifer lithology. Such relationship would help not only to explain the origin and distribution of dissolved constituents but also to elucidate the factors controlling the groundwater chemistry.

In the District Bemetara, Chhattisgarh, the Precambrian sedimentary province includes Chhattisgarh Super group of rocks of upper proterozoic age of marine origin. It mainly consists of arenaceous-argillaceous-calcareous rocks and dominated by Limestone, dolomite and calcareous shale. The weathered, cavernous and fractured part of the formation constitutes the aquifers in the area. The groundwater of Bemetara district is affected by sulphate contamination reported by Public Health Engineering Department, Durg. Berla block of the district has also the possibility of such type of sulphate contamination in ground water. Therefore, Bemetara district is selected for purpose driven study for sulphate contamination in ground water. The high concentration of sulphate in ground water is due to the dissolution of gypsum veins present within maniyari shale formation. Higher concentration of sulphate in ground water causes gastrointestinal irritation. A cost effective, economic viable and environmental friendly measure will be suggested for remediation of groundwater with special reference to sulphate contamination considering hydrogeology of the area. After discussion with WRD, it was decided to focus on Maniyari shell formation region which will cover 9 blocks existing in five districts viz; Bemetara, Kawardha, Bilaspur, Mungeli and Baloda Bazar (Bhatapara).



Study area: Maniyari Shale Formation

10. Approved Action Plan/Methodology:

i) Literature survey on assessment of groundwater quality and issues in the region.
ii) Analysis of groundwater resources in the Bemetara district.
iii) Collection of existing meteorological and groundwater quality data of various locations of the Bemtara district and analysis.
iv) Collection of groundwater levels and lithological data from State Groundwater Department.
v) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.
vi) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.
vii) Analysis on flow and movement of groundwater.
viii) Analysis for physico-chemical parameters: pH, EC, TDS, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4,) and Toxic (Heavy) Metals: As, Cd, Cr, Pb, Cu, Ni, Fe, Zn, Mn in the collected water samples.

ix) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose.

x) Ionic relationships will be developed and water types will be identified. Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards.

xi) Suitability of ground water for irrigation purpose will be assessed on the basis of total soluble salts, SAR and RSC. Classification of water will be made using Piper trilinear diagram, Chadha's diagram, U.S. Salinity Laboratory Classification.

xii) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.

xiii) MODFLOW & MT3D will used for modelling flow and transport of sulphate, the model will calibrated using data collected along space & time for a period of one year.

xiv) Suggesting ameliorative measures to control/ restore the groundwater quality for sustainable use by various users investigating site-specific measures considering contaminant transport, hydrogeology and system dynamics (flow-movement of groundwater, hydrogeology, managed aquifer recharge, withdrawal patterns, etc.).

11. Timeline:

Year	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**
2017-18	-	-	Literature Survey	Field visit and Data Collection, Interim Report
2018-19	Field visit, Sampling, Data Collection and processing of the data	Sample Analysis and processing of the data	Field visit, Sampling, Data Collection, Analysis and processing	Analysis and processing of the data, Interim Report
2019-20	Field visit, Experiment, Data Collection, Analysis and processing	Analysis & Processing of the data	Modelling flow and transport of sulphate using MODFLOW & MT3D	Analysis & Processing of the data, Interim Report
2020-21	Analysis & Processing of data	Writing of Report	Writing of Report	-

12. Objectives and achievement during last six months:

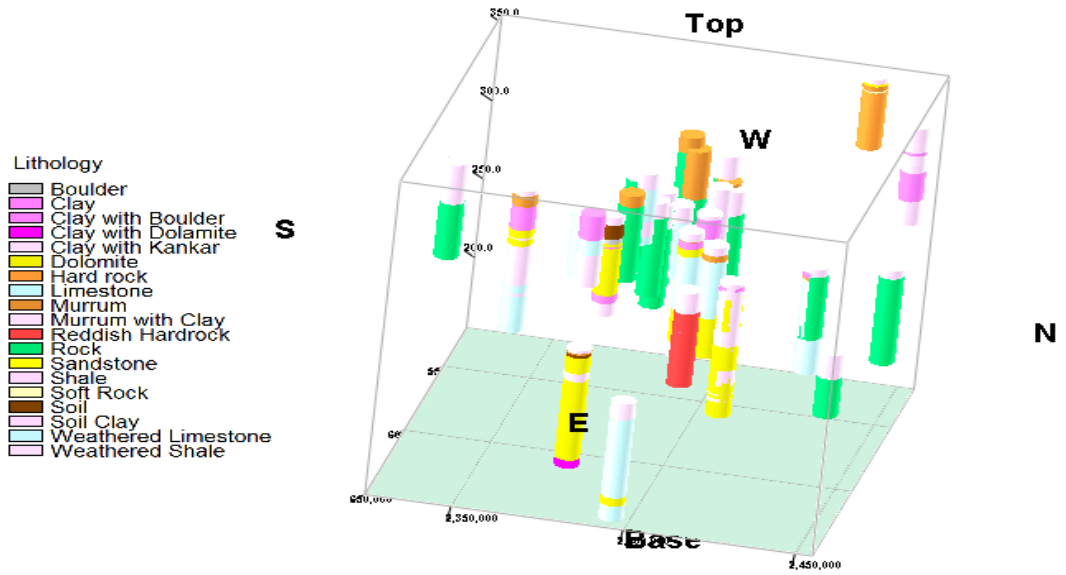
Objectives	**Achievements**
Field visit, Sampling, Data Collection and processing of the data	• A field visit was made during 10-14 June 2019 for pre-monsoon sampling and collected Litholog data from State Ground Water Survey, Durg.
Sample Analysis and processing of the data	• Hydro-chemical analysis completed.
Organization of Training Course	• A 5-day Training Course on "Groundwater Quality Monitoring and Assessment" was organized during 3-7 June 2019 at NIH, Roorkee.

13. Recommendation / Suggestion: No Comments

Recommendation / Suggestion	Action Taken
None	None

14. Analysis & Results:

i) Processed Aquifer parameter data and Litholog data of the study area
ii) Hydro-chemical analysis of collected groundwater sample completed.
iii) Analysed pre- and post-monsoon samples 2018 for metal concentrations.
iv) Processed hydro-chemical data for calculating Water Quality Index.



Litholog Variation in the study area

15. End Users / Beneficiaries of the Study: Policy makers and planners of Government of Chhattisgarh.

16. Deliverables: Technical report and research papers:
i) Sharma, M.K. and Kumar, Mohit (2019) Sulphate contamination in groundwater and its remediation: An overview, Env. Monit. Assess. (Under Review).
ii) Sharma, M.K., Kumar, Pradeep, Singh, Surjeet, Kumar, Mohit and Shukla, A. K. (2019) Source Identification of Sulphate Contamination using Hydrogeochemical Investigation: A Case Study of District Bemetara, Chhattisgarh, India, Submitted for Int. Conf. IGWC-2019 at IIT, Roorke during 21-25 Oct. 2019

17. Major items of equipment procured:

18. Lab facilities used during the study: Water Quality Laboratory (NIH)

19. Data procured or generated during the study: Hydro-chemical data

20. Study Benefits / Impacts:

For any scheme of water supply in an area, it is mandatory to have the status of water quality of the water resources being used for supply. An extensive survey of groundwater quality monitoring of district Bemetara will provide the knowledge about degraded ground water quality zones and possible sources of pollution and specific parameters not conforming to

drinking/ & irrigation water quality standards, which will help the policy makers and society. Further, present PDS will suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking and irrigation purpose by investigating the hydro-geology of the area.

21. Involvement of end users / beneficiaries: Water Resources Department (WRD), Government of Chhattisgarh, Raipur

22. Specific linkage with Institution and /or end users / beneficiaries: CGWB, Raipur and WRD, Raipur

23. Shortcoming/Difficulties: No

24. Future Plan:

- Field visit and Collection of ground water samples in post-monsoon season (November 2019) and their analysis.
- Processing of ground water data and water quality data.
- Development of Lithological model.
- Aquifer characterization.
- Preparation of Groundwater flow model in Modflow.
- Collection of ground water data, aquifer parameter data and hystorical ground water quality from CGWB, Raipur and PHED.

Study - 3 (Sponsored Project)

1. **Title of the Study:** Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures

2. **Study Group:**

Lead Organization	**Project Investigator** Dr. Rajesh Singh,Sc. 'C'
	Co-Investigator Dr. Pradeep Kumar, Sc. 'C' Dr. Mukesh K. Sharma, Sc. 'D' Er. Sumant Kumar, Sc. 'C'
	Scientific/Technical Staff Sandeep Singh, RA Rakesh Goyal, Tech. Gr. I Meenakshi Rawat, JRF Prashant kaushik, TA
Partner Organization	**Project Investigator** Er. Harminder Singh, Chief Engineer, Water Resources
	Co-Investigator Er. Narinder Kumar Jain, Director, WR&ED Dr. K. K. Kaushal, Sr. Hydrogeologist, WR&ED Mr. Sanjeev Bansal, Sr. Tech. Asst., WR&ED
Collaborators	Dr. S. P. Rai, Assoc. Professor, BHU, Varanasi Dr. Karrie A. Weber, Assoc. Professor, UNL, Lincoln Dr. Brijesh K. Yadav, IIT Roorkee Dr. Naseem Ahmed, IIT Roorkee

3. **Type of Study:** Sponsored project under NHP, **Budget: Rs 65.6 lacs**
4. **Nature of Study:** Applied Research
5. **Date of start:** October 2017
6. **Scheduled date of completion:** September 2020
7. **Duration of the Study:** 3 Years
8. **Study Objectives:**

   i) Spatial and temporal variation of water quality parameters and carcinogenic contaminants.
   ii) Quantification of mutagenic potential (carcinogenicity) of water samples.
   iii) Source identification of major contaminants in the study area and impact assessment on human health.
   iv) Suggestions for possible remedial measures to reduce the impact of contaminants.
   v) Dissemination of knowledge and findings to field engineers/scientists and common people through the preparation of manual, leaflets, booklets and by organizing workshops/training.

9. **Statement of the Problem:**

Punjab has been the subject of much skepticism in the last decade. It has previously been called the "grain bowl of the country", but has recently adopted a new nickname, "the cancer bowl of the country". The pride of holding the title "a state with maximum per capita income"

came with the price of cancer due to unrestricted use of chemicals (pesticides, fertilizers, metals, polycyclic aromatic hydrocarbons, pharmaceutically active hydrocarbons, etc.) in the agricultural fields and industries. A train which connects the affected region with the nearby Bikaner city, which contains a cancer hospital, has been nicknamed Cancer Express. Thakur et a. (2015) analyzed trace metals, pesticides, and other relevant parameters in some major drains, water samples (surface as well as groundwater), fodder, vegetable, and blood samples, and concluded that these samples contained harmful contaminants in excess of desired levels. Intake of these contaminants through the water as well as food is leading to deleterious health effects such as gastrointestinal disorders, reproductive toxicity, neurotoxicity, renal toxicity, and carcinogenic manifestations (WHO, 2011). Another study conducted by Thakur et al. (2008) observed a higher prevalence of cancer cases and cancer-related deaths in the area. A year-long study entitled "An epidemiological study of cancer cases reported from villages of Talwandi Sabo block, district Bathinda, Punjab", conducted by School of Public Health (SPH) at the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, compared cancer incidents in the villages producing cotton with those producing rice and wheat, and found high cancer rates in the villages where pesticide usage was high. A recent hospital-based study for Punjab shows that out of the 1328 cancer cases in the state, 1230 cases were from the seven districts of Southern Punjab comprising Muktsar, Ferozepur, Bathinda, Faridkot, Fazilka, Moga& Mansa districts (Aggarwal et al., 2015). Considering the high cancer numbers and poor water quality described above, a comprehensive study of groundwater contaminants, especially carcinogens, is urgently required for the state of Punjab. The objectives of this study is to analyze the water quality of the area with an emphasis on carcinogenic chemicals, identifying their sources, and suggesting appropriate remedial measures.

10. Approved Action Plan/Methodology:

i) Upgradation of literature and data collection
ii) Delineation of villages and finalization of sampling locations
iii) Sampling & analysis of water samples
iv) Statistical analysis of the contaminant data and cancer incidences
v) Mutagenicity of water resources
vi) Contaminant remediation

11. Timeline:

S. No.	Activities	YEAR 1				YEAR 2				YEAR 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Hiring of manpower & training												
2.	Purchase of equipment & consumables												
3.	Upgrading literature and data collection												
4.	Delineation of villages and finalization of sampling location												
5.	Collection and analysis of samples												
6.	Statistical analysis of data and Carcinogenicity test												

7.	Contaminant remediation												
8.	Training & capacity building												
9.	Scientific publications												
10.	Final technical report												

12. Objectives and achievement during last twelve months:

S. No.	Activity	Achievements
1.	Purchase of equipment & consumables	• Laptop & Multiparameter analyzed has been purchased. • For syringe pump, the process was done once unsuccessfully. • Purchase of software is pending. • Standards and consumable planned for the period has been procured.
2.	Delineation of villages and finalization of sampling location	This took a little longer time due to language issue.
3.	Collection and analysis of samples	• The pre-monsoon sampling for the delineated villages has been completed. • Analysis of organoleptic and major ions has been completed. • Processing of samples for pesticide and PAHs analysis has been completed and analysis work will be completed by mid Nov. 2019. • Analysis of trace metals will also be completed by end of mid Nov. 2019.
4.	Statistical analysis of data and Carcinogenicity test	• The health risk assessment for Bathinda district was done. The same will be replicated for other districts once the analytical results are available. • The infrastructure required for carcinogenicity test is ready and the process for procurement of bacterial strains has been initiated.
5.	Training & capacity building	A training course for the government officials was organized during June 17-21, 2019.
6.	Scientific publications	A research paper titled 'An overview of carcinogenic pollutants in groundwater of India' is published in *Biocatalysis and Agricultural Biotechnology*, https://doi.org/10.1016/j.bcab.2019.101288. Two manuscripts are under writing stage.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Dr. S.S. Grewal suggested to collect the samples from the villages/locations in depressions.	The samples for pre-monsoon will also be collected from the villages/locations in depressions.

14. Analysis & Results:

Purchase of equipment & consumables:

- Multiparameter Ion Analyzer with Electrodes: Purchased

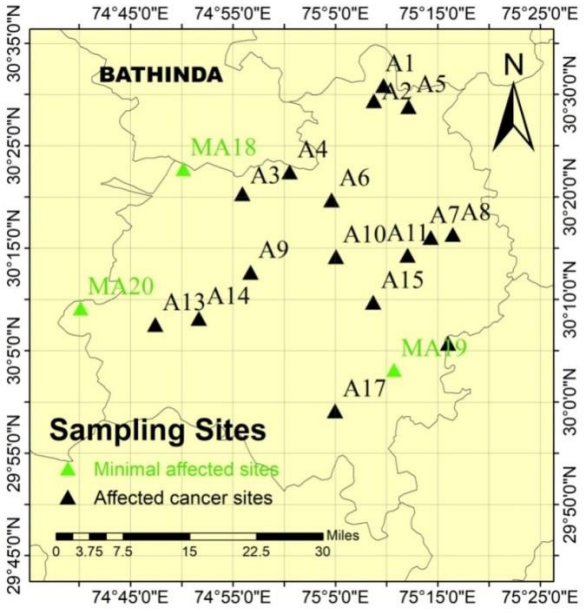
- Laptop & Peripherals: Purchased.
- Syringe Pump along with accessories: The purchase process was completed, however, the procurement was not made due to low response from the vendors. The procurement will be again processed in this financial year.
- Software: Details of software for procurement has been provided to procurement section.
- Required planned glassware, plasticware, filter paper and chemical purchased for sample collection and analysis.

Upgrading literature and data collection:

- The recently published literature related to carcinogens in the water and their assessment was reviewed and a review paper titled 'An overview of carcinogenic pollutants in groundwater of India' is published in "Biocatalysis and Agricultural Biotechnology", published https://doi.org/10.1016/j.bcab.2019.101288. Two more research articles are under writing stage.
- Cancer related patient data collected from district and other Hospitals.
- Translation of cancer related data (2016-2018) from Punjabi to English language has been completed for of all districts.

Delineation of villages and finalization of sampling location

The village-wise number of cases for year 2016, 2017, & 2018 were collected from the district hospitals and Dept. of Health & Family Welfare, Govt. of Punjab, and was used for selecting the sampling sites. The village wise population data was downloaded from the MHA website (http://censusindia.gov.in/2011census/Listofvillagesandtowns.aspx). Each district was divided into grid of 10x10 km, and the cancer prone grids were identified and selected based on number of cancer cases, per capita cancer cases, and number of villages. Further, the village for sampling in a cancer prone grid was selected based on highest per capita cancer cases. Twenty sampling locations were finalized for each district, 17 from cancer prone grids, and 03 from minimal affected grids as shown in below figure for Bathinda district.



Sampling Sites of Bathinda District

Sampling & Analysis

Drinking water samples from the identified villages were collected after discussion with the villagers based on the usage. The handpump were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of

groundwater aquifer. All the groundwater samples were collected from the sources, which are being used extensively. The samples from Bathinda and Mansa for pre-monsoon period were collected in Feb. 2019, Mauktsar and Fardikot in May 2019, and Fazilka and Firozepur in June 2019. From each district, 20 samples were collected, 17 from cancer prone villages and 3 from villages with negligible cancer incidences.The water samples are collected in appropriate sampling bottles as given in using grab sampling method and preserved as per standard methods (APHA, 2017).

The organoleptic parameters, major ion, and trace metals analysis has been completed and analysis of pesticides and polyaromatic hydrocarbons are being analyzed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).

15. **End Users / Beneficiaries of the Study:** Policy makers and planners of State/Central Government Organizations

16. **Deliverables:** Technical report and research papers, First-hand information on water quality of the area related to carcinogenicity

17. **Major items of equipment procured:** i) Multiparameter Ion Analyzer ii) Syringe Pump iii) Geochemistry Software

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH) / Isotope Lab (NIH) / IIC (IITR)

19. **Data procured or generated during the study:** Water quality data of the area

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the first-hand information on the water quality of the area related to carcinogenicity. This will also lead in preparing a protocol for monitoring the carcinogenicity of water and will be helpful for the monitoring agencies. The project will also suggest the remedial measure for providing safe water to the habitation, which can be implemented by concerned state government agencies.

21. **Involvement of end users/beneficiaries:** Water Resources & Environment Directorate, Punjaband Local people

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:** NA

24. **Future Plan:**

i) Analysis of pesticides and PAHs in the pre-monsoon samples.
ii) Analysis of trace elements like U, Th etc. in the pre-monsoon samples.
iii) Collection and analysis of post-monsoon samples.
iv) Statistical analysis of data and carcinogenicity test.

Study - 4 (Internal Research Project)

1. Title of the Study: Water quality assessment of Haridwar District

2. Study Group:

Project Investigator	Er. Rajesh K. Nema, Sc. B, EHD
Project Co-investigator	Dr. Rajesh Singh, Sc. C, EHD Dr. J. V. Tyagi, Sc. G & Head, EHD Dr. Pradeep Kumar, Sc. C, EHD
Scientific Staff	Mrs. Anju Chaudhary, PRA Mr. Rakesh Goyal, Tech. Gr. 1

3. Type of Study: Internal Study, **Budget: Rs 17.1 lacs**

4. Nature of Study: Applied Research

5. Date of start: June 2019

6. Scheduled date of completion: May 2022

7. Duration of the Study: 3 Years

8. Study Objectives:

i) Spatial variability determination of groundwater quality.
ii) Statistical analysis and water quality indexing for different designated uses namely drinking and irrigation.

9. Statement of the Problem:

Water of sound quality is the key for vital socio-economic functions on Earth. Most users of water depend on adequate levels of water quality. When these levels are not met, these water users must either pay an additional cost for water treatment or incur at least increased risks of damage or loss. As populations and economies grow, more pollutants are generated and degradation of water resources has become one of the most pressing global concerns currently facing mankind. Increasingly, the major efforts and costs involved in water management are devoted to water quality protection and management. Conflicts among various users of water are increasingly over issues involving water quality as well as water quantity. Evidently, there is a need for effective management efforts, where one possible action is to focus on minimizing pollutant load from pollutant-producing areas to water resource areas.

After creation of Uttarakhand state in 2002, several industrial parks were developed in Haridwar district. In addition, the cities in Haridwar district also expanded. The industrial and urban development results in contamination of water resources. Groundwater is the main source of drinking in the district and hence, requires analysis of water quality parameters. Keeping in view of the same, this study aims at analyzing the water samples for organoleptic parameters, major ions, trace metals, and pesticides to understand the suitability of water for different usage and to understand the weathering processes controlling the water quality.

10. Approved Action Plan/Methodology:

a) Collection of groundwater samples during pre and post monsoon from selected locations of Haridwar district.
b) Analysis of water samples for organoleptic parameters, major ions, trace metals, and pesticides.

c) Processing the data to understand the contamination of water and suitability of various designated use.

11. Timeline:

Sr. No.	Major Activities	2019-20			2020-21				2021-22			
		2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.
1.	Field Investigation and sampling plan											
2.	Sample Collection and Analysis											
3.	Data Processing and Interpretation											
4.	Interim Report											
5.	Final Report											

12. Objectives and achievement during last six months:

S. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Pre-monsoon samples were collected from 68 locations. • Analysis for organoleptic, major ions, and coliforms in the collected samples completed. • Samples were processed for pesticides and analysis will be completed in November 2019.

13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Sharad K. Jain suggested to assess the water quality of the ponds also.	• Samples from ponds were also collected.
2.	Dr. Ramakar Jha appreciated the study and suggested to compare it with the previous data	• The results will be compared with previous study data.

14. Analysis & Results:

Field Investigation and sampling plan

The district was divided into grid of 5x5 km, and one village in each grid, totaling to 68 locations, was selected for sampling for organoleptic parameters, major ions, and

bacteriological parameters. 19 samples for pesticide analysis were collected by dividing the district into 10x10 km grid.

Sampling & Analysis

Groundwater and pond samples from the identified villages were collected after discussion with the villagers based on the usage. The handpumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of groundwater aquifer. The water samples were collected in appropriate sampling bottles using grab sampling method and preserved as per standard methods (APHA, 2017).

The organoleptic parameters, major ion, and bacteriological analysis are completed and analysis of trace metals and pesticides are being analyzed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).

15. **End Users / Beneficiaries of the Study:** Policy makers and planners of State Government Organizations

16. **Deliverables:** Technical report and research papers, First-hand information on water quality of the Haridwar District

17. **Major items of equipment procured:** None

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH) / IITR

19. **Data procured or generated during the study:** Water quality data of the area

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the first-hand information on the water quality of the area. The project will also evaluate the health hazard impact, which will be beneficial for the state government agency for providing safe drinking water.

21. **Involvement of end users/beneficiaries:** None

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:** The facility for analysis of pesticide is not available in the institute.

24. **Future Plan:**

i) Analysis of pesticides and trace metals in the pre-monsoon samples.
ii) Collection and analysis of post-monsoon samples.
iii) Statistical analysis of data.

Study - 5 (New Sponsored Project)

1. **Title of the Study:** Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures

2. **Study Group:**

Project Investigator/Co-Project Investigator Er. Anjali, Scientist B, EHD Dr. Sudhir Kumar, Scientist G & Head, HID Dr. J. V. Tyagi, Scientist G & Head, EHD Dr. M. K. Sharma, Scientist D, EHD Dr. Nitesh Patidar, Scientist B, GWHD
Scientific/Technical Staff Mrs. Babita Sharma, RA, EHD
Collaborating Agency Dr. S.K.Juneja, Scientist D, CGWB (Delhi Unit)

3. **Type of Study:** Sponsored project by NHP (PDS), Budget: Rs 76,10,000/-

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

5. **Date of start:** 1 November, 2019

6. **Scheduled date of completion:** 31 October, 2022

7. **Duration of the Study:** 3 Years

8. **Study Objectives:**

   i) Understanding of hydrodynamics of groundwater flow in the study area.
   ii) Chemical characterization of Leachate.
   iii) Isotopic characterization of leachate and its variation due to recharge and extraction of groundwater.
   iv) Assessment of Micro-plastic and metals (Hg, Ni, Co) in landfill leachate.
   v) Modelling of leachate migration pattern in groundwater in space and time.
   vi) Suggesting ameliorative measures for contaminant plume migration.
   vii) Dissemination of knowledge and findings to stakeholders through manuals, leaflets, booklets and workshops/training programs.

9. **Approved Action Plan/Methodology:**

   i) Literature review on chemical and isotopic characterization of leachate, groundwater contaminant transport modeling etc.
   ii) Field survey of the region and groundwater sampling – using standard protocols.
   iii) Characterization of leachate using EPA methods- TCLP (method no.- 1310) & column study (method no.- 1312).
   iv) Collection of groundwater levels to ascertain the flow direction.
   v) Identification of groundwater recharge and discharge areas.
   vi) Collection of groundwater samples on bi-monthly basis at identified locations.
   vii) Analyzing the physico-chemical parameters: pH, EC, DO, COD, TOC, Major anions, cations, and trace metals (Fe, Mn, Zn, Pb, Cd, Cr, Radium etc).
   viii) Analysing the stable isotopic characteristics of leachate and groundwater at various identified locations.
   ix) Analysing the groundwater samples and leachate for micro-plastic.
   x) Processing of hydro-chemical and isotopic data on bi-monthly basis.
   xi) Modeling the leachate migration from the landfill to groundwater table. The model will be developed for one dimensional vertical transport of contaminants through unsaturated zone.

xii) Modeling of leachate plume movement in groundwater will be performed using MT3D MODFLOW and HELP. The leachate transport model will be calibrated based on chemical and isotopic data.

xiii) Suggesting ameliorative measure for containment of contaminant plume based on groundwater modeling.

10. Timeline:

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1st Year	Literature survey	Field investigation, data collection and literature survey	Groundwater sampling and data processing	Groundwater sampling and analysis, estimation of flow parameters, and interim report
2nd Year	Groundwater sampling and analysis, and leachate characterization	Groundwater sampling and analysis, plume characterization and model conceptualization	Groundwater sampling and analysis, model conceptualization, training and workshop	Groundwater sampling and analysis, development of mathematical model, and interim report
3rdYear	Development of mathematical model	Computational runs with the developed model and identification of vulnerable areas and hot spots	Computational runs with the developed model and identification of vulnerable areas and hot spots	Finding ameliorative measures, training, workshop and report writing

11. Progress:

i) Field Survey was undertaken for selecting sites for Leachate sampling

ii) For understanding the basic characteristics of leachate, preliminary samples were collected in order to find out the suitability of various experiments and to identify the procedures need to be followed in future.

iii) The physico-chemical, meatl contents and isotopic parameters of Leachate was identified.

iv) Reasons for coloured samples which hinders various experiments is being identified.

12. **Research Outcome from the Project:**

Dumping sites have always seen as a source of groundwater pollution but no serious attempt has been made so far to quantify the extent of this problem and to pay attention on technically feasible remedial measures. The proposed study along with the extensive survey on groundwater quality will help in differentiating the groundwater pollution caused by landfill from those of other sources of pollution. Thus, the study can act as tool in hands of policymakers for appropriate management of landfills and providing sustainable drinking water along with alienating the fears associated with the landfills. The study will also help in arriving at the vulnerable areas and hot spots that need greater attention for groundwater protection and taking measures for associated health risks.

Study – 6 (Internal Research Project - New)

1. **Title of the Study: Simulation of Non-Point Source Pollution Processes in Song River**

2. **Study Group:**

Project Investigator Dr. Pradeep Kumar, Sc. C
Co-Investigators Dr. J. V. Tyagi, Sc. 'G' Dr. M. K. Sharma, Sc. 'D' Dr. Rajesh Singh, Sc. 'C' Er. R. K. Nema, Sc. 'B'
Supporting Staff Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. **Type of Study:** Internal

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

5. **Date of Start:** November 2019

6. **Scheduled date of Completion:** October 2023

7. **Duration of the Study:** 4 years

8. **Study Objectives**

i) Assessment of the point and non-point pollutant loads
ii) Mapping of various non-point pollution sources
iii) Simulation of various hydrological processes in the river catchment
iv) Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment

9. **Statement of the Problem**

Increasing population and subsequently increasing water, food and energy demands have put tremendous pressure on the water resources. The problem is more substantiated by the increasing consumption of the products with high water footprints. The food and energy demands of rapidly increasing population have caused intense agriculture, industrialization and urbanization. This has resulted in indiscriminate discharge of municipal and industrial wastes. Municipal wastes being biodegradable produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effects produced by them may be more serious as nature is often unable to assimilate them. Agriculture is also responsible for degrading the water quality through leaching and runoff from agricultural fields and animal husbandry units, which contain predominantly organic compounds from the use of mineral fertilizers and chemical pesticides. These pollutants ultimately contaminate aquifer system due to surface and groundwater interactions.

The planning of water as a national resource is not merely a question of ensuring the availability of water in the right quantity at the right time for diverse purposes, but also ensuring the right quality for the intended use. Further, for any proper water resources planning, whether long or short term, before going into alternative plans for development, it is very essential to assess water quality problems together with hydrological analysis.

Since, point source pollution meets the river at known locations, it may be addressed by STPs or ETPs. Non-point source pollution reaches the river through the landscape after following a

number of hydrologic, physical, chemical and biological processes. Hence, it is very complex to assess the causes and plan for its remediation. Very few assessments of non-point source pollution have been made in Indian rivers and they are mostly limited upto quantification of pollutant loads through the flux balance approach. Therefore, this study is being envisaged to simulate the non-point pollution process in a lower Himalayan catchment to identify the sources and causes of non-point source pollution.

10. Methodology

i) Procurement of secondary data required for the analysis from various govt. agencies (discharge, sediment concentration, other water quality parameters, soil map etc.)
ii) Collection of water samples at monthly frequency during non-monsoon and daily frequency during monsoon season from selected locations of Song river
iii) Collection of data on usage of fertilizers and pesticides in the Song river catchment.
iv) Analysis of water samples for general water quality parameters, total suspended solids, nutrients and pesticides
v) Hydrological and water quality modelling using SWAT model

11. Work schedule / Timeline

S. No.	Major Activities	2019-20		2020-21				2021-22				2022-23				2023-24		
		3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr
1.	Reconnaissance visit and sampling plan																	
2.	Secondary data collection																	
3.	Field surveys																	
4.	Sample Collection and Analysis																	
5.	SWAT Model: Preparation of database																	
6.	SWAT Model: Calibration, Validation & Simulation																	
7.	Interim Report																	
8.	Final Report																	

12. Cost estimate: Rs. 43,02,000 (NIH Internal Fund)

S. No.	Sub-Head	I Year	II Year	III Year	IV Year	Total
1.	Manpower	438000	438000	438000	258000	1572000
2.	Travelling expenditure	400000	300000	300000	20000	1020000
3.	Infrastructure / Equipment / Consumable	650000	50000	50000	10000	760000
4.	Experimental charges / Analytical charges	250000	250000	250000	-	750000
5.	Misc. Expenditure	50000	50000	50000	50000	200000
6.	Grand Total	1788000	1088000	1088000	338000	4302000

a. Justification for sub-head-wise abstract of the cost

- Manpower: For timely collection of water samples and discharge required for the simulation

S. No.	Manpower Category	Nos.	Gross Salary per month	1st year	2nd year	3rd year	4th year	Total
1.	Resource Person (Junior)	1	21500	258000	258000	258000	258000	1032000
2.	Skilled Daily Wage Personnels (for 4 months in monsoon season)	4	15000	180000	180000	180000	-	540000
Sub-Total				438000	438000	438000	258000	
Total								**1572000**

- Travelling expenditure: For visit to study area, attending conferences, data collection, surveys etc. (one visit per month for sampling during non-monsoon, two visits per month during monsoon, 10 visits of 5 days for village level survey)
- Equipment/Consumables: Purchase of pH-Conductivity meters, chemicals, glasswares, plasticwares etc.
- Experimental/Analytical charges: Towards analysis of samples in outside laboratories and in NIH water quality lab

13. Research outcome from the project:

a. Point and Non-Point pollutant loads at various locations in Song river
b. Quantum of non-point source pollution for various scenarios of fertilizers/ pesticides applications
c. Technical report and papers

14. End Users / Beneficiaries of the study: Deptt. of Irrigation & Deptt. of Agriculture, Uttarakhand

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

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

WORK PROGRAMME FOR THE YEAR 2019-20

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh, C. P. Kumar, P. K. Singh	2 years (05/19 - 04/21) *Status: In progress*	Internal Study
2. NIH/GWH/NIH/19-20	The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year (08/19 – 07/20) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
Sponsored Projects				
3. NIH/GWH/NIH/15-19	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply	Surjeet Singh (Lead), B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal	2.5 years (11/15–12/19) Extended till Dec. 2019 *Status: In progress*	Sponsored by MoWR, RD & GR under Plan Fund
4. NIH/GWH/NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8
5. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	3 years (12/17-11/20) *Status: In progress*	Sponsored by BGS, UK
6. NIH/GWH/PDS/17-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3 years (12/17-11/20) *Status: In progress*	Sponsored by NHP under PDS

7. NIH/GWH/PDS/17-21	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), Surjeet Singh, C. P. Kumar, S. K. Verma *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
8. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-11/22) *Status: In progress*	Sponsored by NHP under PDS
9. NIH/GWH/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme
10. NIH/GWH/DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants	Anupma Sharma (India Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Other Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* School of Water, Energy and Environment, Cranfield University *Project Partners:* Water Harvest, Excellent Development (UK based NGOs)	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme

11. NIH/GWH/ CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi	Anupma Sharma (PI) Sanjay K. Jain, Archana Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Suman Gurjar, Vishal Singh, Nitesh Patidar *Partner Organizations:* Water Resources & Irrigation Dept. Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, New Delhi	4 years (04/18-03/22) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)
12. NIH/GWH/ DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (Lead NIH), C.P. Kumar, Nitesh Patidar (Lead: CAZRI Jodhpur, Partners: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur)	5 years (03/19 - 02/24) *Status: In progress*	Sponsored by DST
13. NIH/GWH/ NMCG/19-20	Environmental Flow Assessment for Yamuna River from Hathnikund Barrage to Okhla Barrage	Anupma Sharma (PI), Sharad K. Jain, Manohar Arora, Pradeep Kumar, Rajesh Singh, Vishal Singh	1 year (04/19 - 03/20) *Status: In progress*	Sponsored by NMCG
14. NIH/GWH/ MoES/19-19	Improving our Understanding of the Aquifer Systems in Sunderbans	Gopal Krishan (PI), C. P. Kumar (Co-PI)	6 months (06/19 - 11/19) *Status: In progress*	Sponsored by India-UK Water Centre (MoES & NERC)
Other R & D Projects				
15. NIH/GWH/ CEHM/18-21	Development of Groundwater Module for Integrated Hydrologic Model	Anupma Sharma (PI), B. Chakravorty, Surjeet Singh, Suman Gurjar, Sumant Kumar, Nitesh Patidar	3 years (08/18 -07/21) *Status: In progress*	CEHM, NHP
Consultancy Projects				
1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	10 months (03/19-12/19) *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) *Status: In progress*	Punjab Government

3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	12 months (04/19-03/19) *Status: In progress*	Irrigation Deptt., Saharanpur
4.	Hydro-geological Study of Goindwal Sahib Area of Tarn Taran District, Punjab	Surjeet Singh (PI)	6 months (09/19-02/20) *Status: In progress*	GVK Power Ltd., Tarn Taran (Punjab)

The details of the studies are given in Annexure-I.

Laboratory and Centre:

- Soil-Water Laboratory
- Centre of Excellence for Advanced Groundwater Research

Trainings planned to be organized:

The division shall be organizing 3 training courses under NHP during 2019-20 in the groundwater domain (i) one for the north-east region, (ii) one for the northern states (iii) one for the central Indian states.

Outreach activities during 2019-2020

1. Scientists published/accepted **15** papers in international/national journals & conferences.
2. Scientists delivered **20** lectures in different training courses and workshops.
3. Scientists guided/guiding **11** M.Tech./Ph.D. students for their thesis work.

1. PROJECT REFERENCE CODE: NIH/GWH/NIH/19-21

Title of the Project: Application of Satellite Data Products for Water Resources Assessment

Project team

a.	Project Investigator	Ms. Suman Gurjar, Sc-C
b.	Co- Project Investigator	Dr. Vishal Singh, Sc-C
c.	Investigator(s)	Dr. Surjeet Singh, Sc-E
		Mr. C P Kumar, Sc-G

Type of study: Internal

Duration: April 2019 - March 2021

Objectives:

- Assess the applicability of using multi satellite data approach for water resource assessment
- To analyze the accuracy of the satellite data product by calibrating it with the observed data and use the satellite data at places where there is scarcity of observed data.
- Explore the use of satellite data on scales smaller for water resources management

Study area: **Ganga Basin**

Methodology:

The process of water resources assessment involves developing a complete understanding as possible of these flows and stores and their interrelationship over time. Only then is it possible to estimate what sustainable surplus flows may be made available for human or other uses as both sources and systems change in the future through climate change, natural evolution or human made interventions. Ganga Basin is used for water resource assessment in the study. A comprehensive gathering and collation of recent and historical hydrological available satellite data related to the basin area (for example, surface water resources, groundwater resources). This will include satellite data on precipitation, evaporation, river flow, surface storage, soil moisture and groundwater and, where relevant. Since the data is of different scale and time duration, the further step required is to bring the spatial and temporal data in one resolution scale and common time duration by downscaling/upscaling of data. After having assembled all the data, water balances for the basin will be done. For assessment of surface water and groundwater, hydrological models such as SWAT-MODFLOW will be used.

The results will be calibrated and validated using the observed data at certain locations of the basin, to verify and check the accuracy of the generated results.

Progress made so far:

- Wrote the script to download data from online sources.
- Wrote the script to convert the downloaded data into usable form for the modeling
- Only small set of data is downloaded due to large size of data sets.
- Installed and performed the basic operations on SWAT model.

2. PROJECT REFERENCE CODE: NIH/GWH/NIH/19-20

Title of the Project: The regional hydrological impact of farm-scale water saving measures in the Gangetic plains

Project team

Project Investigator	Dr. Sumant Kumar, Sc-C &PI
Co- Project Investigator	Er. C.P. Kumar, Sc-G & Head, GWHD
Investigator(s)	Dr. Archana Sarkar, Sc-D
	Dr. Surjeet Singh, Sc-E
	Dr. P.K. Mishra, Sc-C

Type of study: Internal

Duration : August 2019 - July 2020

Objectives:

- A review of agriculture practices and agricultural water saving measures and their impact on groundwater resources.
- Trend analysis of groundwater level data to understand recharge and discharge processes.
- To study surface water and groundwater interaction based on the available and monitored data.

Study area: Bhojpur district of Bihar

Methodology:

The scoping study will be mainly based on a desktop analysis using existing hydrological, meteorological and agricultural data. However, hydrological data would also be generated based on field investigation. River water level and groundwater level would be monitored to study the interaction between SW and GW. Based on the available and generated data, a coarse GW modelling would be attempted to study the impact of water saving measures on groundwater resources.

3. PROJECT REFERENCE CODE: NIH/GWD/NIH/15-19

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 2019), extended by nine months up to December, 2019

Type of study: Sponsored by MoWR, RD & GR, GoI Under NIH's Plan Fund

Nature of study: Demonstration and applied research

Methodology

Six pilot demonstration schemes in 5 states, viz. one in Uttarakhand (Laksar along Solani river), two in Uttar Pradesh (Mathura and Agra along the Yamuna river), one in Jharkhand (Sahebganj along Ganga river), one in Bihar (Ara along Ganga river), and one in Andhra Pradesh (Visakhapattnam area) were planned to develop. Respective State Jal Sansthan/PHED/Jal Nigam was included as the collaborating partner for the schemes. HTWD, Germany was associated as scientific and technical adviser. The roles of State Jal Sansthan/PHED/Jal Nigam are to extend administrative and logistic supports in the field including identification of sites and providing required land for the scheme and electrical facilities for installation of tube wells and O & M of the pumps.

Deliverables

Schemes demonstrating effectiveness of 'Riverbank Filtration' technique for sustainable drinking water supply in different hydrogeological settings, river hydraulic and groundwater conditions are the planned deliverables 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, particularly in rural areas.

Progress

Based on the progress made so far on the study, a detailed report (Part-1) has been prepared and the report is available on NIH's website: ***nihroorkee@gov.in*** (click: old website, in the old website click, 'Institutional Digital Repository')

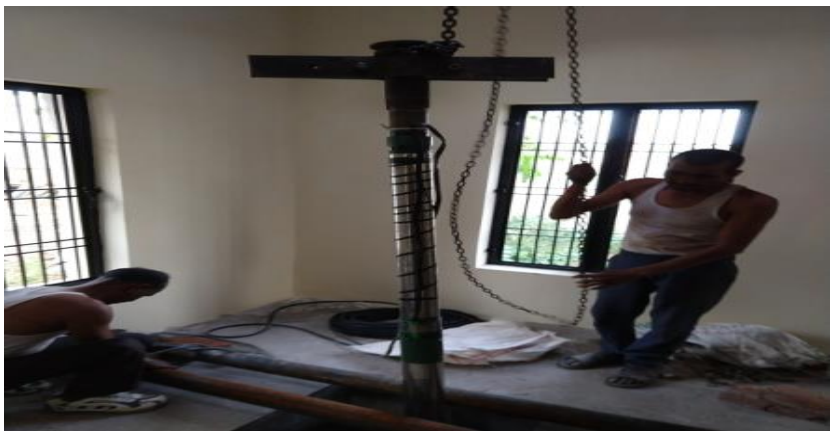
Location-wise progress is given below:

(i) Laksar Site, Uttarakhand

The RBF site explored and installed tube well at Kuan Khera village in Laksar, UK in the year 2016 was abandoned because of water quality problem of geogenic origin and also due to its damage by bank erosion and threat of riverbank shifting.

(ii) Mathura and Agra Sites

Phase-I that dealt with exploratory drilling, development and installation of production tube wells both at Mathura near Gokul barrage **and Agra** near Agra Water Works were completed through U.P. Jal Nigam, Agra as deposit work. Phase-II that deals with installation of submersible pumps, construction of pumping plants, pump house, stand post, etc. for both the sites is almost complete. Quarterly water quality of RBF well, Yamuna river and nearby hand pumps, drain, etc. is being monitored for arsenic, trace metals and other water quality parameters. After ascertaining the water quality of the RBF well, both the sites will be handed over to U.P. Jal Nigam for public water supply.



Developed scheme at Agra

(iii) Ara site in Bihar

PHED, Govt. of Bihar has carried out the drilling, lowering and development of the bank filtration tube well in the premise of the temple, identified as the location for RBF (latitude - $25^0$41' 0.00" N and longitude - $84^0$43' 34.94"E) in Barhara village of Ara district, Bihar. The site is located about 50 m away from the Ganga river water line. Resistivity survey of the location was carried out before the drilling work.

Figure : RBF site in the temple premise of Bahara village, Ara district

Photographs of well development: (a) Exploratory drilling, (b) Air compressing for well development, (c) a stage of well development, and (d) water sample collection from the Ganga river for analysis.

Most of the villages in Ara district along the Ganga river have groundwater arsenic contamination and villagers have no organized safe drinking water supply. The aquifer at a depth below 30/35 m has generally been reported as arsenic affected. The pilot RBF scheme at Ara was elected as an alternate to provide safe drinking water supply in the rural arsenic affected areas. Phase-I works have been completed. For Phase-II works, estimate is being pursued by RC-Patna from PHED, Patna. Water quality of the RBF well and nearby Ganga river is being monitored.

(iv) Vishakapattanam, A.P.

A site along the Varaha river located in between Kakinada and Vishakapattnam city was selected in consultation with A.P. RWS & S, Govt. of Andhra Pradesh for exploratory drilling and installation of RBF well. The Varaha river is a seasonal type river at the upstream with subsurface flow below the riverbed; however, as it flows downstream, the river possesses the characteristics of perennial river. Most of the villages along and around the downstream stretches of the Varaha river have the problem of groundwater salinity, TDS (> 1000 mg/L) and most of the villages don't have organized drinking water supply system. As a result, some of the villages are forced to drink dug wells based groundwater, which has also high TDS. The site located in the village named Vommavaram in S. Rayavarammandal with latitude $17^0$27'20.1" N and longitude $82^0$47'19.2" E along the right bank of the Varaha river was selected for exploratory drilling and tube well installation through RWS & S, Govt. of Andhra Pradesh.

Geophysical survey, water quality analysis of both river and groundwater was carried out. After geophysical survey and water quality analysis, of late, drilling and lowering of tube well was carried out. Well development and pumping test were also conducted.

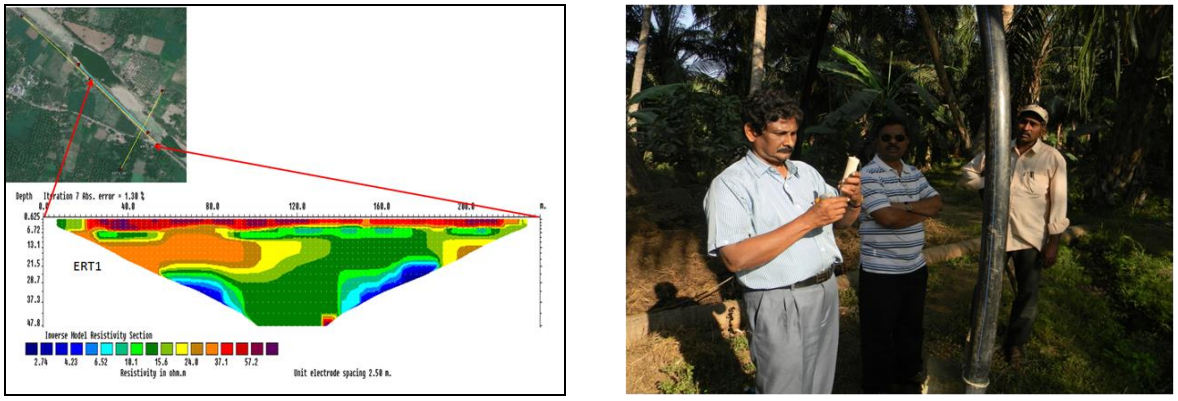


Figure showing result of geophysical survey for a section, and a snapshot of infield water quality analysis.

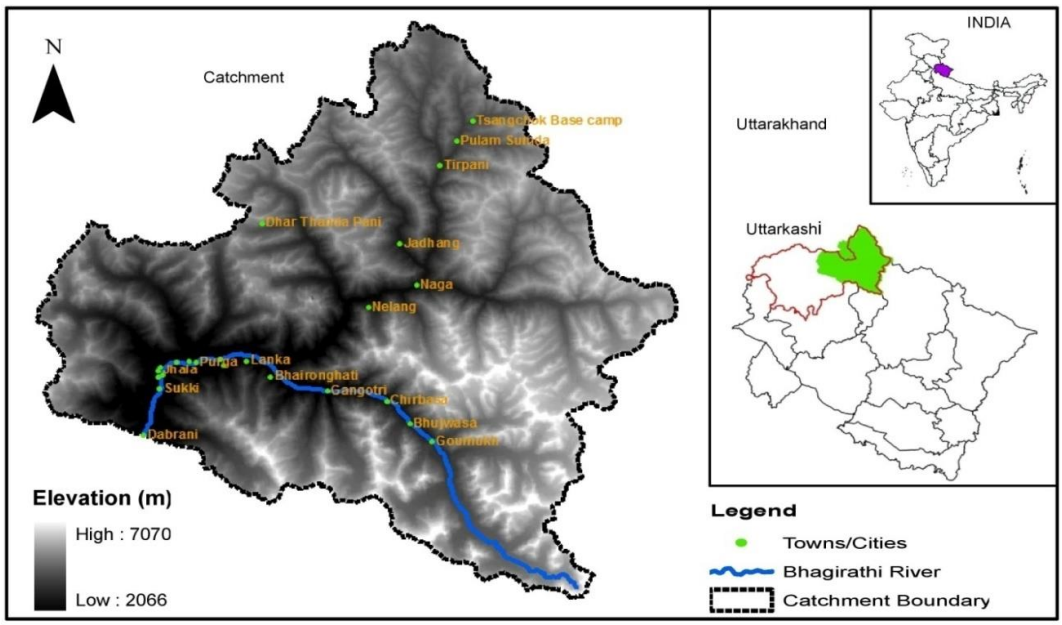
Phographs showing stages of drilling work in progress

Phase-I works are completed. For Phase-II works, an amount of Rs.7.80 lakhs has been transferred to RWS & S, Govt. of AP and execution of works is likely to be completed soon.

4. PROJECT REFERENCE CODE: NIH/GWH/NMSHE/16-20

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) : January 2016
Scheduled date of completion: December 2020
Location : Bhagirathi Basin up to Dabrani (Uttarkashi)



Study objectives:

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

Approved Action Plan:

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 and aquifer characterization.
- Collection of water samples and monitoring of groundwater levels.
- Analysis on the stream-aquifer interactions and dynamic processes.
- Estimation of groundwater recharge and water potential.

Time-line and Justification for time over runs:

Two piezometers have been developed and three more are in process of development by the Uttarakhand Jal Sansthan (UJS), Uttarkashi.

Objectives vis-à-vis Achievements:

Part of Objectives	Achievements
Literature review	Completed.
Database preparation	DEM, drainage, sub-basins, 3D map, slope map, sampling location, geology, landuse, soil.
Selection of sites for piezometer development	- Sites were selected. - Map for selected sites also prepared.
Data collection	Geological map, litho logs of five locations, water quality, isotopic data from water sampling, rainfall and meteorological data from IMD and CWC.
Piezometer development	Two piezometers are developed.

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

Analysis of Results:

The study is envisaged on the stream/river and groundwater flow interactions and dynamics including potential assessment emerging from snow and glacier melt recharge to answer the question of groundwater development prospects in the hilly areas as well as base flow regimes of the mountainous streams. In order to carry out the study, the existing basin information, geological and geo-hydrological investigations and development of piezometers for groundwater data acquisition are necessary. The study area, lying in the Uttarkashi district of Uttarakhand state, comprises an area of 3,487.06 sq.km. The Bhagirathi is the main river of the study area. The elevation of the basin varies from 2,066 to 7,070 m above mean sea level. Under the study, various thematic maps viz., digital elevation model, demarcation of basin boundary up to Dabrani, study area map, elevation zone map, 3D map, geological map, drainage map and stream ordering, sub-basin map, slope map, aspect map, digitization of ground surface contours at 10 m interval (SOI at 1:50,000), sampling location map, piezometer sites map, soil map, landuse, etc. have been prepared. Geological traversing from Dabrani to Gangotri was also done. Borelog data of five locations were collected and analyzed. The soil map of the area has also been prepared.

Water sampling from Bhagirathi river, precipitation and groundwater is being continuously done at 10 daily frequency at ten locations for the isotopic and water chemistry analysis for studying the stream-aquifer interactions. These water samples are being collected from springs, river, stream, hand-pumps and rainwater on event-basis for the isotopic and water chemistry analysis. Preliminary interpretations indicate that isotopic values for most of the river and groundwater samples rest close to the Local Meteoric Water Line which indicate the mixing of surface water and groundwater. Two piezometers are developed; one in Jhala and one in Harsil. Process for developing three more piezometers is in progress. Groundwater level is being monitored in both the developed piezometers.

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, EC Meter and Water Level Indicators.

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Nuclear Hydrology Laboratory
- Water Quality Laboratory
- Soil Water Laboratory

Data Procured/ Generated during the Study:

- Geological map; Water quality data; Isotopic data; Surface contours; Land use; Soils; Bore logs.

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

Future Plan:

- Processing of borelogs
- Aquifer characterization
- Continue monitoring of groundwater levels
- Collection and testing of water samples from surface and groundwater for quality and isotopic analysis (groundwater, spring, rainfall and river samples)
- Estimation of groundwater recharge.

5. PROJECT REFERENCE CODE: NIH/GWH/BGS/17-20

Title of the study	:	Groundwater fluctuations and Conductivity Monitoring in Punjab- New evidence of groundwater dynamics in Punjab from high frequency groundwater level and salinity measurements
Name of PI and members	:	**NIH, Roorkee, India** Dr. Gopal Krishan (PI) Er. C.P. Kumar (co-PI) Dr. M.S. Rao (co-PI) Dr. Surjeet Singh (co-PI) **BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator)
Type of study	**:**	**Sponsored,** BGS, UK.
Date of start (DOS)	**:**	December 2017
Scheduled date of completion	**:**	November 2020
Location	**:**	Bist- Doab Punjab

Study objectives:

1. To characterise multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers
2. To collate new evidence on recharge processes, groundwater quality, groundwater residence times, and connectivity of the layered aquifer systems and surface water by repeated sampling of shallow and deep piezometers using a suite of environmental tracers
3. To prepare a status report on groundwater issues in Punjab

Statement of the problem:

Higher rate of withdrawals are observed in the state of Punjab where the annual rate of groundwater level decline is increasing by about 80% and projected to fall by about 21 meter in 2/3rd area of central Punjab during next 2 decades. The large drop in groundwater levels can be due to several reasons like high withdrawals, low-recharge, low-transmissivity, poor conditions of surface water recharge source conditions etc. In addition to declining water level, the quality of groundwater is also a concern in Punjab. Considering these facts, National Institute of Hydrology, Roorkee, is carrying out a research project jointly with BGS, UK duly approved by Ministry of Water Resources, RD and GR during 2017-2020 to get a high frequency water level and conductivity data long with the analysis of water samples for a suite of tracers.

Recent evidence shows that water levels in groundwater monitoring boreholes in Bist-Doab Punjab comprising of Nawanshahr (new name SBS Nagar), Jalandhar and Kapurthala districts over short (hours, days) and longer (weeks, months) periods driven principally by extractions, rather than as a hydrological response to groundwater recharge and flow. The data analysis carried out demonstrates (i) the limitations of using groundwater levels in piezometers to indicate groundwater recharge, as conventionally applied in groundwater resources management, and (ii) conditions under which groundwater levels respond primarily to changes in the mass of terrestrial water storage. Surface water loading effects are dominant, the conventional assumption that groundwater levels indicate the status of groundwater storage is invalidated. Strategies for expansion of regional or national groundwater monitoring programmes (spatially or in depth) should account for the scale and styles of loading effects. For getting aquifer specific measurements for shorter screened intervals of conductivity and water level will provide some conclusive results for proper water resource management of this important region of the Punjab state.

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

Methodology:

In this study, groundwater level and conductivity data are monitored and high resolution field based observations are collected. For this water loggers are installed in the Saroya, Bhogpur and Sultanpur Lodhi in the month of May, 2019 (Fig. 1).

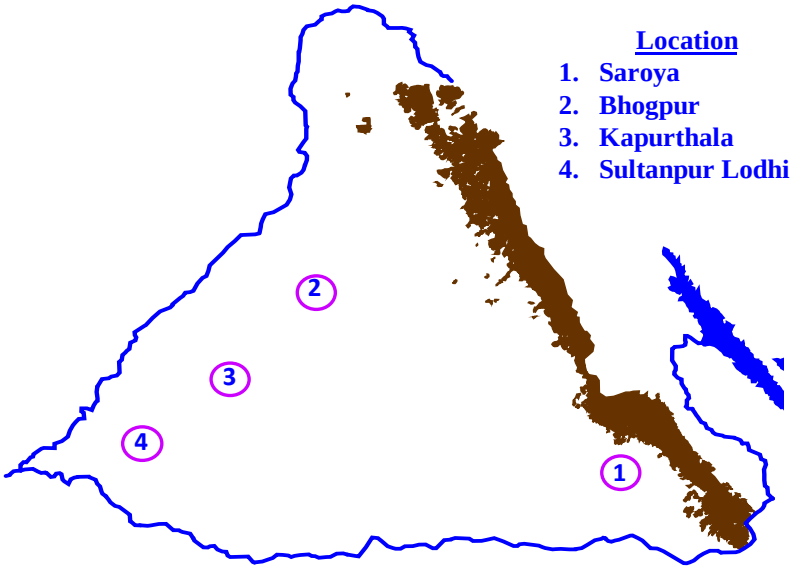


Fig. 1. Study area, Bist Doab, Punjab

These loggers are installed considering the physiography, geomorphology and hydro-geological conditions of the area.

(i) Saroya: Saroya is in Siwalik area where sandstones constitute good water bearing zones. These areas require special attention to mitigate the water needs of the people. Groundwater draft is 80%. In a Kandi tract of the State low height dams across choes are constructed for water harvesting.

(ii) Bhogpur – where farmers have adopted paddy cultivation due to profitability and incentives from the Government leading to extensive development of groundwater. There is an urgent need to change the cropping pattern in these areas and to adopt cultivation of those crops which require less irrigation. Groundwater draft is 80-90%.

(iii) Kapurthala- which is in the city area and stress on pumping of groundwater is increasing to meet the ever-increasing demand of water for domestic and industrial uses. This has resulted decline of water levels at faster rates as compared to adjoining rural areas. This over exploitation of groundwater has caused formation of groundwater troughs in the central part of the cities resulting in increased energy consumption. In order to arrest the water table decline, either canal water should be supplied to the thickly populated areas or well fields may be developed in the outskirts of the cities and water be supplied through pipeline. Groundwater draft is 90%.

(iv) Sultanpur Lodhi- low lying area and might experience rise in water levels. This area is near to Harike wetlands. Groundwater draft 60-70%.

Water level responses were consistent at 4 sites, initial observations are as below:

- Groundwater levels are impacted by a range of processes which operate at a range of different frequencies: pumping for irrigation and domestic use, groundwater recharge and earth tides. Sharp rise in groundwater levels, likely due to changes in pumping, are observed at the end of monsoon in all sites.
- Water levels recover during pre-monsoon period when pumping is minimum. There is also sub-monthly variation observed in the groundwater levels which may be due to number of factors: pumping schedules and possibly recharge response to episodic rainfall.
- Conductivity data shows consistency at Bhogpur, Kapurthala and Sultanpur Lodhi while fluctuations were found at Saroya

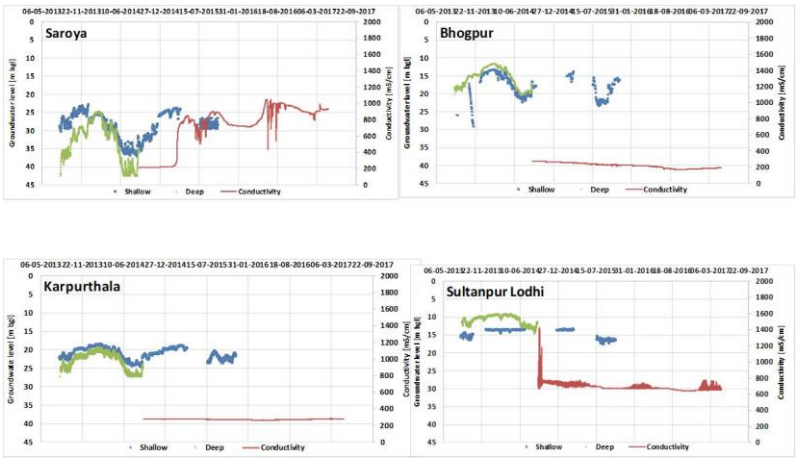


Fig. 2. Variations in water level and EC

Water samples were collected from these piezometers in the month of May, 2019 and were analysed for ions and isotopes.

Water chemistry data reveals that

- Samples were collected from these sites and were analysed for isotopes, ions and heavy metals. EC values were found to range from 290 µS/cm (Kapurthala) to 900 µS/cm (Sultanpur Lodhi).
- Dominant ions at Sultanpur Lodhi were Na^{+}, Ca^{++}, HCO_3^{-} , SO_4^{--} and NO_3^{-}.
- Isotope results show influence of meteoric water on groundwater
- All heavy metals were found within permissible limit (BIS, 2012)

Action plan:

Year	**Dec. 2017 to Nov., 2020** (Annexure 1)	**Remark**
Dec. 2017 to Nov. 2020	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 Water sampling and analysis for isotopes 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 Activity Schedule.

Study Benefits /Impact:

- An overview report on groundwater status in Punjab
- Suggesting some water resources management plans
- Research publication in high impact journals.
- Upload of results on Websites.

Specific linkages with Institutions: BGS, UK

ACTIVITY SCHEDULE (QUARTER WISE FROM DEC. 2017 TO NOV. 2020)

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Downloading data	♦		♦		♦		♦		♦			♦
Sample collection and analysis			♦			♦			♦			
Collection of data from various agencies (NIH)	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
First Draft (NIH-BGS)				♦								
Second Draft Report/Technical publication(NIH-BGS)								♦				
Final Report/Publication(NIH-BGS)											♦	♦

Progress

- New water loggers provided by BGS,UK have been installed
- The water samples were collected from piezometers

Future plan

- Downloading data from water level loggers
- Collection of samples from piezometers
- 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

6. PROJECT REFERENCE CODE: NIH/GWH/PDS/17-20

Title of the study : Hydro-Geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin

Type of study : Sponsored (NHP)
Date of Start : January 2018
Scheduled Date of Completion : December 2020 (3 years)
Budget : Rs.70 lakh

Location : Bhojpur District, Bihar (Figure 1)

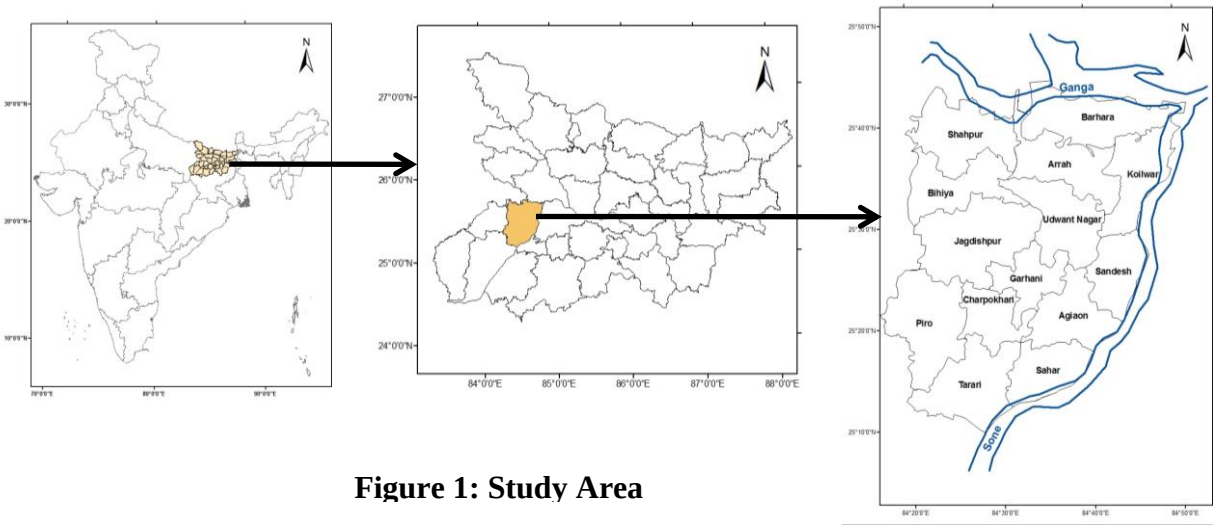


Figure 1: Study Area

Objectives

- Determination of the spatio-temporal variation of arsenic along with other water quality parameters in groundwater.
- Delineation of arsenic safe zone for drinking water supply.
- Evaluation of the controls of regional and local hydrology on arsenic contamination through monitoring of contaminated aquifer.
- Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.

Statement of the problem:

The symptoms of chronic arsenic (As) from prolonged consumptions including skin lesions began to be observed in early 1980 in residents of the lower Gangetic plains of West Bengal and adjoining Bangladesh. Subsequent research over the years reported that elevated As (relative to a 10 µg/L drinking-water standard of World Health Organization) is widely present in the potable groundwater, and as many as 15 million residents in West Bengal and 35 million residents in Bangladesh are at risk. This led to a huge number of hydro-geological studies in the lower Gangetic plain and delta for identification of the source and cause of As-contamination. But there is very little information available for central Ganges basin. The central Ganges basin comprises mainly Uttar Pradesh and Bihar is one of the largest fluvio-deltaic systems and most populous region\s of the India. In recent few decades, the increasing demand of groundwater for domestic, irrigation (round the year for food production) and industrial with the growing population rate led the extensive exploitations of fresh and potable groundwater.

In last decades, few investigators reported the elevated arsenic concentration and the process of the contamination in central Gangetic basin, but none seems to be studied the fate, transport and

mobilization of the arsenic although initial estimates indicate that the poisoning might be widespread and several million people may be at risk. The study is focused on the hydrogeological controls on arsenic mobilization, fate and transport in order to develop an understanding of arsenic release mechanism and demarcation of arsenic safe aquifer for Bhojpur district, Bihar (Central Ganges Basin). Inferences about the processes controlling the composition of groundwater will be evaluated from field measurements, statistical analyses and geochemical modelling. Column experiment will be performed to define the fate and contaminant transport; and conclusions would be made by combining the above mentioned techniques with geospatial analyses to identify the safe aquifer.

End Users/ Beneficiaries: Minor Water Resources Dept., Govt. of Bihar, Public Health Engineering Department, Govt. of Bihar, Ministry of drinking water and Sanitation, Govt. of India, NGOs, Local Community etc.

Objectives & Achievements

Determination of the spatio-temporal variation of arsenic along with other water quality parameters in groundwater.	Based on the previous water quality results, sampling was more focused on arsenic affected villages and 45 samples were collected during May 2019. The chemical analyses and interpretation of major ions and trace metals have been completed while isotopic analyses are under progress.
Delineation of arsenic safe zone for drinking water supply.	Based on previous data, Arsenic safe and contaminated zones have been delineated but final map will be prepared based on more data set.
Evaluation of the controls of regional and local hydrology on arsenic contamination through monitoring of contaminated aquifer	The site for piezometer construction has been finalized and drilling will be commenced by Nov. 2019.
Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.	Setting of a column experiment is under progress and experiment will be performed after drilling work, as sediment would be brought to our lab after drilling.

Analysis and Results: Previous water quality results revealed that Sahapur, Barahara, Bihea, Ara and Koilwar blocks situated along Ganga river are affected with As (0-336.5 µg/L) while blocks along Son river are not affected by the As. Therefore, Sampling during the pre-monsoon (May, 2019) was planned based on previous analytical results and focused on arsenic affected areas. Forty-five samples were collected from the district (Fig. 1) and analysed at NIH Lab. The physico-chemical including trace metals analyses of these samples have been completed while isotopic analyses is under progress. The water chemistry data suggest that the area is dominated by alkaline metals. Ca is the dominant cation and it constitutes 55.9 % of the total cations (TZ^+) whereas HCO_3^- is the dominant anions and the anion chemistry of the samples shows the abundance in the order of HCO_3^- (91.9%) > Cl^- (4.4%) > SO_4^{2-} (2.8%) >NO_3^-(0.8%) > F^- (0.1) in the groundwater samples. The water is classification into 'Ca-Mg-HCO_3 Type' class based on piper diagram. The relationship of As with various solutes have been demonstrated in Fig. 2. As is showing very good relationship with Fe but it does not correlate with other ions. The drilling and installation of eight numbers of piezometer is under progress. The continuous monitoring of contaminated aquifer will help in understanding geo-chemical processes that are controlling As mobilization.

Fig. 1: Sampling location in the study area

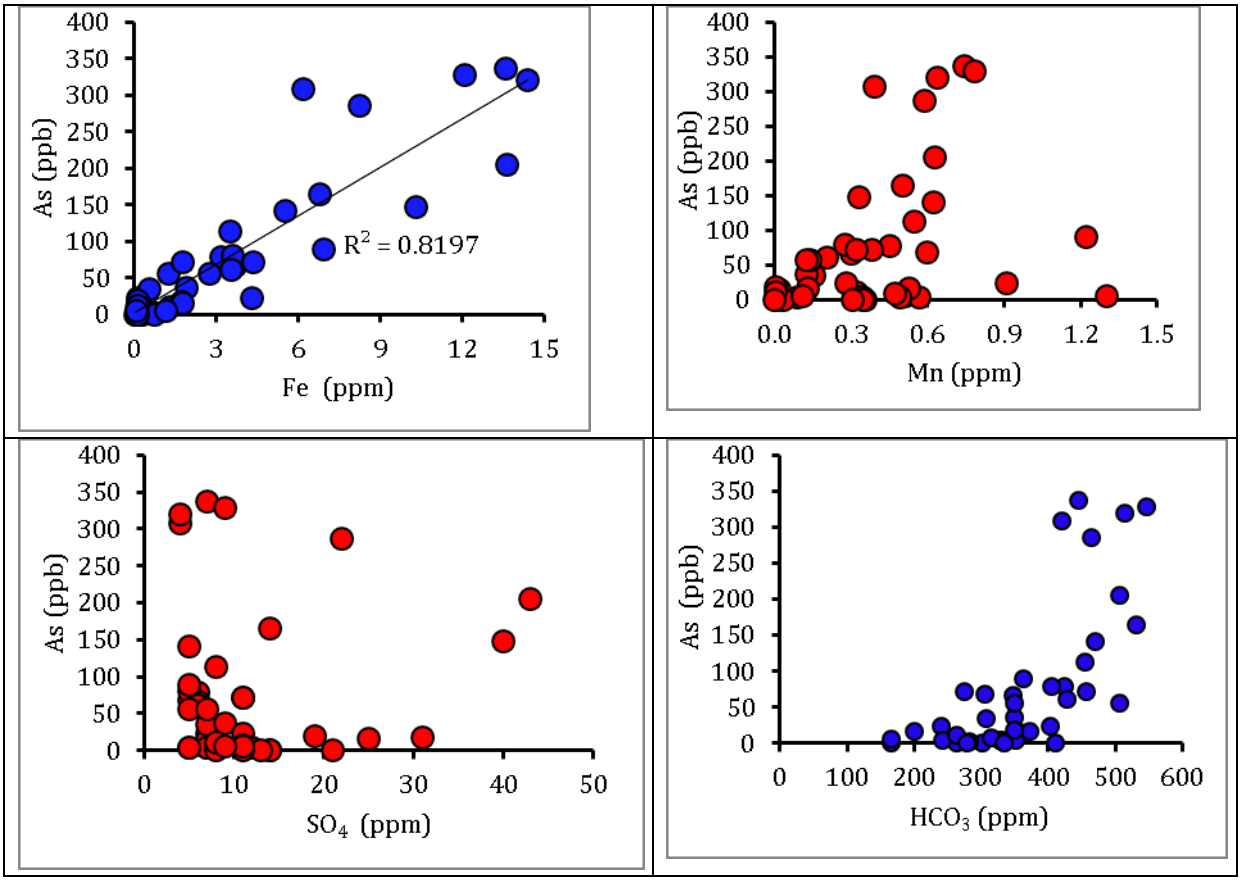


Fig.2: Bivariate scatter plot showing relationship of As with other chemical parameters

7. PROJECT REFERENCE CODE: NIH/GWH/PDS/17-21

Title of the study	:	Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures
Name of PI and members	:	NIH, Roorkee, India Dr. Gopal Krishan (PI) Er. C.P. Kumar (co-PI) Dr. Surjeet Singh (co-PI) Er. S.K. Verma (co-PI) **Haryana Irrigation Department** X'en Mewat **Consultants** **IIT-Roorkee** Prof. M.L. Kansal Dr. Brijesh Yadav **Sehgal Foundation, Gurgaon** Sh. Lalit Mohan Sharma
Type of study	**:**	Applied Research
Date of start (DOS)	**:**	January**,** 2018 (NHP-PDS)
Scheduled date of completion	**:**	December, 2021
Location	**:**	Mewat district, Haryana

Study objectives:

1. Assessment of lowering of water table (depletion in groundwater level) in the salinity impacted area using the historical data.
2. Detailed qualitative analysis of the area and the aquifer depth impacted by higher salinity levels, and preparation of maps.
3. To monitor influx of saline groundwater into fresh water zone
4. To assess the impact of groundwater salinity on socio-economic aspects
5. To develop and demonstrate management and resilience building measures

Statement of the problem:

Groundwater salinity is a widespread problem in many productive agricultural areas in India including many districts in Haryana. Aquifer salinization gradually affects the agro-economy, livelihoods and drinking water supply in local and regional scale due to lowering of groundwater levels. Salinity is the main factor limiting the continued use of groundwater in surface water scarce area, and future reliance on groundwater is further diminished as groundwater levels decline, creating increases in salinity and in exploitation costs. A systematic groundwater development and management fulfilling the technical needs of supply-side and demand-side components can arrest the aggravation of salinity and provide sustainable solution to problem.

The proposal deals with to undertake a comprehensive study on hydrological and hydrogeological features together with chemistry and isotopic characteristics of groundwater for evaluating the causes of aquifer salinity including its aggravation and effect on agro-economy, drinking water supply and livelihoods considering the problem of Mewat district in Haryana as the pilot study areas. A few demonstrative schemes as resilience building measures towards arresting the aggravation of salinity and increase of managed aquifer recharge together with their impact assessment on overall groundwater resources are also proposed to undertake. Development of a model to predict changes in groundwater salinity as a result of aquifer recharge and extraction is another focus of the study.

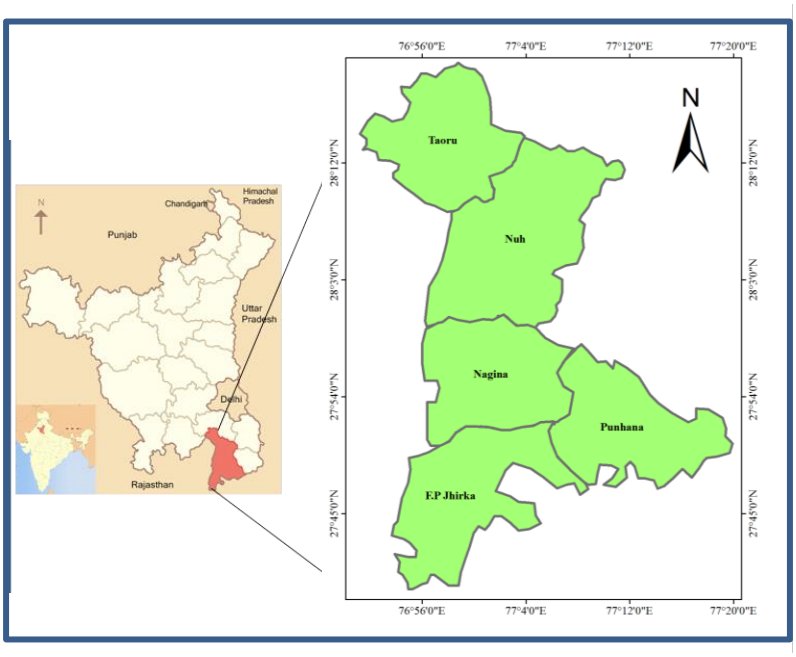


Fig. 1. Map of Mewat district

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

Methodology:

This work is being accomplished in five phases as identified below:

In Phase 1, socio-economic based survey is being carried out by Sehgal Foundation, Gurgaon to find out the impact of salinity on the socio-economic condition of the people on the basis of some selected indicators. The findings of the study will help in initiating the development activities as coping strategies for the survival of humankind in the presence of salinity in the district of Mewat. The study proposed to employ both qualitative and quantitative method. Under the quantitative method, a well structured coded interview schedule will be used. Focus Group Discussion (FGD), as a qualitative method, will be administered to collect information on the above socio economic characteristics of the farmers.

Phase 2 of the study is developing of a hydrogeological framework of the aquifer system in Mewat district based on all existing lithologic, stratigraphic and hydrologic information collected from various agencies. The saline areas in the district are being mapped.

Phase 3 include a hydro-chemical characterization (on the basis of anions, cations, physico-chemical characteristics etc.) and quantification of salinity

Phase 4 is to target the areas surrounding the drinking water wells that showed presence of salinity in Phase 2 using existing and new tube wells. Further, the water extracted from tube wells within and down gradient from the industrial areas will be examined where untreated wastewater may have been disposed on the surface (e.g., in infiltration ponds) or injected into the subsurface. The main purpose of the study in Phase 3 will be to identify cause/source areas using isotopes (release locations).

Phase 5 includes suggestion and development of resilience building measures. Some proposed measures are development of fresh water bubble; construction of hydraulic barrier, solid barriers (clay); high pressure recharge etc.

Progress

- Field work has been conducted for pre-monsoon, monsoon and post monsoon seasons in the years 2018 and 2019 (For 2019 post monsoon season sampling will be commenced soon)
- Samples for year 2018 have been analysed and for 2019 analysis is in progress
- Water level data for 2004-2017 has been collected from State Agriculture Department
- Rainfall data has been collected from State Revenue Department
- Experimental model has been fabricated and experiment work is in progress
- Work of socio-economic survey has been awarded to Sehgal Foundation, Gurgaon

Groundwater level variation data reveals that rate of water level decline (2004-2017) in Tauru and Firozepur Jhirka is higher due to the higher extraction of potable groundwater from the wells in the Aravali hills foothills as compared to other 3 blocks. Rate of extraction of groundwater is low in central part of district comprising of blocks Nuh and Nagina due to high salinity.

Groundwater salinity ranged from 0.05 to 37.05 g/L with average of 6.15 g/L in pre-monsoon season; 0.40 to 34.17 g/L in monsoon season with average of 5.25 g/L; 0.30 to 35.11 g/L in post monsoon season with average of 5.40 g/L and high salinities were generally found in areas away from Aravalli hills, arable land irrigated by groundwater, and depression cone area. It has been observed that the area affected by salinity decreased during monsoon seasons and increase was seen in post monsoon season. The relationship of the stable isotopes with EC and $\delta^{18}O$ studied and found that the samples having high salinity do not show any marked change in all the 3 seasons, while most of the samples fall in recharge region and mixing of rain water is clearly observed in monsoon and post-monsoon seasons. The data indicated that during the mixing of rain water and groundwater $\delta^{18}O$ values rise. The R^2 of the d-excess and the salinity regression line of groundwater is less in pre-monsoon where evaporation might be contributing to salinity but generally low values of R^2 do not back up this. The work is being carried out on remediation by developing an experimental model.

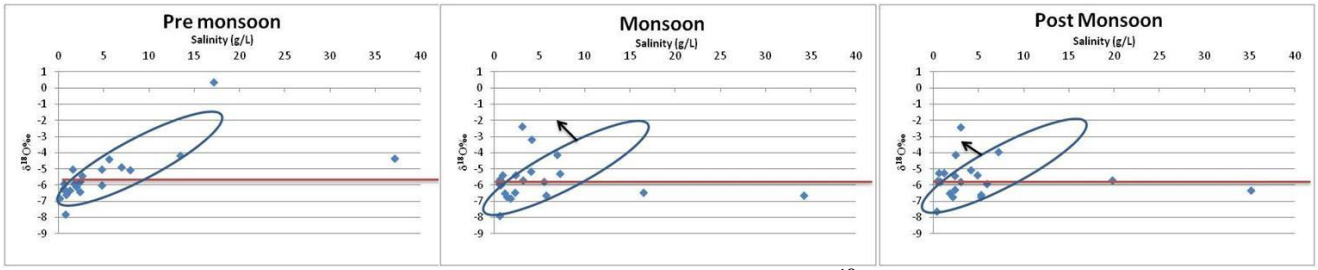


Fig. 2. Seasonal variations in salinity v/s $\delta^{18}O$

The experiment on development of freshwater pocket in saline zone is under process so that suitable management measures for the salinity affected areas may be developed. For this, the experimental model has been fabricated and is shown in fig. 3.

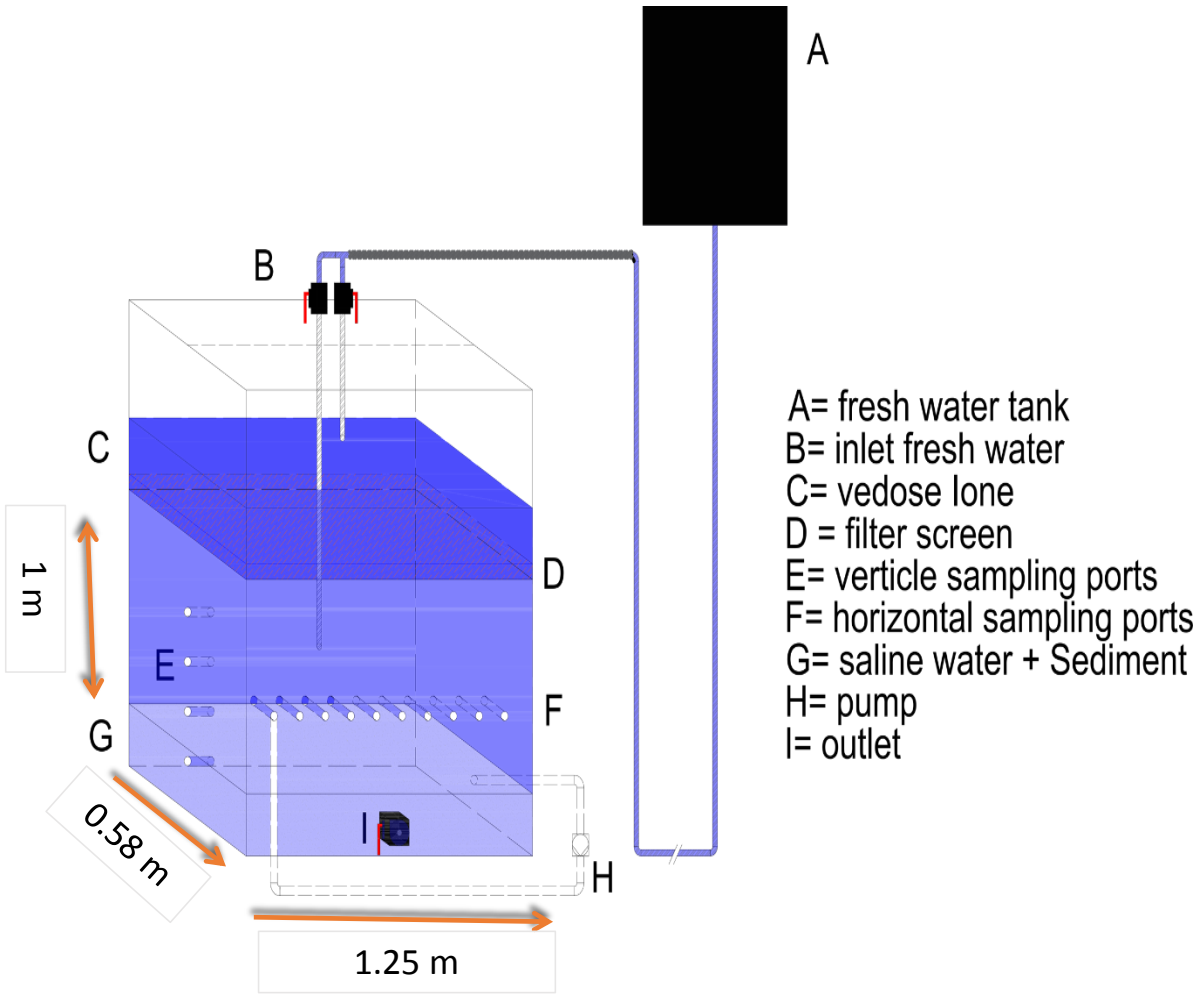


Fig. 3. Experimental model

Description of work planned:

- Experiment on salinity
- Continuation of sample collection for pre monsoon, monsoon and post monsoon
- Procurement of field instruments (rain gauges) and their installation and also development of 4 piezometers

Action plan:

Year	**Jan 2018 to Dec 2021**(Annexure 1)	**Remark**
2018 to 2021	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:

Problem of salinity to be identified

- Suggesting the suitable remedial measures

Specific linkages with Institutions: Irrigation department, Haryana**,** IIT-Roorkee, Sehgal Foundation-Gurgaon

Annexure - 1

ACTIVITY SCHEDULE FOR THE BASELINE DATA COLLECTION AND ANALYSIS IN MEWAT, HARYANA

(FOUR MONTHS WISE FROM JAN. 2018 TO DEC. 2021)

Item/Period quarterwise	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Data/literature collection												
Field Surveys												
Sample collection												
Analysis												
Data interpretation												
Suggestions/remedial measures												
Report writing/publications												

Data requirement & Expected source:

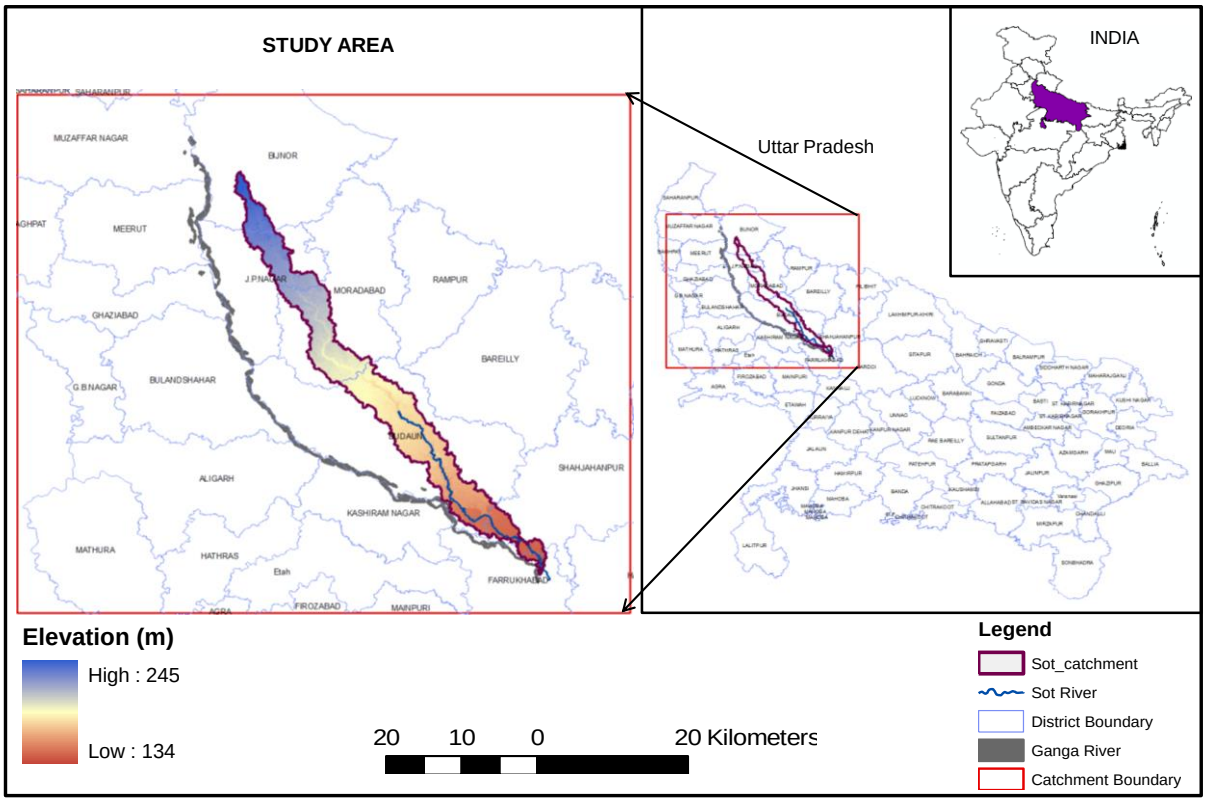
Hydro-meteorological data will be collected from the state departments.

IPR potential and issues **:** Filed a patent vide no. UCS&T/PIC/PATENT-33/2018-19 but it has been suggested to show the success of work in the field

Major items of equipment: EC-probe for soil salinity and; water level and conductivity loggers, rain gauges and drilling of piezometers

8. PROJECT REFERENCE CODE: NIH/GWH/PDS/17-22

Title of the study	:	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services – A Pilot Study
Type of study	**:**	Sponsored by NHP under PDS
Date of start (DOS)	**:**	March 2018
Scheduled date of completion:		February 2022 (Four Years)
Location	**:**	Sot River Catchment (Uttar Pradesh)



Study objectives:

- Hydro-geological characterization of the area
- Analysis of meteorological and hydrological variables *vis-a-vis* cessation of river flows during lean season
- Estimation of surface water and groundwater availability
- Analysis of stream-aquifer interaction
- Aquifer management measures for enhancing river flow during lean season

Statement of the problem:

Declining groundwater levels, diminishing river flows, turning perennial rivers into ephemeral rivers, impact of climate change are posing extreme scarcity of water availability in many tributaries of the Ganga river. Such phenomena are not only affecting the water resources but also the livelihood of farmers and the river ecosystem.

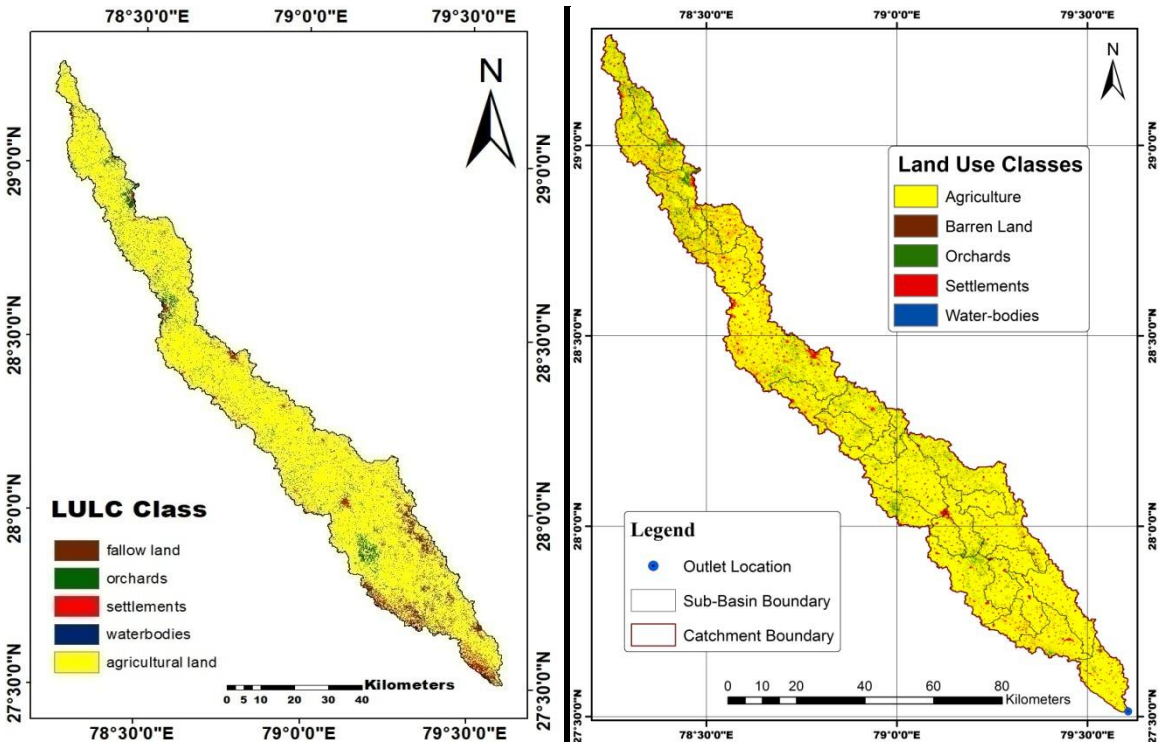
The study area comprises of the catchment of Sot river, a tributary of the Ganga river. The river flows in between the Ganga and the Ramganga river. Though both these rivers have good water potential, the Sot river is drying-up in recent years after monsoon season, and its catchment faces acute water problem and many hydrological problems, including extra-deep groundwater levels, recurrent droughts, soil erosion and desertification in some of the areas. The catchment area falls in districts of JP Nagar, Moradabad, Budaun, Shahjahanpur and Farrukhabad. The region suffers from extended droughts, depleted water resources, declining groundwater levels, and uncontrolled developmental activities. These factors coupled with the threat of the impending climate change may lead to an aggravation of the crop losses and desertification process in the area. The Sot river, earlier used to be perennial, has now become seasonal river. Under this background, it was felt necessary to investigate the river-aquifer interactions and dynamics to identify causes of drying of river and suggest measures for rejuvenation.

Methodology:

- Aquifers will be delineated using litholog/ borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks software.
- Time series analysis will be carried out by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river flows during the lean seasons of various years.
- Parametric and non-parametric trend analysis using Mann-Kendall and Sen-Slope Estimator, and change detection using Pettitt technique will be carried out on the hydro-meteorological variables to find the declining trends in river flows, groundwater levels and rainfall during both monsoon and non-monsoon seasons in various years.
- Surface water availability shall be estimated from river flow data using flow-duration curve and groundwater availability using GEC-2015 methodology.
- Vulnerability analysis shall be carried out using SAHP/DRASTIC approach.
- Catchment water balance shall be carried out using mass balance approach.
- Integrated surface water and groundwater modelling shall be used for river-aquifer interactions and future scenarios for river flows during lean seasons.
- Isotopic analysis shall also be carried out to verify the reaches of recharge/discharge zones to/from the river.
- A management plan will be developed for the enhancement of water resources both surface and underground.

Analysis of Results:

The study is envisaged on the river and groundwater flow interactions and dynamics to answer the questions on drying of Sot river. To carry out the study, existing catchment information, literature survey, meteorological, hydrological and geo-hydrological investigations, and groundwater data acquisition are essential. Review of literature related to the study was completed. The study area lies in the Uttar Pradesh state of India and covers an area of 3,027 sq.km. The elevation of the catchment varies from 138 to 245 m above mean sea level. Various thematic maps have been prepared which include digital elevation model, study area map, 3D map, drainage map, soil map including infiltration and conductivity, stream ordering, land use, grid maps, etc. The spatial variation of groundwater levels in the Sot catchment is analyzed for the period 1998 to 2017. IMD gridded rainfall and temperature data have been analyzed from 1970 to 2016 and 2015, respectively for temporal and spatial variation on weekly, monthly and annual basis. Non-parametric trend analysis has also been carried-out. The landuse/ land cover change detection for the period 1998 to 2018 was completed.



Land use change detection in the Sot catchment

Soil samples have been collected from 48 locations in the study area for generating soil information. At all these 48 locations, hydraulic conductivity and infiltration tests were conducted. Soil samples are being analyzed for determination of soil texture in the Soil and Water Laboratory. Forty-eight lithologs were collected for which processing is in process. Water quality and isotopic samples of groundwater and river are being monitored on quarterly basis. These data and information shall be used in the surface water and groundwater modelling.

Adopters of the Results of the Study and their Feedback: CGWB; Agric. Deptt., GWD and IWRD, Govt. of U.P.

List of Deliverables: Reports; Research papers; Training Workshops.

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Nuclear Hydrology Laboratory
- Water Quality Laboratory

Data Procured/ Generated during the Study:

- Toposheets, DEM, Meteorological data, Soil information, Groundwater Levels, Landuse, River flows, Lithologs.

Study Benefits /Impact:

- Increased surface water and ground water availability - Regional water security
- Farmers' access to irrigation
- Social and cultural activities
- Improvement in water quality by continuous flushing and dilution of domestic and industrial wastewaters
- Economic benefits through livelihood upliftment
- Climate resilience

Future Plan:

- Determination of soil texture
- Analysis on variation of river flows
- Continue collection and testing of water samples from surface water and groundwater for quality and isotopic analysis (groundwater, rainfall and river samples)
- Estimation of evapotranspiration
- Analysis on changes in cropping pattern and demographic changes
- Analysis of changes in water demands and irrigation supplies, cropping intensity, etc.
- Catchment water balance

9. PROJECT REFERENCE CODE: NIH/GWH/DST/18-20

Title of the Project: Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA

Type of Study: Sponsored by Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund

Nature of study: Applied Research

Duration: 3 (three) years: 01/2018-12/2020

India Project Partners: NIH (India Lead); IIT Kharagpur; IIT Roorkee; and Mahavir Cancer Sansthan, Patna.

UK Project Partner: University of Manchester (UK Lead), British Geological Survey, Salford University; and Univ. of Birmingham.

Aims:

- Investigate the vulnerability of representative shallow sedimentary aquifer systems in the Ganges river basin to secular increases in arsenic
- Predict future secular changes in groundwater arsenic
- Communicate with key stakeholders to inform them of future hazards and risks and how groundwater management practices and strategic selection of water remediation technologies and approaches might accordingly be modified.

Objectives:

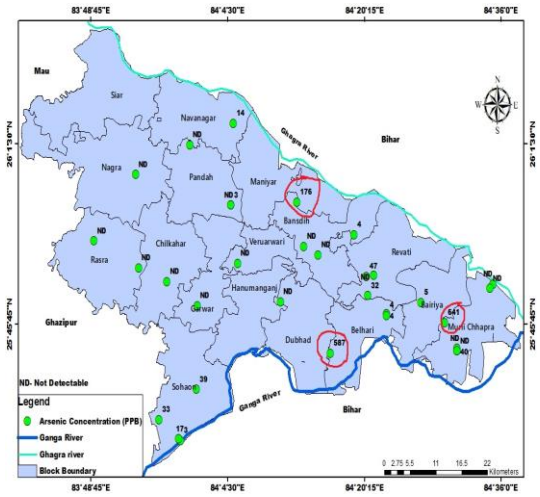
- Produce a national risk assessment of shallow groundwater arsenic from carefully selected tectonic, geological, geo-morphological and climatic variables;
- Produce recommendations for the remediation/ mitigation of human exposure and health risks arising from current and future arsenic prone groundwaters, with a particular focus on managed aquifer recharge (MAR), based on the data and models generated in this project, together with strong and effective participatory approaches with key stakeholders/end-users and by networking with other relevant research and water resource management institutions and projects.

Progress

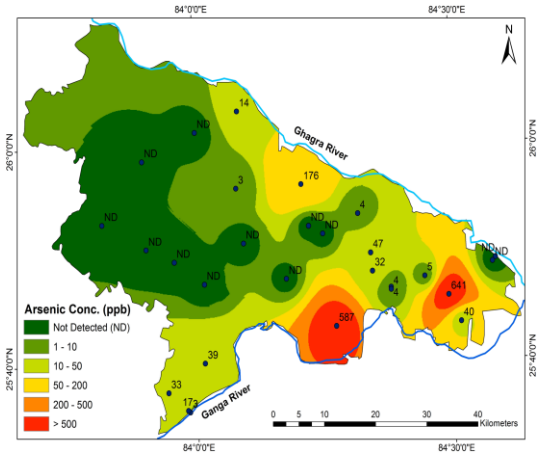
Water sampling for arsenic, general water quality parameters, trace metals, etc. as well as for isotopic analysis is being done on quarterly basis in the Ballia district. The collected samples are being analyzed in NIH WQ Laboratory, GWQ Annex and Nuclear Hydrology Laboratory. Soil samples were also collected from Ganga river bed in the Ballia district which were analyzed in the CSSRI Laboratory at Karnal.

One piezometer is developed in Laksar near the bank of the Ganga river where the reference water quality is being monitored from this piezometer, Ganga river and some nearby hand pumps. GW level is also being monitored. Quality of soil samples, that were generated during developemnt of piezometer, was also tested.

A cluster of four piezometers of varying depth is also being developed in the Murlichchapra block of Ballia district which is in progress.



Sampling locations and a snapshot of sampling campaign in Ballia district along the Ganga and Ghagra river



Results of sampling campaign in Ballia and a snapshot of sample collection from a tube well

The progress of the study was reviewed during 15-18 May, 2019 in the Project Management Board (PMB) Meeting in Manchester (UK). Again the progress was reviewed by DST and NERC during 09-10 July, 2019 during the Mid-term review in London. Next PMB meeting is scheduled during 13-14 November, 2019 at NIH, Roorkee wherein all the UK and Indian project partners are participating.

10. PROJECT REFERENCE CODE: NIH/GWH/DST/18-20

Title of the study **:** Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micropollutants

Type of study (sponsored/consultancy/referred/internal): Sponsored Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund**:** Rs. 255.884 lakh (total)

Nature of study: Study components include technology development, technology dissemination, technology adaptation, capacity building

Duration: 01/2018 to 12/2020

India Project Partners: NIH Roorkee (India Lead); IIT Ropar; IIT Jodhpur

UK Project Partner: Cranfield University

Location Map

Fig. 1 Locations of study sites in Rajasthan

Project Aim & Objectives

To assess the impact of rainwater used for MAR on groundwater quality and specifically understand how DOM present in rainwater affects fluoride and other pollutant levels, thereby improving MAR structure design and management practices. Specific objectives:

1. Evaluate water level and quality at three selected MAR sites in Rajasthan;
2. Assess the proportion of recharged groundwater attributable to MAR systems at selected sites;
3. Investigate the consequences of recharging aquifers with rainwater on the fate and transport of pollutants into aquifers, and understand the role of rainwater DOM levels in remediating fluoride and other groundwater contaminants;
4. Develop analytical protocols to facilitate the detection of micropollutants in water bodies;
5. Understand the interactions of local users with the MAR structure and also their role in water management.

Work Packages
WP1: Field Surveys & Investigations
WP2: Laboratory Experiments & Analysis
WP3: Simulation of Pollutant Transport
WP4: Research Impact and Knowledge Dissemination

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.
Field experiments and laboratory investigations	– Field visits June 2019, August 2019, Sept 2019, Oct 2019 – Monitoring of meteorological parameters – DTWL measurements in Laporiya watershed and Bayana; water levels in surface water bodies – Collection of soil (disturbed/undisturbed) and water samples – Field experiments for saturated hydraulic conductivity and infiltration ; Pumping tests – Socio-economic surveys – Laboratory experiments for grain size analysis, ICW and soil moisture retention curves – Chemical analysis of water samples – Piezometers constructed at two sites in Laporiya and at one site in Bayana; collection of geological samples and analysis
Database preparation	DEM, land use, soil texture, drainage, groundwater levels, water quality
Data analysis and Website development	Analysis of water level and water quality data, satellite data, land use; analysis of soil samples and data for infiltration rates and saturated hydraulic conductivity; chemical analysis of water samples; Project website developed
Organization of Indo-UK Consortium Meetings	Webex Meetings held on Apr. 2019; June 2019; Aug 2019 Indo-UK Consortium Workshop Oct 8-11, 2019 at Cranfield University; Joint Review Meeting July 9-10, 2019

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Water Quality Laboratory

Deliverables & Beneficiaries: The project primarily addresses the Newton-Bhabha priority area "public health and well-being". Beneficiaries will include fluoride affected communities in Rajasthan. Deliverables include research papers, reports, software, manuals, brochures, flyers, users' interaction workshops.

11. PROJECT REFERENCE CODE: NIH/GWH/PDS/18-22

Title of the study: Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi

Type of study: Special Study under Centre of Excellence in Hydrological Modelling (NHP)
Date of start: April 2018
Duration of study: Four Years
Location Map:

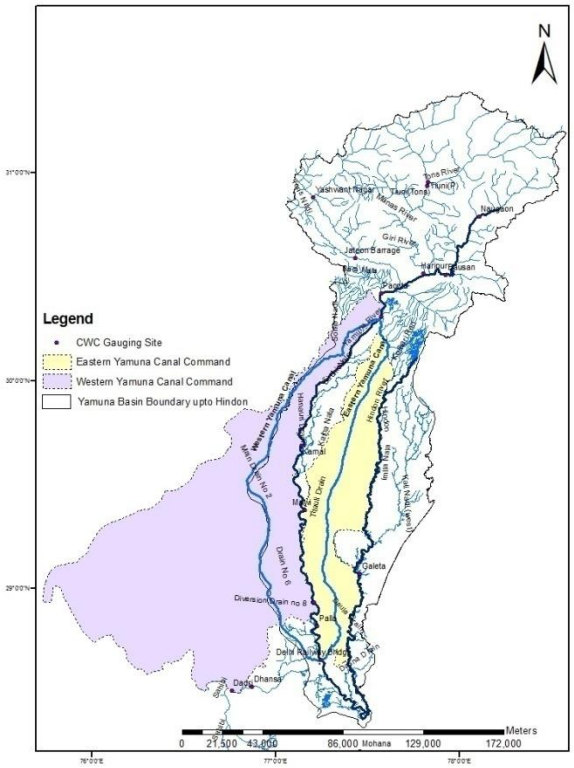


Fig. 1 Study area showing the Upper Yamuna Basin and the command areas of EYC and WYC

Study objectives:

1. Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality
2. Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons river
3. Assessment of changes in baseflow contribution to river Yamuna.
4. Assessment of present and future water availability under alternate scenarios of climate change
5. Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command
6. Formulation of adaptation measures in the context of climate change
7. Flood frequency analysis and flood plain mapping of river Yamuna
8. Assessment of anthropogenic activities on water quality
9. Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable groundwater resources
10. Roll out of technical know-how through training workshops for partner organizations

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Data collection	Historical groundwater level data from State and Central Ground Water Depts., hydro-meteorological data pertaining to river Yamuna, crop cultivation, meteorological data, relevant reports and maps, data collection during field visits
Field experiments and Laboratory investigations	– Field visits in June 2019, Aug 2019, Oct 2019 for collection of water samples along Yamuna river and drains joining Yamuna – Chemical analysis of water samples in laboratory – Collection of soil samples and field, laboratory experiments
Database preparation	Geo-referencing and digitization of drainage network (including Himalayan terrain); Digitization of canal network in WYC Command and EYC Command; Watershed delineation of UYB upto confluence of Hindon with Yamuna; watershed delineation of Hindon River Basin; Geo-referencing and digitization of soil maps (1:50,000) for area in UP, Haryana, Delhi, HP, Uttarakhand; LULC classification; Cropping pattern; Database preparation for SWAT, HEC-HMS, VIC, MODFLOW.
Hydrological Modeling	Preliminary runs of SWAT / VIC/ HEC-HMS for sub-basins of Upper Yamuna basin

Deliverables:

1) Application of various models pertaining to surface water hydrology, groundwater hydrology, basin planning, optimal water utilization and their inter-comparison in respect of UYB;

2) Evaluation of the impact of climate change, land use change and population growth on the water resources in UYB;

3) Assessment of changes in baseflow contribution to river Yamuna and strategies to enhance the contribution;

4) Evaluation of impact of climate variability on renewable groundwater resources;

5) Training Workshops for State Department officials of UP and Haryana.

12. PROJECT REFERENCE CODE: NIH/GWH/DST/19-23

Title of the study : Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water

Type of study (sponsored/consultancy/referred/internal): Sponsored by DST
Nature of study: Applied research
Duration: 03/2019 to 02/2024

Lead agency and project partners: CAZRI Jodhpur (Lead agency), NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur

Aims

- Enhancing water productivity at farming system as well as its components level
- Analyzing future demand and supply of water at regional and sub-regional level
- To develop improved methods for reusing industrial effluents in agriculture
- Capacity building of stakeholders in enhancing water productivity and developing policy guidelines

Objectives

I. To enhance water productivity in farming systems/regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
   a. Improve understanding of surface water and groundwater recharge and their interactions in relation to the environment
   b. Reducing evaporative losses from water bodies
   c. Characterization of pollutants in groundwater, periodical fluctuations and recharge in irrigated land uses
   d. Effect of irrigation with conjunctive use of fresh and poor quality ground water on crop productivity and soil properties in field and under protected cultivation
   e. Development of software/model for better management of water

II. To develop improved methods for reusing industrial effluents in agriculture

III. To analyze future demand and supply of water at regional and sub-regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)

IV. To develop policy guidelines and capacity building of stakeholders

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.
Field experiments and laboratory investigations	– Field visit Aug 2019 to two sites in Barmer district – DTWL measurements and water levels in identified ponds – Collection of soil (disturbed/undisturbed) and water samples – Laboratory experiments for grain size analysis, ICW and soil moisture retention curves – Chemical analysis of water samples
Database preparation	DEM, land use, soil texture, groundwater levels, water quality
Data analysis	Analysis of water level and water quality data, satellite data, land use; analysis of soil samples; chemical analysis of water samples
Organization of Joint Meetings	Aug. 2019

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Water Quality Laboratory

Deliverables & Beneficiaries: Beneficiaries will include farming communities in arid regions of Rajasthan. Deliverables include research papers, reports, software, manuals, brochures, flyers, users' interaction workshops.

13. PROJECT REFERENCE CODE: NIH/GWH/NMCG/19-20

Title of the study **:** Environmental Flow Assessment for Yamuna River from Hathnikund Barrage to Okhla Barrage

Type of study (sponsored/consultancy/referred/internal): Sponsored by NMCG
Nature of study: Applied research
Duration: 04/2019 to 03/2020

Objectives

1. Assessment of environmental flow for Yamuna River from Hathnikund Barrage to Okhla Barrage
2. To suggest the management options for maintaining the recommended e-flows

Location Map

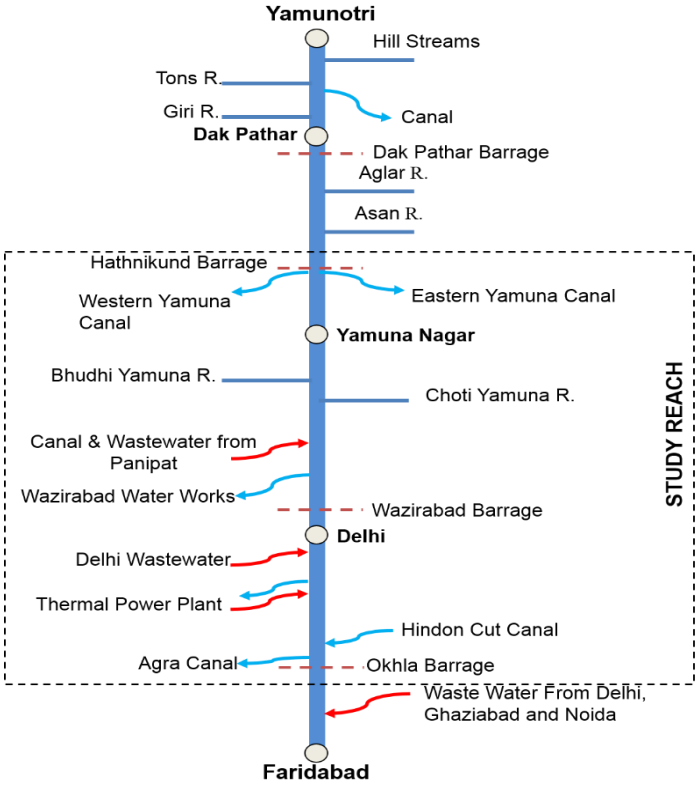


Fig. 1 Study reach on Yamuna River from Hathnikund Barrage to Okhla Barrage

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Data collection	River cross-sections and discharge data of River Yamuna, flow and water quality data of drains joining Yamuna, relevant reports and maps, meteorological data, data collection during field visits.
Field experiments and laboratory investigations	– Field visits June 2019, Sept 2019, Oct 2019 – Chemical analysis of water samples – Habitat requirement of keystone fish species (field survey and analysis supported by Wildlife Institute of India, Dehradun)
Database preparation	DEM, Geo-referencing and digitization of drainage network upto Okhla barrage, land use, soil texture, water quality, database preparation for HEC-RAS, SWAT; preparations for field survey of river cross-sections at

	pre-defined intervals
Data analysis	Analysis of discharge data, rainfall, satellite data, land use; chemical analysis of water samples
Hydrological Modeling	1D steady and unsteady flow simulations using HEC-RAS producing results of velocity and water depth; developed plots of discharge vs depths at selected sites; preliminary assessment of flow requirement for important fish species of Yamuna River

Lab Facility used during the Study:

- Centre of Excellence for Advanced Groundwater Research
- Soil and Water Laboratory
- Water Quality Laboratory

Deliverables & Beneficiaries: Report on e-flow assessment with management options. Deliverables include research papers, reports, and flyers. Beneficiaries include riparian communities.

14. PROJECT REFERENCE CODE: NIH/GWH/NIH/19-19

Title of the study:	Improving our Understanding of the Aquifer Systems in Sunderbans	
Name of PI and members	:	NIH, Roorkee, India Dr. Gopal Krishan (PI) Er. C.P. Kumar (co-PI) **BGS, UK** Mr. Andrew Mackenzie (PI) **Prasari** Dr. Purnaba Dasgupts (PI)
Type of study	**:**	Sponsored, MoES (IUKWC).
Date of start (DOS)	**:**	June, 2019
Scheduled date of completion	**:**	November, 2019
Location	**:**	Indian Sunderbans, West Bengal

Study objectives:

1. Develop a conceptual model of the island aquifer systems and collate available evidence on aquifer extent
2. Collate aquifer property data on the aquifer systems, including data on the shallow saline aquifers.
3. To assess potential and feasibility of aquifer storage and recovery

Statement of the problem:

Deltaic coastal areas face challenges in dry season water availability, with brackish rivers and limited reservoir constructing opportunities. Water supplies and irrigation may depend on groundwater. In aquifers where confined saline layers are present aquifer storage and recovery can be developed to provide extra water resources during drought.

The Sundarbans area of West Bengal is an example of a deltaic system with islands where the population rely on groundwater for public supply and irrigation. Groundwater resources are supplemented by farm ponds, but the low relief means that reservoirs can't be constructed without excessive sacrifice of productive agricultural land. A multi-layered aquifer is present; the upper unconfined and confined layers normally saline. Deeper freshwater aquifers are heavily exploited, suffering from deteriorating yields and water quality. The potential of aquifer storage and recovery (ASR), where water is injected into the saline aquifers during the monsoon season, and recovered during dry months will be explored through a combination of participatory survey by local villagers and mathematical simulation. The project's conclusions will help guide pilot implementations of ASR as an approach to water management and to help increase community resilience to drought and cyclone induced flooding that periodically contaminates the farm ponds.

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

Methodology:

A participatory groundwater management approach was adopted for data collection, using the skills of village self-help groups to collect field data on aquifer properties using a range of simple field measurements and interviews with farmers and borewell drillers, with a particular focus on the saline aquifers. The collection of aquifer properties data for the saline aquifers has complemented existing data on the properties of the freshwater aquifers. The data have informed a simple 2d groundwater model that has been used to explore the sensitivity of operation to a range of aquifer parameters.

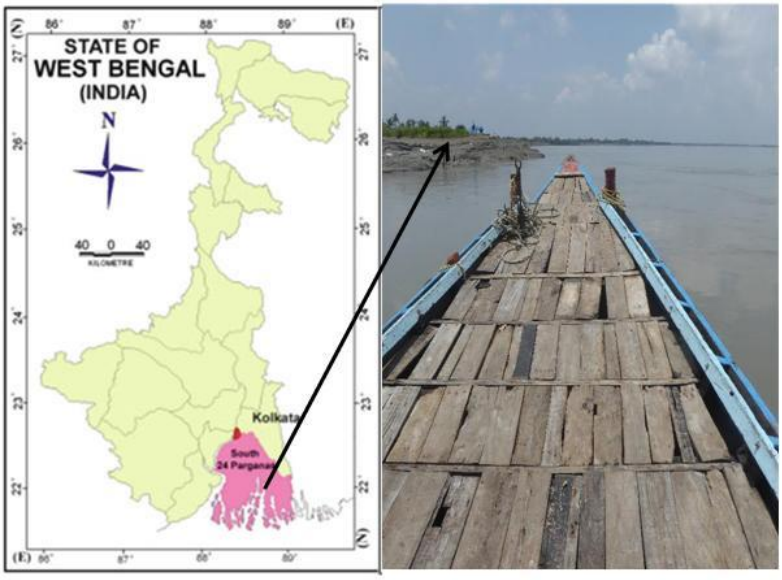


Fig. 1. Study area, Sunderbans, West Bengal

Water level and quality parameters in the saline and fresh water aquifers were determined based on information derived from Focused Group Discussion, Rapid Rural Survey and field experiments conducted with barefoot-hydrogeologists in two blocks; Gosaba and Sandeshkhali II of Sunderbans West Bengal, India. Measurements were made on existing and in-progress wells to quantify aquifer properties and water quality within the saline systems. The data on the saline aquifers has been integrated with available data for the deeper fresh water aquifers; data that has demonstrated deterioration in both yield and water quality as a result of over abstraction. The focused group discussions highlighted the principal water resource challenges facing farmers; including limited access (because of cost) to the deeper freshwater aquifers, uncertainty over long term recharge to deeper aquifer units and the impact of cyclone flooding with saline water on the usability of surface water ponds. The modelling shows that an ASR approach can be used in this area to store water as a reserve supply in the driest season, or post cyclone but the practicality of this intervention is sensitive to the exact aquifer geometry and to the costs of drilling and injecting fresh water.

Action plan:

Period	**June 2019 to Nov., 2020** (Annexure 1)	**Remark**
June 2019 to Nov. 2019	Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects. Collection of data from hydro meteorologists. Prepare a status report and proposal for Aquifer storage Recovery.	Report preparation as per Activity Schedule.

Study Benefits /Impact:

Characterization of saline aquifers

- To develop groundwater model to assess feasibility of small scale ASR

Specific linkages with Institutions: BGS, UK and PRASARI

ACTIVITY SCHEDULE (MONTH WISE FROM JUN. 2019 TO NOV. 2019)

Activity	Jun	Jul	Aug	Sep	Oct	Nov
Collecting data	♦	♦	♦	♦		
Organization of community/state/regional level workshop	♦		♦	♦	♦	♦
Report preparation					♦	♦
Proposal for ASR study						♦

Progress

- Groundwater level and hydrogeological data has been collected
- Community/state level workshops have been organized

Future plan

- Formulation of proposal to apply small scale ASR schemes

15. PROJECT REFERENCE CODE: NIH/GWH/CEHM/18-21

Title of the study : Development of Groundwater Module for Integrated Hydrologic Model

Type of study (sponsored/consultancy/referred/internal): Sponsored under CEHM, NHP
Nature of study: Technology development
Duration: 08/2018 to 07/2021
Project partners: NIH Roorkee (in coordination with IIT Ropar), IIT Kharagpur

Objectives
To develop a groundwater model for Integrated Hydrologic Model under the project 'Development and Testing of a Large-Scale Conceptual Hydrological Model'

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Software development	Development of groundwater flow software in progress based on hydraulic approach and using finite difference method (in coordination with IIT Ropar)
Testing of developed groundwater model	Testing of groundwater model in progress for single aquifer domain

Deliverables & Beneficiaries: Deliverables include groundwater flow simulation software, research papers, reports, and flyers. Beneficiaries include groundwater professionals.

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sudhir Kumar	Scientist G & Head
2	Dr. S D Khobragade	Scientist F
3	Dr. M S Rao	Scientist E
4	Sri S K Verma	Scientist D
5	Dr. Santosh M. Pingale	Scientist C
6	Sri Hukam Singh	Scientist B
7	Ms. Nidhi Kalyani	Scientist B
8	Sri Rajeev Gupta	PRA
9	Sri U K Singh	SRA
10	Sri V K Agarwal	SRA
11	Sri Vishal Gupta	RA

PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2019-20

As per the approved work program during the 48th meeting of working group held on 02nd – 03th May, 2019, the Hydrological Investigations Division had to work on 6 sponsored projects and 4 consultancy project (See annexure-I). However, after the 48th Working Group meeting, one sponsored and 1 consultancy project were also added. The current status of studies being carried out in HI Division during 2019-20 is given below:

Type of study/Project	***Continuing in Studies***	***New studies proposed***	***Total***
Internal Studies	2	0	2
Sponsored Projects	7	1	8
Consultancy Projects	4	1	5
Total	13	1	15

The progress and the results of the sponsored projects is given below:

1. PROJECT REFERENCE CODE: NIH/HID/R&D/19-22/1

Title of the Study:	Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand
Study Team:	S M Pingale (PI), Sudhir Kumar, S. D. Khobragade, Soban Singh Rawat, Rajeev Gupta, and Padam Singh (GBP Uni., Tehri)
Type of Study:	Internal R&D Study
Budget	Rs. 31.82 Lakh
Date of Start:	April 2019
Date of Completion	March 2022

Statement of the Problem

The watershed/springshed are dynamic and complex systems involving a range of physical processes (natural or anthropogenic) which may operate simultaneously and have different spatial and temporal influences. Understanding those processes is essential for managing the quality and quantity of water availability from both surface runoff and natural springs flow under changing LULC and climatic conditions. The springs form the lifeline for the large part of the population particularly from the most inhabited lesser Himalayan ranges. These natural springs recharge area delineation is essential for protection and management of important spring's water systems. Protection and management of the springs cannot be conducted unless one has a basic understanding of where the relevant lands are located, infrastructure development for water harvesting. Otherwise, it fails in the extreme events of rainfall, causes stresses during dry season as well as drying of springs due to anthropogenic activities and climatic changes need to be understood for taking adaptive measures. The accurate information and response of natural springs from different geological settings (i.e., lithological units, hydro-chemical and physiographical units) under variable climatic and LULC change conditions are needed for sustainable development and management of natural springs in the lesser Himalayan watersheds. It is also important to address the various model uncertainties and address it properly in hydrological modeling studies.

Objectives

1. To inventorize and geo-tag the springs in the study area.
2. To characterize springs with respect to different lithological and physiographical units.
3. To develop Intensity-Duration-Frequency (IDF) curves for different return periods of rainfall and characterization of Flow Duration Curves (FDC) for sustainability analysis of the springs.
4. To assess the impact of anthropogenic activities/climate variability on hydrologic responses of springs and develop the adaptive measures to sustain the livelihoods.

Study area

Tehri Garhwal is a district in the hill state of Uttarakhand, India. The district has a population of 618, 931 (2011 census). It is surrounded by Rudraprayag District in the east, Dehradun District in the west, Uttarkashi District in the north, and Pauri Garhwal District in the south. In the district generally, groundwater occurs locally within disconnected bodies under favorable geo-hydrological conditions such as in channel and alluvial terraces of river valleys, joints, fractures and fissures of crystalline and meta-sedimentary rocks, well vegetated and relatively plain areas of valley portions and in subterranean caverns of limestone and dolomitic limestone country rocks. Groundwater emerges as springs and seepage under favorable physiographic conditions such as in gently sloping areas, broad valleys of rivers and along the lithological contacts (Bagchi and Singh, 2011). The present study is being carried out for the selected springs in the Tehri-Garhwal district of Uttarakhand (Fig. 1).

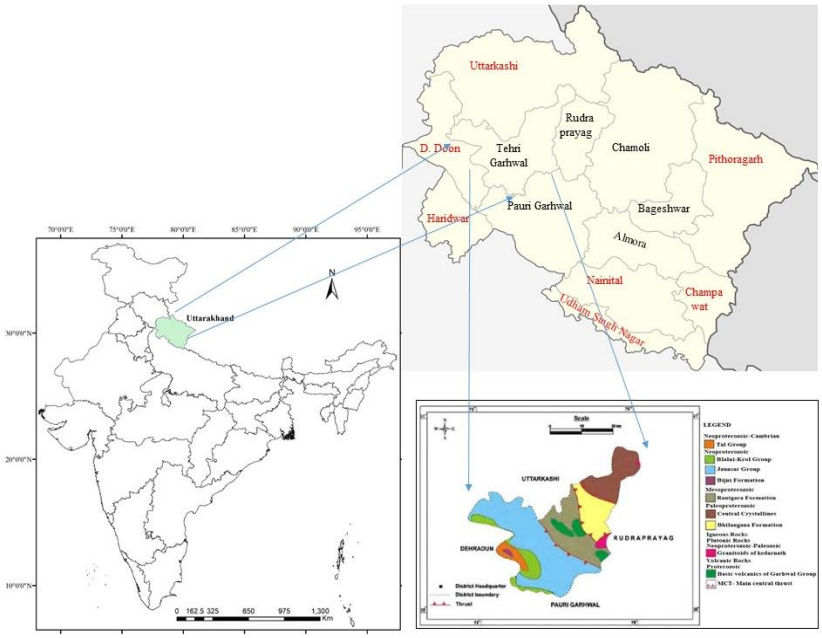


Fig. 1 Location of the study area (lithology map Source: Soil and Land Use Survey of India, 2019).

Methodology

The methodology adopted in the present study is shown in Fig. 2 and subsequently described here:

a) Preparing comprehensive GIS-based inventory and mapping of available natural springs in the study area.
b) Creating geo-database for the springs which can be updated time to time.
c) The representative springs from different lithological units will be selected for continuous monitoring hydro-chemical, physical and social parameters (e.g. Discharge, pH, EC, TDS, major anion and cation), dependent population, use of water and land use conditions around the spring's sources/springsheds/watersheds.
d) The characterization of spring in different lithological units is being carried out using hydrological investigation techniques involving isotopic and chemical characteristics.
e) The trends and shifts in hydro-climatic variables using different statistical techniques (e.g., Mann-Kendall (MK), Modified MK testand Pettit's Mann-Whitney test) and LULC change will be undertaken for the selected study area.
f) The characterization and development of Intensity-Duration-Frequency (IDF) curves for rainfall and Flow Duration (FD) curves of the springs flow will be undertaken to assess the sustainability of available water resources for the selected springs.
g) The impacts of anthropogenic activities/climate variability on selected natural springs flow in different lithological units within the watershed/springshed will be identified.
h) Finally, suitable interventions and scaling out plan will be suggested based on hydrological investigations.

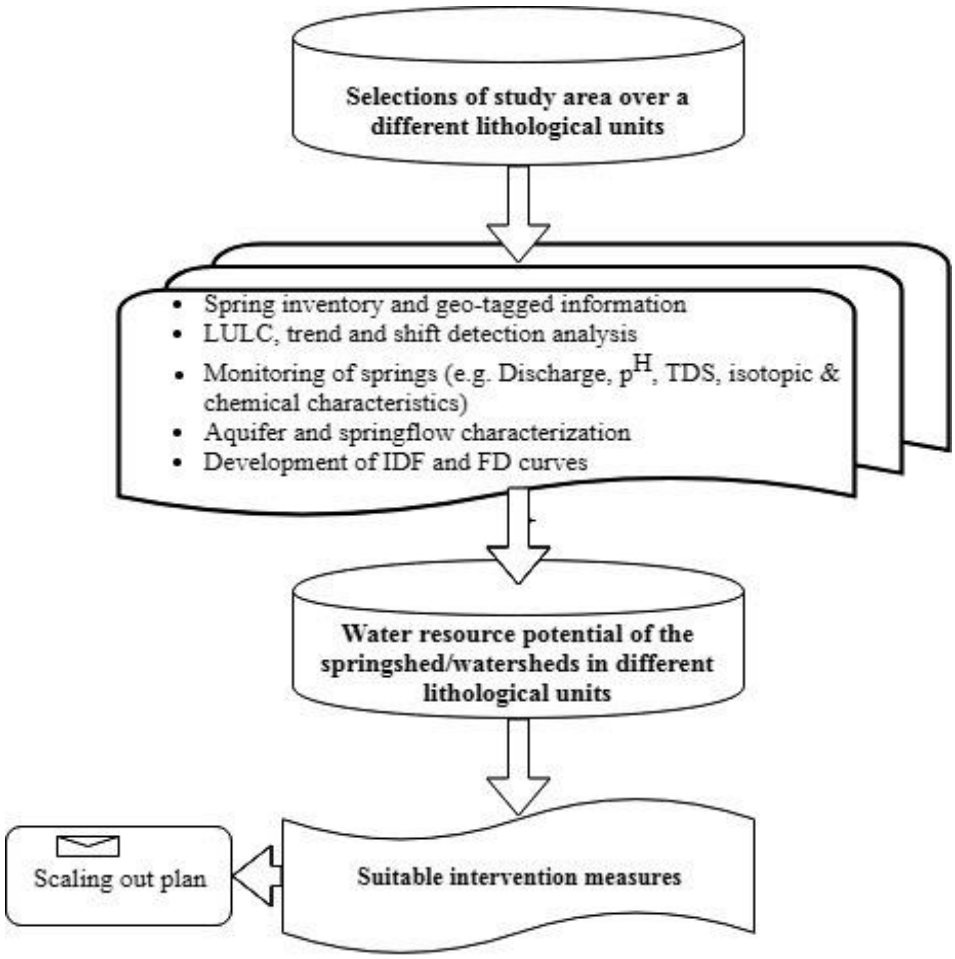


Fig. 2 Flow chart of methodology adopted in the present study.

Progress of work during 2019

- Literature survey on springs studies in and around selected study area as well as national and international level studies was carried out.
- The aquifer and lithological map of Tehri Garhwal district have been collected from different sources (e.g. CGWB, India-WRIS) (Fig.1 & 3). It has been found that Tehri Garhwal district comes under Schist, Gneiss, Quartzite, Phyllite and Shale with limestone aquifer formations (Fig. 3).
- Process for administrative and financial approval for instrument purchase initiated.
- Visited Ranichauri, Gaja, Kanatal, Chamba, Nagini, Narendra Nagar blocks from Tehri-Garhwal district and identified 20 natural springs during field visit (Table 1).
- The different data have been collected from 20 identified springs such as discharge, pH, EC, geographical location (latitude & longitude), elevation and water samples for isotopic analysis ($\delta^{18}O$ & $\delta^{2}H$) (Table 1).
- Twenty spring water samples have been analysed in the laboratory and started processing of collected field data and preparation of spring inventory is under progress.
- The historical hydro-climatic data for Ranichauri & Fakua springs from College of Forestry, Ranichauri were procured. In addition, two springs sites for detail hydrological investigations have been identified (Fig. 4) where spring monitoring can be started to understand the springs responses in different lithological and geographic settings.
- The hydro-meteorological monitoring network available at Ranichauri and Fakua springs was checked, which was set up by IMD and College of Forestry, Ranichauri. However, it was observed that one Automatic Weather Station (AWS) need to be installed at Gaja site and additional field visits are required for identifying springs in this block as well as in the remaining study area.

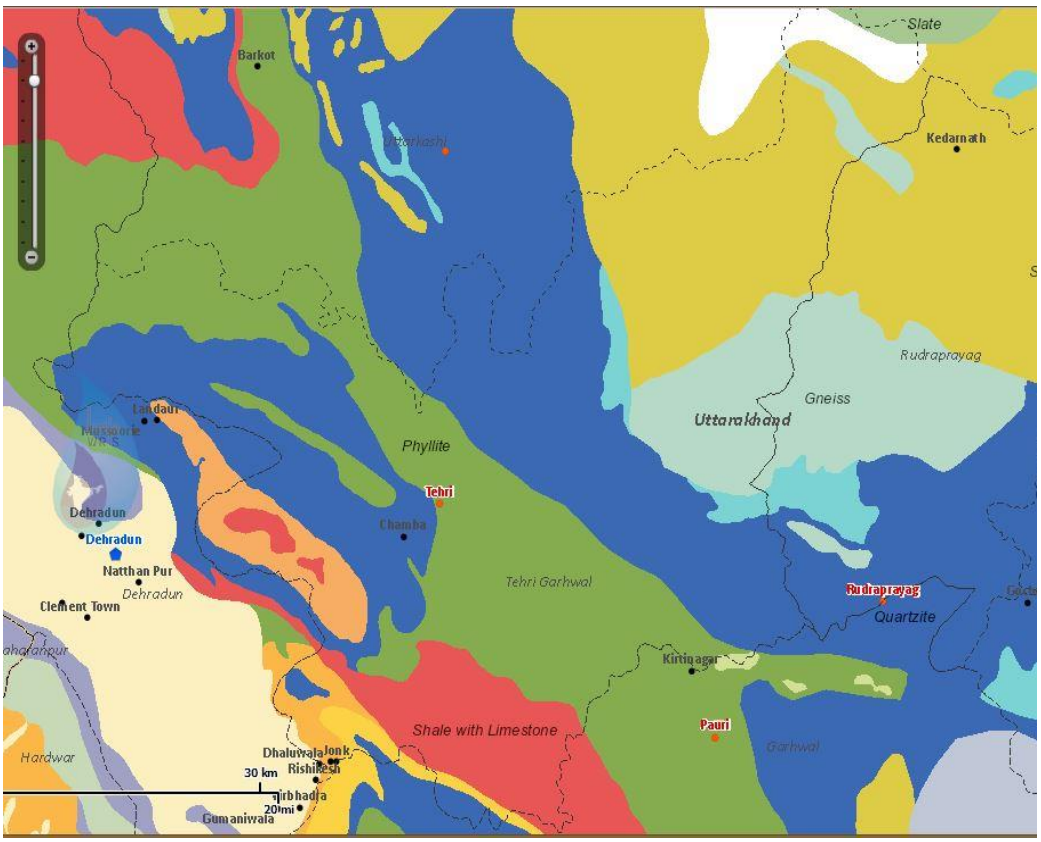


Fig.3 Aquifer map of Tehri-Garhwal (Source: India-WRIS, 2019)

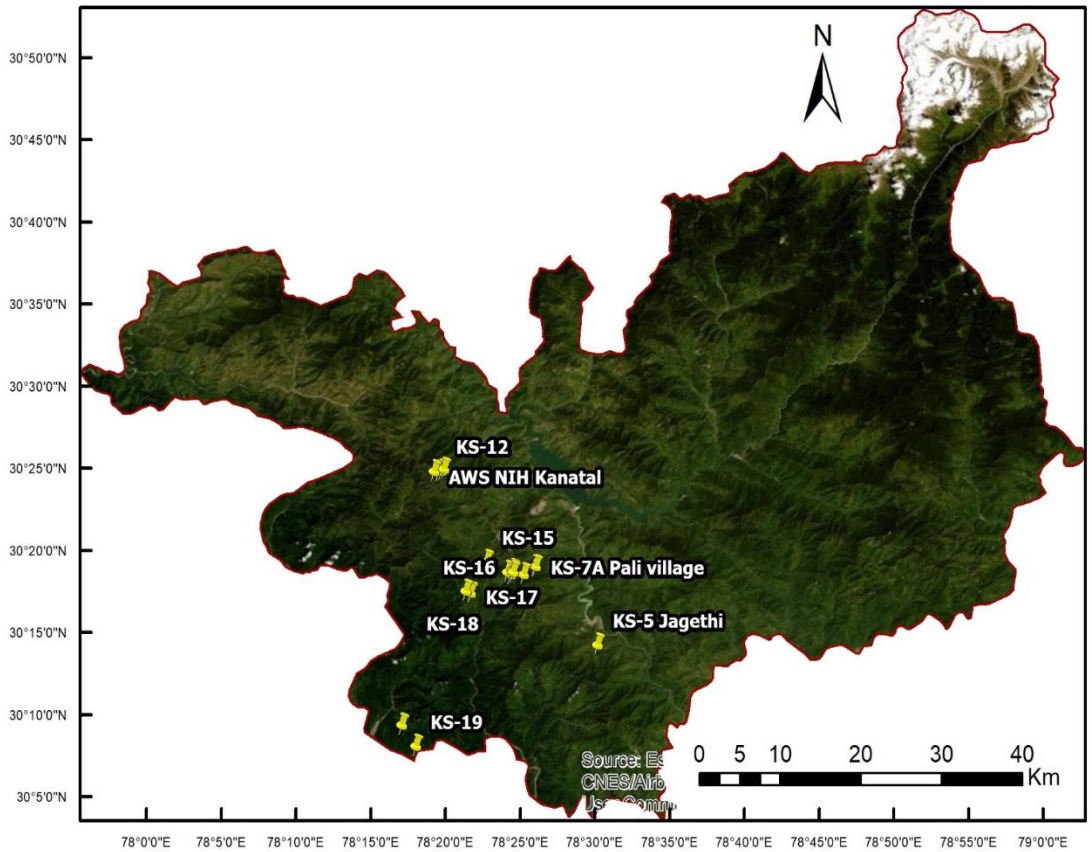


Fig.4 Sampling location of spring water in the study area

Fig.5 Identified sites for spring monitoring and detail hydrological investigations.

Table 1: Characteristics of identified springs in the study area (in the month of Sept 2019)

S.N.	Sample Code	Block, District	pH	EC	Temp. (°C)	Discharge (lps)	Altitude (m)	$\delta^{18}O$ (‰)	δD (‰)	H
1	KS1	Dhandchilli	7	140	15.8	7.09		-8.70	-57.78	11.85
2	KS2	Dua Koti	6.8	80	19.4	12.28		-8.71	-58.79	10.88
3	KS3	Ghargaon	7.2	70	18.8	3		-8.75	-57.88	12.14
4	KS4	Biman Village Gajabhali	7.8	50	18.2		1518	-8.26	-53.57	12.53
5	KS5	Jagedi	7.4	190	19.8	2.63		-8.83	-62.35	8.30
6	KS6	Chhati (Nakot)	7.1	210	20.2	2.55		-8.99	-60.72	11.22
7	KS7	Palli Village , Chamba	7.9	130	18.8	19.4	1455	-8.43	-57.70	9.77
8	KS8	Weet Village, Ranichauri	7.4	120	17.8	7.39	1528	-8.64	-56.53	12.57
9	KS9	Ranichauri Hill Campus	6.9	90	15.8	11.62	1853	-8.71	-57.26	12.43
10	KS10	Downstream of Main Campus, Ranichauri	7.5	210	16.6	11.99	1799	-8.15	-54.14	11.09
11	KS11	Fakua spring	7.1	60	17.1	33.16	1750	-8.79	-58.13	12.18
12	KS12	Simswani	6.9	90	15.4		2317	-9.42	-62.56	12.78
13	KS13	Near Simswani, Kanatal	6.9	60	15.7	15.09	2286	-9.47	-61.90	13.82
14	KS14	Near Kanatal	7.1	90	15.2	6.15	2289	-9.38	-63.59	11.48
15	KS15	Musani, Choydiyali, Chamba	7.5	490	17.8		2289	-8.52	-56.37	11.79
16	KS16	Aamsira	8.4	1440	25.7		2123	-6.95	-47.85	7.72
17	KS17	Near Selu Pani (NH-94)	8.5	910	22.5	0.5	894	-7.43	-50.05	9.35
18	KS18		8.5	720	23.3	4.59	882	-7.30	-49.67	8.70
19	KS19		8.5	480	20.7	4.5	1084	-7.10	-46.61	10.23
20	KS20	Narendranagar (Kinwani)	7.2	190	22.3	16.1	991	-6.61	-44.06	8.78
21	KS21	Kanatal Lake	7.1	40	18.8		2408	-9.19	-63.46	10.07

Future Work Plan and Activity Schedule for the period 2019-20

- The monitoring stations (n=4) have been identified to collect the water samples from rain and spring water for stable and radiogenic isotopes. These stations will be monitored by NIH (*n=2*) & VCSG UUHF Ranichauri (*n=2;* Ranichauri & Fakua). Additional, field visits will be undertaken during 2019-20 by the study team and samples of rain, spring water will be collected for chemical and isotopic analysis.
- The location of map of springs along with isotopic values of spring water and rainfall will be prepared in the study area.
- Altitude-wise variation in isotopic composition of spring water will be quantified in the study area.
- Identification of recharge sources and zones of selected springs will be undertaken based on isotopic characterization of precipitation and spring water source.
- The different maps will be prepared for the study area (e.g., Physiographic zone, DEM, Slope, Drainage map).

2. PROJECT REFERENCE CODE: NIH/HID/R&D/19-22/2

Title of the Study:	Isotope fingerprinting of precipitation over Indian Region
Study Team:	Nidhi Kalyani (PI), Sudhir Kumar, MS Rao, and Scientists from RC's
Funding Agency	DST, Govt. of India
Budget	Rs. 39.24 lakh
Date of Start:	Jul 2019
Date of Completion	Jun 2022

Rationale: Precipitation stable isotopes can be used to trace the water cycle and to interpret paleo-climatic archives. Forecasts of natural and anthropogenic impacts on climate require a better understanding of factors controlling regionalized precipitation regimes. This is especially important in tropical areas, where the complexities of atmospheric circulation and water cycle's seasonal intensity limit our capability to predict changes in precipitation patterns and water availability. This project will focus on present day isotope information in precipitation and its use for interpretation of validation of hydro-climatic phenomenon and models respectively. The data will be compared with already available isotope data available from various paleo-climatic archives to better inform climate models.

Objectives:

Major Objective of the project is to better assess impacts of climate change on water resources variability, availability and sustainability by use of environmental isotopes.

The specific objectives shall be

- Improve interpretation of past climate archives such as speleothems, lake sediments, ice cores, tree rings etc. using environmental isotopes in order to better understand regional and local climate dynamics and their possible impact on water resources at present and in the future.
- Improve regional climate and water balance model outputs using present day precipitation/ vapor isotope data.
- Initiate/consolidate daily and/or event based monitoring programs of precipitation stable isotopes.
- Review/assess the level of understanding of links between stable isotopes and various factors that control them in tropical regions at different spatial and temporal scales.

Present state-of-art

The International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO) runs worldwide isotope monitoring network of hydrogen and oxygen isotopes in precipitation -The Global network of isotopes in precipitation (GNIP) since 1960. This data is extensively used as a key tracer in hydrology, hydro-climatology and paleo-climatology studies. The stable isotopic characteristics of Indian precipitation was studied in the context of geographical and meteorological conditions and the associated atmospheric processes for several Indian regions (northern India, southern India and Himalayan region) during the period 2003-2006 and the Indian Meteoric Water Line was established_. Atmospheric moisture content was examined for Indian monsoonal patterns_. Several other researchers across the world have studied characteristics of isotopes in precipitation and atmospheric water vapor, eminent work being Dansgaard (1964), Craig and Gordon (1965), Jacob et. al. (1991) and Rozanski et.a al. (1993).

Methodology

The envisaged objectives will be achieved through –
Establishing of precipitation isotope monitoring stations at 15 locations out of the following sites across India: :

1. Bangalore
2. Bhopal
3. Bhuvneshwar
4. Chennai
5. Gandhinagar
6. Guwahati
7. Jammu
8. Kakinada
9. Kathmandu (Nepal)
10. Kolkata
11. Lucknow
12. Mangalore
13. Mumbai
14. New Delhi
15. Patna
16. Ranchi
17. Roorkee
18. Srinagar
19. Thiruvananthapuram
20. Udaipur

a. Sampling of precipitation isotopes and laboratory analysis for investigations of deuterium and ^{18}O content in precipitation.
b. Spatiotemporal mapping of D and ^{18}O values in precipitation samples for hydrological investigation studies.
c. Identification of the role of geographic, meteorological and atmospheric circulation /Indian monsoon in the space-time variations of isotopic composition of precipitation over Indian region.
d. Application of available data on isotopic composition of precipitation for parameterization of processes in Global Circulation Models, which influence isotope composition in precipitation.
e. Continuation of collection and analysis of stable isotope data over established networks.
f. Identification of climate signals in isotopic composition of precipitation (Climatic variables such as temperature have shown good correlation with isotopic composition of precipitation) to improve interpretation of paleo-climatic archives.

Progress of Work

Literature review
Establishment of sampling stations at 4 locations
Collection and compilation of all available data/information

Activity Schedule for 2019-2022:

	2019		**2020**				**2021**				**2022**	
	Jul-Sep	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**
Recruitment of project staff												
Literature Review												
Collection and compilation of all available data/information												

Establishing network of station for precipitation sampling												
Sample collection and transportation												
Laboratory Analysis of samples for isotopic composition												
Space-time mapping of isotope composition in precipitation samples												
Application of data/maps for the study of Indian monsoon and hydrological cycle												
Assessment of climate change signals in isotope composition												
Preparation of interim report												
Preparation of final report												

Expected outcome from the project

The output of the study would be in the form of a comprehensive report. The report would contain all hydro-meteorological data and isotopic composition of precipitation samples at different locations across India. It would provide temporal and spatial variations of environmental isotopes in precipitation (oxygen-18 and deuterium) over India for use in hydrological investigations studies and identify the role of Indian monsoon and/or hydrological cycle in determining the space-time variations of isotopic compositions in precipitation. Model parameterization of global circulation models will be done using observed isotope signals to better simulate regional climate dynamics for hydrological studies. A continued program would attempt to identify climatic signals in isotopic composition of precipitation for paleo-climatic studies.

Sponsored Projects:

1. 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:	S. D Khobragde (P.I.), Sudhir Kumar, Suneel Kumar Joshi (Res. Sc 'C'), Dr. Rajesh Singh, M. Arora, R. J. Thayyen, and Er. S. K. Verma
Type of Study:	**S**ponsored (under NMSHE Project)
Collaborating agencies:	WIHG and HNB Garhwal University
Funding Agency	DST, Govt. of India
Budget	Rs. 177.228 lakh
Date of Start:	April 2016
Date of Completion	March 2021

Study area description

The present study area confined within the geographical coordinates of 29°15' N to 31°30' N latitude and 78°15' E to 80°15' E longitudes, covering an area of ~21,800 km2 (Fig. 1), it is ~2% of the total drainage area of the entire Ganges River basin in north India [Rao, 1975; Chakrapani et al., 2009]. The Alaknanda and Bhagirathi rivers are the main tributaries in this region, originates at higher Himalayas from the snout of the Satopanth and Gangotri glacier [Joshi et al., 1993], respectively. Both the river system drains southern front of the study area and traverses four tectonic discontinuities in the north-south direction [Srivastava et al., 2017]: Southern Tibetan Detachment System (STDS); Main Central Thrust (MCT); Main Boundary Thrust (MBT); and Himalayan Frontal Thrust (HFT). The Bhagirathi river system drains predominantly through dolomitic limestones, quartzites, and metabasic formation; whereas, the Alaknanda river system drains through massive quartzites, phyllites, slates, carbonates, and greywackes. The annual precipitation is from ~500 mm/year to ~3000 mm/year in the Himalayan region, whereas the southern front of the mountains in Garhwal Himalayas receives approximately 1400 mm/year [Wasson et al., 2013; Srivastava et al., 2017].

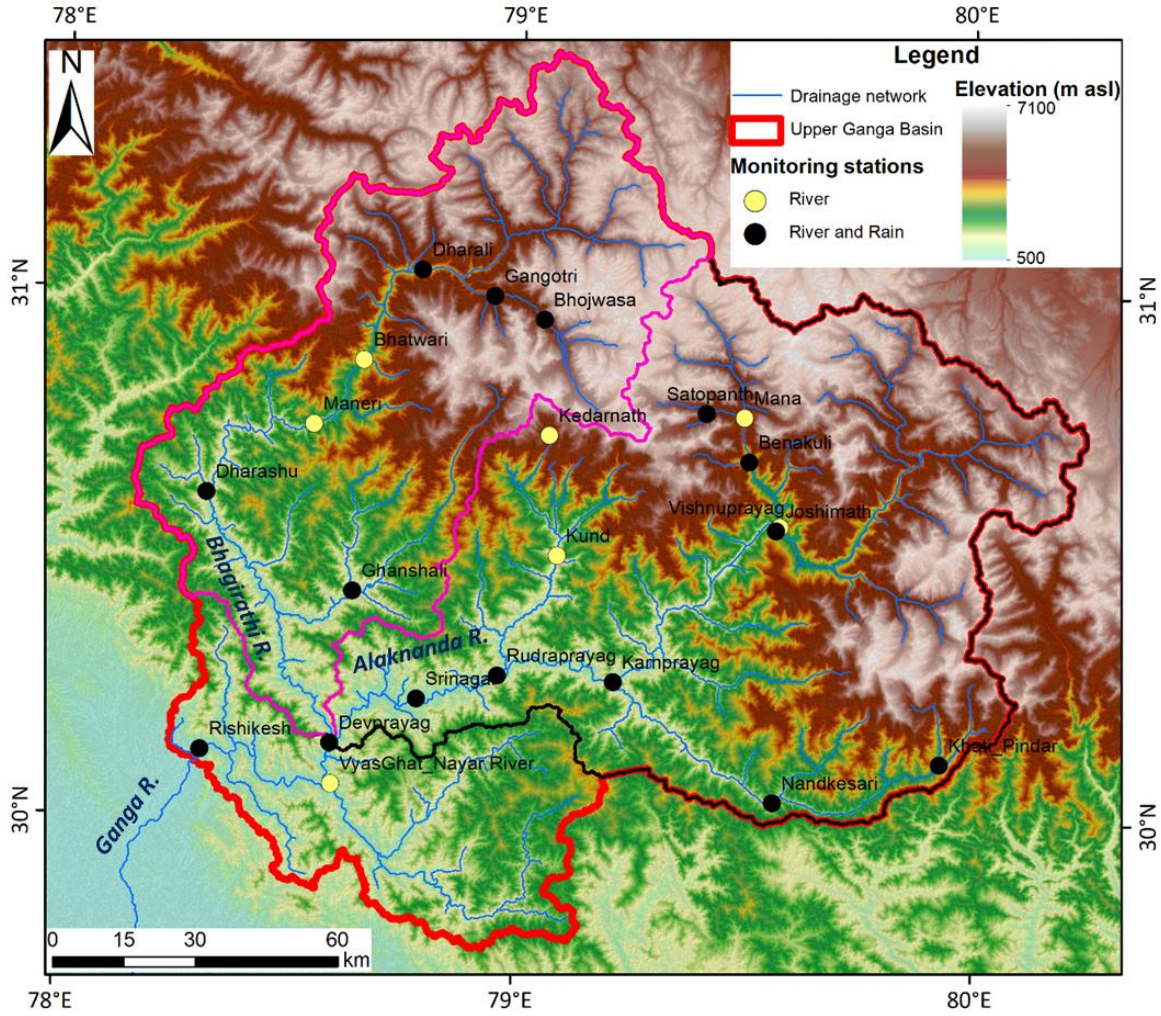


Figure 1: Study area map is showing monitoring stations in the study area. Red color boundary shows the upper Ganges basin, black color indicates the Alaknanda river basin, and pink color boundary shows Bhagirathi river basin in the study area.

Study Objectives

- Isotopic characterization of precipitation and identification of sources of vapor.
- Runoff generation processes in the headwater region of Ganga using isotope and modelling.
- Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries.
- The contribution of transient groundwater and its role in the sustainable flow of Ganga.
- Groundwater dynamics in the 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 severe environmental degradation and climate change. Continuing climate change is predicted to lead to significant 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 ecosystem, as well as on people and their livelihoods, could be dramatically affected, although the effect is not expected to be the same in terms of rate, intensity, or direction in all parts of the region. Therefore, a thorough understanding of hydrological processes operating in the Ganges River Basin is essential.

Brief Methodology

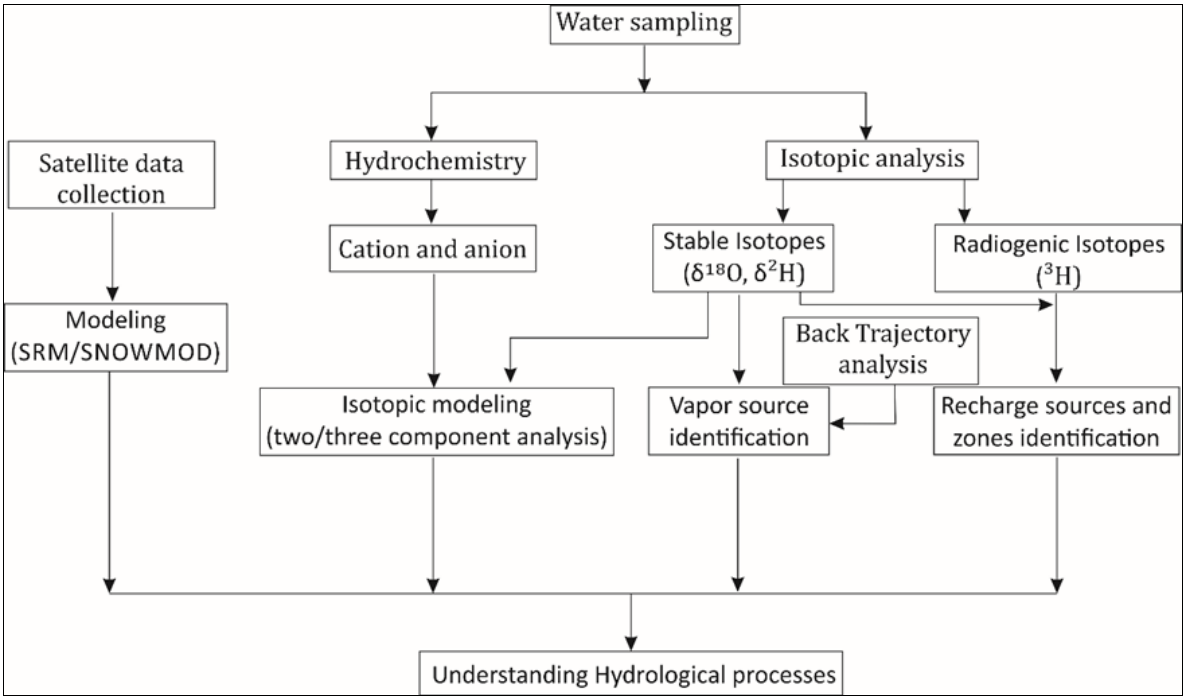


Figure 2 Detail methodology to understand the hydrological processes in the study area.

Achievement vis-à-vis Objectives

Objectives	Achievements
Isotopic characterization of precipitation and identification of sources of vapor	• Precipitation samples have been collected from 21 monitoring stations since 2016. • Local Meteoric Water Line (LMWL) has been established using $\delta^{18}O$ and $\delta^{2}H$ of precipitation for the study region. • Three different meteoric water lines for different seasons (winter, pre-monsoon, and monsoon) have been developed using $\delta^{18}O$ and $\delta^{2}H$ of precipitation. • Temporal plots of the isotopic composition of precipitation have been prepared for all monitoring stations. • Seasonality has been observed in precipitation $\delta^{18}O$ and $\delta^{2}H$ in all monitoring stations. • Temporal plots of rainfall amount have been prepared for a few monitoring stations. • Backward trajectory has been used for few (*n=10*) extreme precipitation events. • Wind direction maps have been prepared for a few extreme rainfall events. • Analysis of the altitude effect is in progress. • The effects of local factors on stable isotopes of precipitation are in progress. • Moisture sources from three directions have been identified during the study period. Detail analysis is in progress.
Runoff generation processes in the headwater region of Ganga using isotope and modeling	• The water samples (river, springs, snow, and glacier melt) have been collected from different locations in the study area. • Isotopic characteristics of snowmelt have been established for a few locations in the study area. • The hydrochemical analysis is in progress.

	• End member mixing analysis is in progress. • Hydrograph separation (two- and three-component) analysis for 6 locations have been completed, and detail analysis is in progress. • The identification of the source of river water and runoff processes is in progress. • Snow cover area has been monitored using MODIS data between 2005 and 2016. Detail analysis is in progress.
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	• Regular water samples have been collected from river monitoring stations to understand the spatio-temporal variability of snow and glacier melt. • Stable isotopic characterization of snowmelt and glacier melt has been established. • Temporal and spatial plots of $\delta^{18}O$ and $\delta^{2}H$ of river water have been established. • Estimation of runoff, snowmelt, and glacier melt contribution to the river flow has been initiated. Initial results for 6 locations have been estimated. Detail analysis is in progress. • Analysis of snowmelt contribution is in progress. The detailed report of $\delta^{18}O$, $\delta^{2}H$, ^{3}H, and water chemistry is in progress. • Uncertainty analysis is in progress.
The contribution of transient groundwater and its role in the sustainable flow of Ganga	• The water samples (river, rain, spring, groundwater) have been collected for tritium analysis, and samples are under laboratory analysis.
Groundwater dynamics in the mountainous area including identification of recharge sources and zones of major springs	• Isotopic characterization of springs and groundwaters has been completed, and further analysis for identification of recharge source and zones is being initiated. • Spatial and temporal maps of the isotopic composition of groundwater and spring waters have been prepared. • Initial results on altitude effect and identification of recharge area have been initiated. • A geological map of the study area has been prepared. • Groundwater source and relative age have been identified. Detail analysis is in progress. • Understanding hillslope response to the hydroclimatic conditions is being initiated. • The linkage between the isotopic signature of water and hydrogeological processes is being initiated.

Progress of Work/Results and Analysis

- The monitoring stations (*n=21*) have been established to collect the water samples from rain and river for stable and radiogenic isotopes (Fig. 1). These stations are being monitored by NIH (*n=13*), WIHG (*n=6*), and HNBGU (*n=2*) since 2016. Also, nine field visits have been undertaken during 2016-2019 by the project staff, and additional samples of rain, river, snow/ice, glacier, springs, and hand pumps have been collected.
- Details of samples collected and analyzed until October 2019:

Parameter	Samples collected	Samples analyzed
Stable isotopes ($\delta^{18}O$ and $\delta^{2}H$)	10126	8851
Radiogenic isotope (^{3}H)	833	147
Chemistry	701	536

- Following analysis has been carried out so far:
  - Spatial and temporal distribution of isotopic composition of rain, river, ice, snow, springs,

and groundwater samples in the study area.

- Backward trajectory analysis for the identification of moisture sources.
- Altitude effect for both the river basin (Alaknanda and Bhagirathi)
- Hydrograph separation (two- and three-component approach) to estimate surface runoff, groundwater, and glacier melt to river discharge.
- Relationship between the observed and estimated contribution of river discharge at Devprayag monitoring station using isotopic approach.
- A detail geological maps and their linkage with isotopic signature of groundwater and spring water in the study area.
- Detailed analysis of the spatial and temporal distribution of Shatopanth glacier.
- Long-term snow covers distribution in different months during 2005-2016 using MODIS data (by WIHG).

Future Plan: as per activity schedule

Activity Schedule for 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 for stable and radioisotopes		√	√	√	√	√	√	√		
Compilation of data, interpretation, and analysis					√	√	√	√	√	
Organization of training course and workshop						√		√		
Preparation of final report										√

2. PROJECT REFERENCE CODE: NIH/HID/SPON/16-19/GBPIHED

Title of the Study:	**Rejuvenation of springs and spring-fed streams in Mid-Himalayan Basin using spring sanctuary concept**
Study Team:	Dr Sudhir Kumar, Sc. 'G' (PI), Sh. S.K. Verma, Sc. 'D'
Type of Study	**S**ponsored
Funding Agency	G B Pant National Institute of Himalayan Environment and Sustainable Development (GBNIHESD), Almora under NMHS
Budget	Rs. 15.00 Lakhs
Duration:	3 years
Date of Start:	01.04.2016
Date of Completion	31.03.2019

Objectives and Scope of Work:

Environmental Isotope application for study of regional scale altitude effect and recharge zone identification of springs in Lesser Himalaya and Tarai regions in Garhwal and Kumaon

Study Area

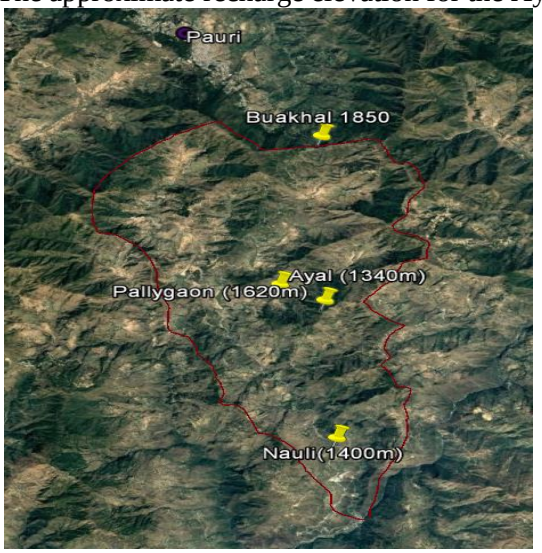
The study area of Garhwal region of Uttarakhand is a part of Paschimi Nayar sub-basin (**Figure 1**) having highest elevation of 2143m to a lowest elevation of 700m.The study area is bounded between latitudes 30^{o}00' N and 30^{o}8' N and longitudes 78^{o}45'E and 78^{o}50'E. Geologically the study area falls in Lesser Himalaya, which ranges between 700-to-2500m high, and is represented by Pauri Phyllite and Khirsu Quartzite members of the Maithana formation in the Dudatoli Group.

Analysis and Results

Stable isotope investigation was carried out in Ire-gad watershed for the monsoon period (June – September) of 2017. A total of 139 samples of rainfall was collected from four different elevation ranging between 1400m to 1850m to generate the local meteoric water line as well as to decipher the recharge elevation of Ayal village spring located within the study area .The samples were analyzed at National Institute of Hydrology, Roorkee. The LMWL (Fig. 2) is represented by the equation $\delta D = 8.08\ \delta^{18}O + 9.71$, $R^2 = 0.98$.

The deciphered altitude effect from the rainwater samples collected from four different elevations within the Ir-gad altitudes within 450m of elevation difference for the month of July showed an altitude effect of -0.3‰ per 100m.

The approximate recharge elevation for the Ayal village spring is around 1700 m a.m.s.l (Fig.3).



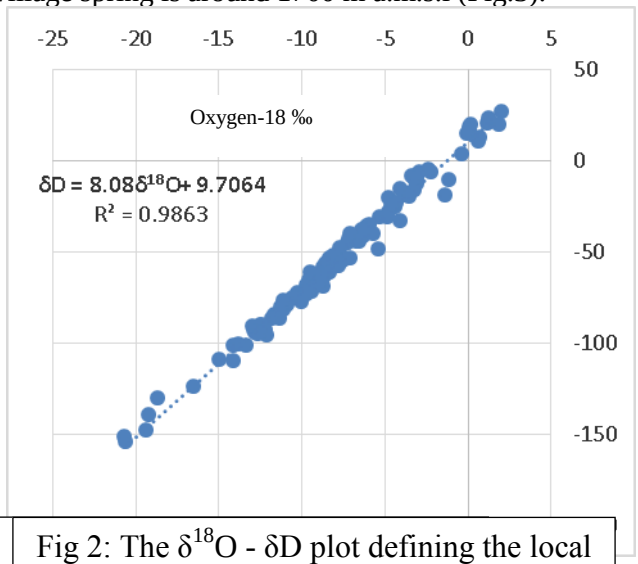


Fig 2: The $\delta^{18}O$ - δD plot defining the local meteoric water line (LMWL).

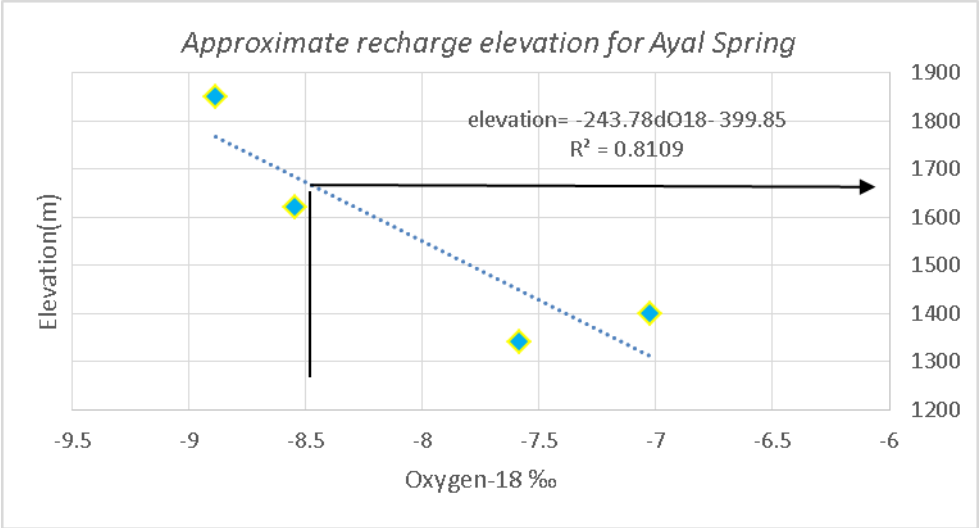


Fig 3: Altitude effect indicating an approximate recharge elevation of 1700m a.m.s.l. for Ayal village spring.

Future Plan:

- **Report writing.**

<u>Extension of the project upto 31st March, 2020 is requested</u>

3. PROJECT REFERENCE CODE: NIH/HID/SPON/16-19/IAEA

Title of the Study:	**Dating vary old groundwaters of deeper aquifers in Ganga Plains, India**
Study Team:	Dr M. Someshwar Rao Sc. 'E' (PI), Dr Sudhir Kumar, Sc. 'G', Sh. S.K. Verma, Sc'D'
Type of Study	**S**ponsored
Funding Agency	IAEA, Vienna (Austria)
Budget	18,000/- Euros
Duration:	3 years
Date of Start:	01.10.2016
Date of Completion	30.09.2019

The details are combined with new project "**Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin" (Project No. *NIH-26_2017_62).***

4. PROJECT REFERENCE CODE: NIH-26_2017_62

Title of the Study: Chemical and Isotopic Investigation of Groundwater in Deep Aquifers of Middle Ganga Basin, India

Study Group: Dr. Sudhir Kumar (PI), Dr. C.K. Jain, Dr. M. Someshwar Rao, Sh. S.K. Verma

Collaborating Institution: CGWB (MER, Patna & NER, Lucknow)

Funding Agency: PDS-NHP

Budget: Rs. 55.60 Lakhs

Nature of Study: Applied Research

Date of start: Jan, 2018

Scheduled date of completion: May, 2021

Duration of the Study: $3^1/_2$ Years

Study area: The study area is a part of Ganga basin falling in the alluvial plains of Uttar Pradesh in the region enclosed between the rivers Ghaghra and Yamuna of the Middle Ganga Basin. The Ganga basin is bounded in the north by the Himalayan frontal fault and by the peninsular fringe fault in the south. The alluvium thickness of basin increases from south to north and the basin slopes towards the southeast. From north to south, the Ganga Plain shows four distinct regions: (i) high permeable Bhabhar zone (10-30km wide) (ii) low permeable Terai zone (10-50 km wide and usually spotted with springs, ponds & small sandy rivers) (iii) the central Ganga plain (occupied by the main Ganga river, its flood plain and the network of Ganga canal) (iv) the marginal alluvium plains of low groundwater potential with aquifer thickness less than 200m.

Objectives:

i. To identify the various aquifers present in Upper / Middle Ganga Plains.

ii. To identify the source of recharge of deep aquifers

iii. To assess interaction of deep aquifer with overlying aquifers.

iv. Water quality of deep aquifer

v. Sustainability of deep aquifer for its exploration and future use

Statement of the Problem: Growing demand of food grain, speedy economic growth, agricultural droughts, climate change etc., are accelerating the water demand and thereby causing the groundwater depletion at an alarming rate. Today, in most part of the country the shallow aquifers are either dried up or nearly un-usable for economic use.

Even the Ganga basin, one of the largest groundwater multi-aquifer systems in the world is witnessing the groundwater depletion and contamination problem. The Indo-Gangetic basin occupies nearly 26.2% of the total geographical area of India. 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 relatively static in nature and therefore it is not accounted in the groundwater balance computation by CGWB, Govt of India. With the progressive water demand as the groundwater withdrawn is going to deeper depths, the deeper aquifers are coming under the influence of anthropogenic activities of groundwater depletion and contamination. Huge amount of groundwater withdrawal for irrigation is taking place all across the Ganga basin leading to dewatering of its shallow & middle aquifers and to small quantity from the deeper aquifers. It is not known what the composition of old is and modern groundwater in the total withdrawal. Shallow water table fluctuation data does not provide any clue to this problem. Isotopes helps trace groundwater, flow pattern and age. The present project is intended to investigate the quasi-static nature of deep aquifers of Ganga basin, their recharge sources, the pristine groundwater quality and sustainability for its use for the future.

Study area: Indo-Gangetic plain encompasses a large alluvial track consisting of multi-tier aquifer system. Of this, the central Ganga plain is one of the most densely populated regions in the subcontinent. In the study region (Fig 1), deep aquifer groundwater (depth > 250 m) have been sampled from piezometers developed by CGWB, GoI in their studies. At, most of the places these piezometers were found choked. After detailed survey, piezometers from 10 locations were sampled for water quality and isotopic analysis. The sampled locations are shown in the figure below.

(a) (b)

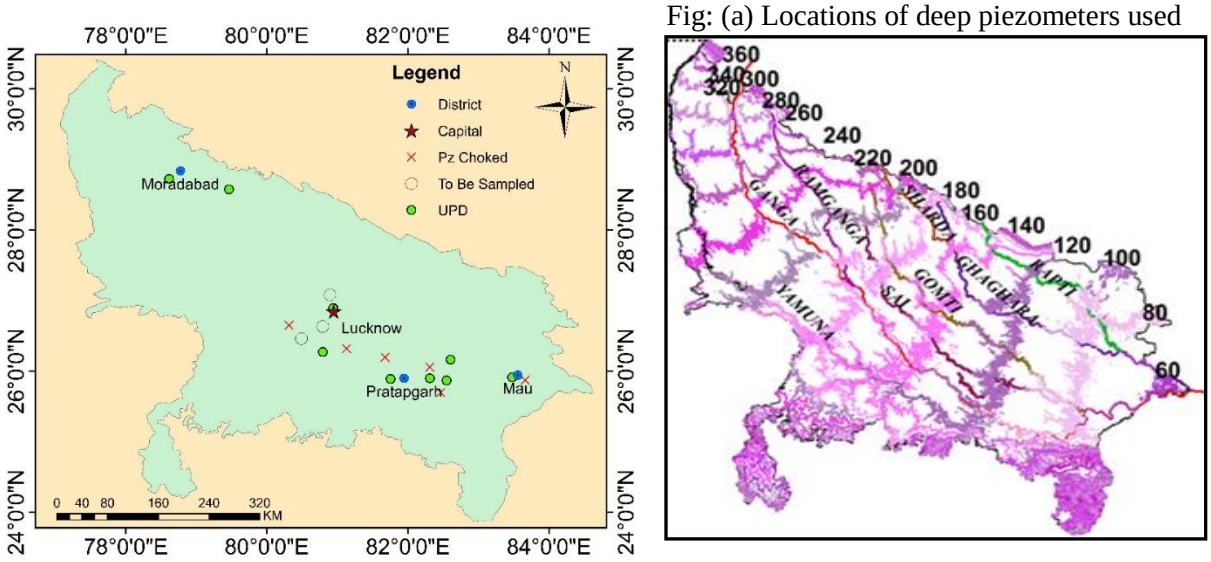


Fig: (a) Locations of deep piezometers used for water sample analysis in the present study (b) Important rivers in the study area and topographic elevation contours.

Methodology:

Water sampling: In the study region, deep tube-wells of CGWB/ State owned wells are being examined and the selected for groundwater sampling. Water samples from surface water sources (rain, river canal etc.) are also being 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 (^{3}H) 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 $^{3}H/^{3}He$ and ^{36}Cl techniques.

Interpretation: Data will be interpreted in terms of its formation (recharge conditions & flow dynamics), turn over time 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.

Table 1: Sampling Details

Dist.	Place	Sampling code	Month of Visit	Lat	Long	Depth (m)	Samples collected for				
							^{3}H	^{14}C	δD, δ^{18}O	WQ	In Cu-tubes
Barreilly	Pandri Halwa	1 UPD 1	Mar 2018	28.57241	79.46077	279 - 487	✓		✓	✓	x
		1 UPD 2	Oct-2018				✓	✓	✓	✓	✓
		1UPD 2A	Oct-2018				✓	✓	✓	✓	x
Moradabad	Bataua	2 UPD 1	Mar-2018	28.7248	78.61412	265 - 315	✓	✓	✓	✓	✓
		2 UPD 1A	Mar-2018				✓	✓	✓	✓	✓
Lucknow	Itaunja	To be sampled	Visited	27.08288	80.892	214 - 435					
	Aliganj	2UPD 1	Mar-2018	26.89135	80.93986	208 - 214	✓	x	✓	✓	✓
	Kendriya Bhawan, Aliganj	3UPD 1 3UPD 2	Mar-2018 Jan 2019	26.89332	80.94494	337 - 612	✓ ✓	X ✓	✓ ✓	x ✓	X ✓
Unnao	Badarka	To be sampled	Mar-2018	26.46312	80.48656	287 - 430					
	Marounda	Pz Choked	Mar-2018	26.6498	80.31348	295 - 332					X
	Datauli	To be sampled	Mar-2018	26.63217	80.78631	214 - 395					
	Sarai Maniharan	4UPD 1	Mar-2018	26.26949	80.79364		✓		✓	✓	
Pratapgarh	Laxmanpur	5UPD-1	Jan 2019	25.89443	81.76116	240 - 308	✓	✓	✓	✓	✓
	Belharamau	6 UPD-1	Jan 2019	25.89768	82.31265	249 - 261	✓	✓	✓	✓	✓
Sultanpur	Indauli Thakur Basti Iry Sc.	Pz choked	Jan 2019	26.05361	82.30833	249 - 261					X
Jaunpur	Gairwah Baba Gangdaski kutiya	7 UPD 1	Jan 2019	26.16262	82.58585	393 - 411	✓	✓	✓	✓	✓
	Kurni, Samadhganj	Pz Choked	Jan 2019	25.69861	82.46389	240 - 340					X

Dist.	Place	Sampling code	Month of Visit	Lat	Long	Depth (m)	Samples collected for				
							^{3}H	^{14}C	δD, $\delta^{18}O$	WQ	In Cu-tubes
	Leduka	8 UPD 1	Jan 2019	25.86667	82.55	264 - 340	✓	✓	✓	✓	✓
Mau	Banka	Pz Choked	Jan 2019	25.87222	83.6625	433 - 484					
	Pinjara	9 UPD 1	Jan 2019	25.9111	83.4777	362 - 459	✓	✓	✓	✓	✓
Rae Barreli	Anguri	Pz Choked	Mar-2018	26.32482	81.13851	224 - 261					X
	Pacheri	Pz Choked	Mar-2018	26.19412	81.67788	312 - 385					X

Table 2: Status of the Analyzed Samples

Dist.	Place	Sampling code	Date of Visit	Samples collected for				
				^{3}H	^{14}C	δD, $\delta^{18}O$	WQ	In Cu-tubes
Barreilly	Pandri Halwa	1 UPD 1	Mar 2018	✓	X	✓	X	--
		1 UPD 2	Oct-2018	✓	X	x	✓	X
		1UPD 2A	Oct-2018	✓	X	X	✓	--
Moradabad	Bataua	2 UPD 1	Mar-2018	✓	X	✓	✓	X
		2 UPD 1A	Mar-2018	✓	X	X	✓	X
Lucknow	Aliganj	2UPD1	Mar-2018	✓	X	✓	X	X
	Kendriya Bhawan, Aliganj	3UPD1 3UPD2	Mar-2018 Jan 2019	✓ ✓	X	✓ ✓	✓	X
Unnao	Sarai Maniharan	4UPD1	Mar-2018	✓	X	✓	X	X
Pratapgarh	Laxmanpur	5UPD-1	Jan 2019	✓	X	✓	✓	X
	Belharamau	6 UPD-1	Jan 2019	✓	X	✓	✓	X
Jaunpur	Gairwah Baba Gangdas ki kutiya	7 UPD 1	Jan 2019	✓	X	✓	✓	X
	Leduka	8 UPD 1	Jan 2019	✓	X	✓	✓	X
Mau	Pinjara	9 UPD 1	Jan 2019	✓	X	✓	✓	X

Work Plan for the 4th Qr of 2019-20:

1. Field work will be taken-up in the month of Nov, 2019 for collecting deep aquifer water samples from Itaunja, Badarka and Datauli; and to collect overlying aquifer water (60 -150 ft depth) from the locations where deeper water samples have been collected
2. Completion of the analysis of the water samples collected
3. Preparing the aquifer disposition map of the study area

5. PROJECT REFERENCE CODE: NHP-NIH-22_2017_38

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

Study Group: Dr. M. Someshwar Rao (PI), Sudhir Kumar, Sh. S.K. Verma, Sc. 'D', Dr. A. R. Senthil Kumar, Dr. V. S.Jeyakanthan

Collaborating Scientist/Institutions: Er. Subrata Halder, Ex. En., State Water Investigation Directorate (SWID), Dept of Water Resou. Invest. & Develop. (DWRI&D), Govt. of West Bengal

Type of Study: NHP - PDS

Budget: Rs 51.0 Lakhs

Nature of Study: Applied Research

Date of start: January 2018

Scheduled date of completion: July, 2021

Duration of the Study: $3^1/_2$ Years

Statement of the Problem: Approximately, 22.74 million people residing in the 59 blocks of the three coastal districts of West Bengal viz., South24 Parganas, North 24 Parganas and Purba Medinipur are in the range of seawater-groundwater interaction zone and under the threat of changing groundwater salinity. 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, saline/freshwater interface and flow regime of coastal groundwater will be investigated using isotopic & chemical techniques in conjunction with the conventional data. The project involves investigation of seasonal variation in the seawater groundwater interface and the responsible factors affecting this dynamic condition in the coastal zone of West Bengal. 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. The project is undertaken jointly with Government of West Bengal. The West Bengal Govt is installing large number of piezometers in the coastal region under National Hydrology Project. The interpretation of the data will be done jointly. With the involvement of State Officers, the knowledge of the study can be more effectively disseminated to the stake holders in their native language.

Study area: The study area covers the coastal region of West Bengal falling in the districts of Purba Medinipur, South 24 Parganas and North 24 Pargana. Coastal zone occupies important position in West Bengal. It covers an area of 9630 km^2 and it extends over the coastal length 220 km. The important geomorphic features of the coastal zone includes estuarine plains, deltaic region, levees, sand beaches, saltpans & salt marshes, forest cover, islands separated by tidal channels, creeks, mangrove forest and mud flats. The coastal zone is getting invaded due to expansion of industrial establishments viz; petrochemical, thermal power, steel, automobile, transport, ship building/breaking, deep water port, tourism, coastal aquaculture, etc.

Objectives:

1) Assessment of spatio-temporal variables (sea level change, variation in groundwater levels, rainfall trend etc.) influencing dynamics between seawater & groundwater interface using archival data

2) Spatio-temporal variation map of fresh water – saline water interface from the present observations.

3) Identification of source of salinity in groundwater

4) 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

5) Management measures for safe & sustainable coastal groundwater use

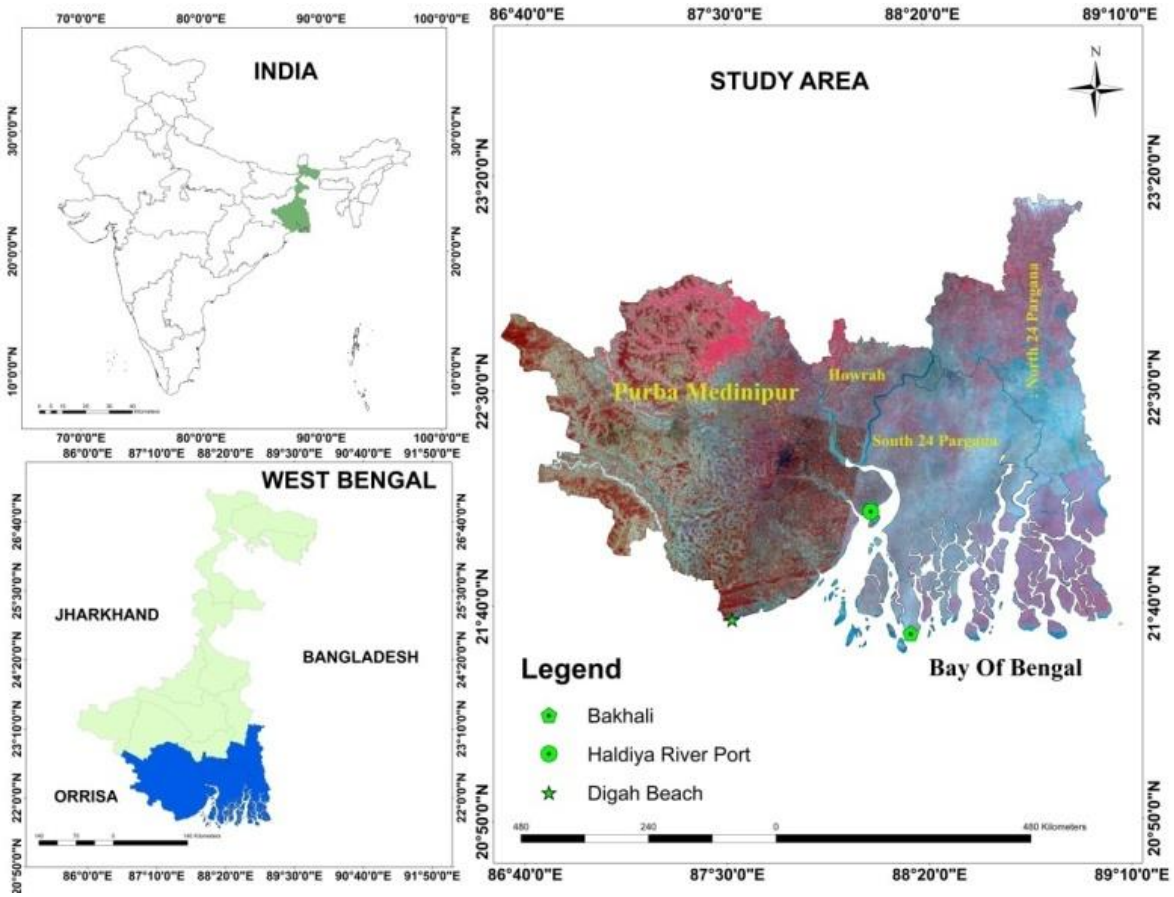


Figure 1: Study area map

Methodology:

i) Preparing review/status report on seawater intrusion (SI) and submarine groundwater discharge (SGD)

ii) Collection and analyzing of archival data influencing SI & SGD processes. This include collection archival data on change in sea-level, groundwater level data, rainfall data, river stage etc. and, their trend analysis.

iii) **Field work & sample analysis:** Water samples will be collected at uniform frequency for isotopic and chemical analysis (st. isotope, dating, major ion, radon concentration).

iv) **Data synthesis**: Field data and archival data will be converted into thematic layers on GIS environment. This will provide vulnerable zones for salinization, area experiencing SGD; influence of natural and anthropogenic factors in SI/SGD etc. Rainfall runoff modelling through SWAT hydrological modelling, DEM, optical dataset, land use, soil texture, drainage, groundwater levels (pre & post monsoon), and water quality data will be used for preparing thematic maps. Data will be analyzed to estimate run-off excess for AR-measures and in controlling SI process.

v) **Management Measures:** Data will be interpreted in terms of augmentation of SGD and control over GW salinization.

vi) **End use:** (i) Identification of recharge areas, adoptive management strategies for AR-measures, groundwater withdrawal strategies, knowledge dissemination jointly with State

Department through mass interactive programmes and brochures in local languages (ii) Review report (iii) DPR will be prepared for field implementable programme.

Work accomplished (as on date)

Objective	Target (2019-20)	Achievement
Rainfall-Run-off through SWAT hydrological model	Land Use Land Cover	Completed
	Hydro-climatological Data collection	Collected archival data (2003-2013) (Precipitation, Temperature, Solar Radiation, Relative Humidity, Wind Speed)
	Digital Elevation Model (ASTER,30m)	DEM prepared
	Soil Map	Under process
	River Discharge Data	Under process
Groundwater Potential Zone Mapping	Digitization of hydrogeological & geomorphological features	Geomorphological feature digitized
		Digitization of hydrogeological features under progress
Changes in the hydrological conditions using archival data	Changes in water quality data (groundwater, & surface waters)	Collected Water quality data i) River & canal water Quality data (2010-2019 at monthly interval) ii) Groundwater (2010-2019; twice in a year) iii) Lake (Aug 2013-2019; twice in a year)
	Change in Sea level (changes in per day)	Daily data (Jan 2019 onwards at 3 locations)
	Details of aquifer zone (depth), water level and water type (saline, fresh, arsenic contaminated zone)	Details collected from 100 locations. 25 locations from South 24 Pargana 21 locations from North 24 Pargana 29 locations from West Medinipur 25 locations from East Medinipur This data will be used in making cross section of the aquifer types in the study area.

Work to be done in 2019-2020:

1) SWAT model run (Sensitivity Analysis, Model Calibration and Validation using river discharge data)
2) Hydrogeology study (for mapping of groundwater potential zones)
3) Update these archival data per day basis and Lithology of Howrah

6. PROJECT REFERENCE CODE: NIH/HID/NHP/2018-21/1

Title of the Project:	**Development of a Comprehensive Plan for Conservation and Sustainable Management of Bhimtal and Naukuchiatal Lakes, Uttarakhand**
Project team:	S.D. Khobragade **(PI),** Sudhir Kumar, Dr M. K. Sharma, and team from IRI, Roorkee
Collaborating agency:	**IRI, Roorkee**
Type of Study:	**Study under NHP**
Duration:	**3 years**
Date of Start:	**1st January, 2018**
Date of Completion:	**31st December, 2020**
Budget :	**34.97 Lakh (NIH Component)**

Study area description

The study has been conducted for two lakes viz., Bhimtal and Naukuchiatal located in Kumaun Lesser Himalaya. The lakes are significant in terms of drinking water, irrigation requirements, fisheries, recreation and aesthetic values. Due to the various anthropogenic activities (intensive construction and increase in population), the lake and their respective catchments are suffering from various environmental problems, particularly since two decades. The sedimentation problems are increasing for both the lakes continuously due to sever erosion in catchment area and disposal of sewage into the lake (Agrawal et al., 2007). Declining storage capacity and increasing water demand for drinking and irrigation purposes deteriorating the lakes ecosystem with alarming rates. Based on the data of the period of 1996-2005 the average annual rainfall of the study area is about 1600 mm (Agrawal et al., 2007). The study area is recognized as sub-tropical climate region, with maximum temperature during summer (May and June) goes up to 32°C, whereas during winter (December and January) the minimum temperature falls even below 0°C (Agrawal et al., 2007).

Bhimtal lake: Bhimtal is largest lake of all the Kumaun lesser Himalayan lakes. The lake is about 22 km away from the Nainital and situated at 29° 21' N and 79° 34' E at an altitude of 1345 m, amsl. The surface area of the lake is about 0.46 km^2 and perimeter of the lake is about 4.23 km. The maximum length is about 1701 m and maximum width is about 480 m. The catchment of the lake is about 10.8 km^2. The maximum depth of lake is about 24.7 m and storage capacity is about 5.27 Mm^3. Bhimtal lake has southeast orientation with irregular boundaries. Lake Bhimtal formed as a consequence of tectonic activity, resulting from the uplift of sediments in the Tibetan and Indo-Gangetic plains (Valdiya 1988).

Naukuchiatal lake: Naukuchiatal is deepest lake of all the Kumaun lesser Himalayan lakes. The lake is about 4 km away from the Bhimtal and situated at 29° 19' N and 79° 35' E at an altitude of about 1320 m, amsl. The lake is closed water body, has irregular shape with nine corners. The surface area of the lake is about 0.30 km^2 and perimeter of the lake is about 3.13 km. The maximum length is about 983 m and maximum width is about 693 m. The catchment of the lake is about 1.6 km^2. The maximum depth of lake is about 42.7 m and storage capacity is about 5.17 Mm^3. The lakes are warm monomictic with one period of circulation in winters, which may extend 2-3 months, and a prolonged period of circulation for 9-10 months (WAPCOS Limited, 2013). The Naukuchiatal is formed on the core of an anticline. Reactivation of faults around it blocked off an ancient river valley by landslides (WAPCOS Limited, 2013). Figure 1 shows study area map of Bhimtal and Naukuchiatal lakes and their respective catchments.

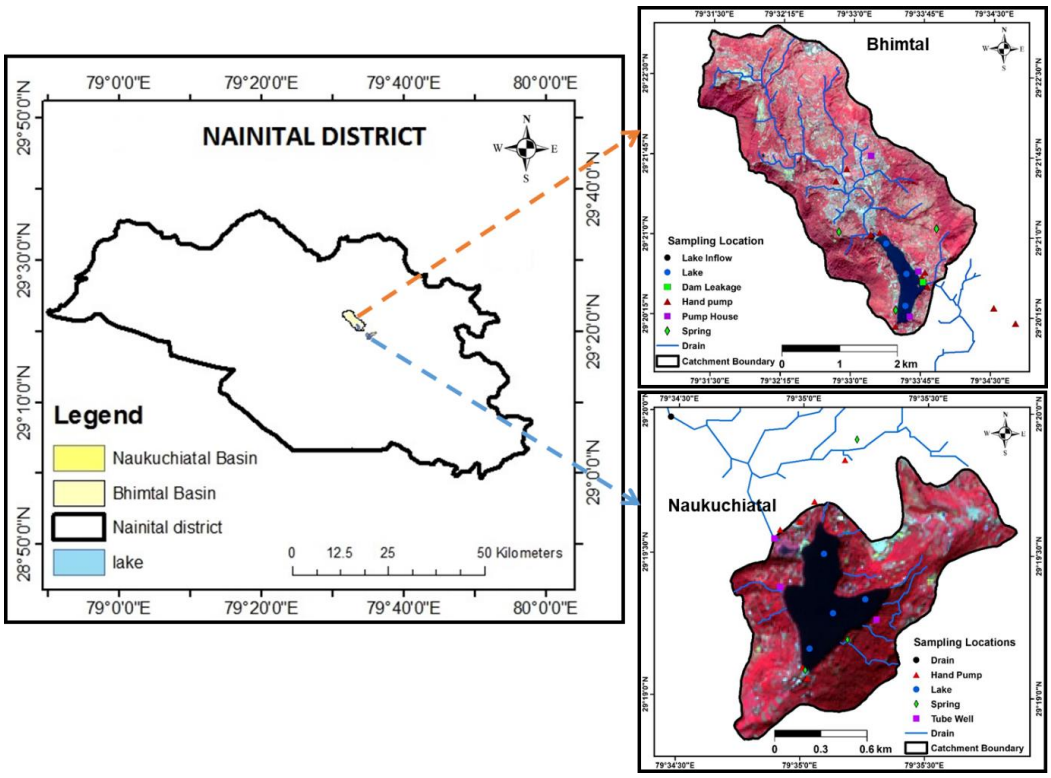


Figure 1: Study area map of Bhimtal and Naukuchiatal lakes and their respective catchments

Study Objectives

The major objectives of the proposed study are:

(i) To assess the seasonal water availability of the lakes and assess its adequacy in meeting future demands
(ii) To assess the water quality of the lakes and possible causes of its degradation
(iii) To estimate sedimentation rate and expected life of the lake
(iv) To suggest a comprehensive plan for conservation and sustainable management of the lakes

Statement of the Problem

- The catchments of Bhimtal and Naukuchiyatal lakes are subjected to anthropogenic disturbances over the last few decades.
- Problems such as heavy sedimentation, pollution etc. have been reported for both lakes.
- The two lakes have been identified for conservation under the National Lake Conservation Plan (NLCP) of the Government of India
- A number of studies have been reported on water quality, ecology and sedimentation aspects of these lakes but there are no reported hydrological studies
- No comprehensive conservation plans exist for these lakes
- Both the lakes are owned by the Irrigation department, Uttarakhand who want to rejuvenate the lakes, as these are prime sources of drinking and irrigation water

Brief Methodology

In the present study, land use and land cover maps of 2002 and 2018 were prepared to understand pattern of changes in land use and land cover of the study area. The Landsat-7 ETM+ image (30 m spatial resolution) of 2002 and Sentinel image (10 m spatial resolution) of 2018 were used. For land use and land cover classification, ground truth data and Google Earth images were used as reference. The images were classified using supervised classification technique by maximum likelihood algorithm in Arc GIS 10.3 software. For preparation of slope map and drainage maps of the Bhimtal and Naukuchiatal lakes catchments, ASTER Digital Elevation Model (DEM) was used. Lake water level and rainfall data have been collected on daily basis. Based on lake water level, daily lake storage and surface area of both lakes have been calculated. Seepage discharge data have been collected on

daily basis from Bhimtal lake to understand relationship of lake water level with seepage. Preliminary water budget of both lakes have also been carried out.

Sedimentation deposit profile have been obtained for the Bhimtal and Naukuchiatal lakes, which depicts the regions and pattern of sediment deposition in the lakes during the period from 2002 to 2018. Sediment deposition profile maps have been prepared by superimposing the bathymetry map of 2018 (present study) over the bathymetry map of AHEC (2002). The difference in lake bed depth provides the deposition profile. However, it may be noted that bathymetric data of 2002 was digitized from the map available in the literature (AHEC, 1993) and at number of places where there were broken contours, they were interpolated. Thus, there may be some errors in the actual depths of deposition as indicated in the deposition profile map but nevertheless it provides a general picture of where the sediment is getting mostly deposited in the lake.
For water quality and isotopic analysis, samples have been collected from both lakes as well as from their respective catchments. For water quality, samples have been collected seasonally while for isotopic analysis samples have been collected fortnightly. Depth wise samples have also been collected from both lakes. The sample have been collected for physical and chemical water quality analysis and isotopic analysis. Physical water quality parameters have been analyzed in-situ using sonde probe while chemical water quality parameters and isotopic analysis has been carried out in the Nuclear Hydrology laboratory of National Institutes of Hydrology, Roorkee.

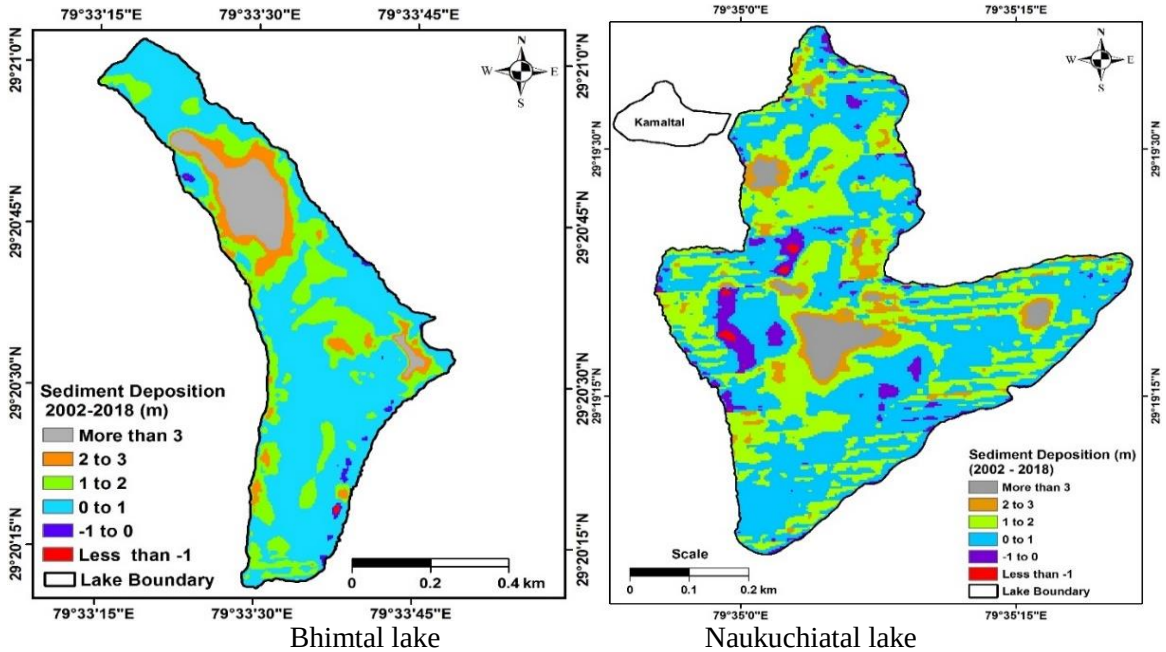
Achievement vis-à-vis Objectives

Objectives	Achievements
To assess the seasonal water availability of the lakes and assess its adequacy in meeting future demands	(1) Rainfall data has been collected for both lakes (2) Pumping data has been collected and analysis is under progress (3) Storage capacity and surface area of both lakes have been calculated. (4) Seepage discharge for Bhimtal lake has been calculated (5) Lake water level data for both lakes have been collected and preliminary analysis has been carried out (6) Preliminary water budget for both lakes has been completed
To assess the water quality of the lakes and possible causes of its degradation	(1) Samples from both lakes and their respective catchments have been collected seasonally (May and September) (2) Water quality analysis of September 2018 and December 2018 has been completed. Samples of May 2019 and September 2019 are under processes in the lab
To estimate sedimentation rate and expected life of the lake	(1) Sediment deposition profiles of both lakes have been prepared (2) Soil samples from the both lakes catchment has been collected for particle size analysis, dry and bulk density and organic matter content analysis. Samples will be handover for analysis in IRI, Roorkee laboratory (3) Land use and land cover maps of Bhimtal and Naukuchiatal lakes have been prepared
To suggest a comprehensive plan for conservation and sustainable management of the lakes	The final objective will be carried out after achieving above objectives

Progress of Work/Results and Analysis

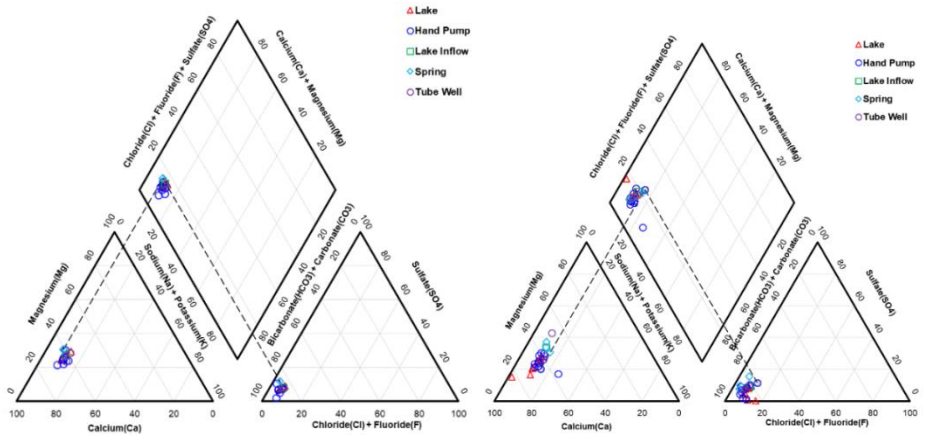
1. Thematic maps of the study area have been prepared:
    a. Land Use and Land Cover (LULC)
    b. Drainage map
    c. DEM, Slope and Aspect Map
2. Seepage from the Bhimtal lake has been computed
3. Relation between Lake water level vs. Rainfall has been developed

4. Monthly Water Balance Components of Bhimtal and Nakuchiatal Lake have been estimated
5. Sediment deposition profile has been developed (Figure 2)
6. Water quality of both the lakes has been analysed (Figure 3)



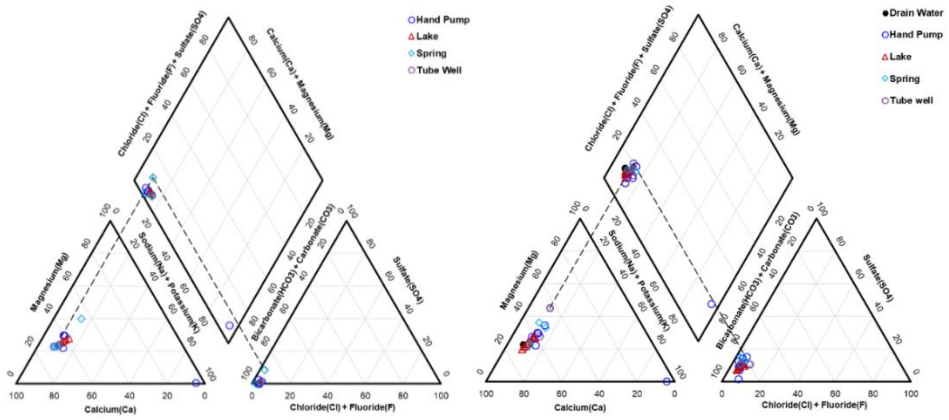
Bhimtal lake Naukuchiatal lake

Figure 2: Sediment deposition profile of Bhimtal and Naukuchiatal lakes



Sep 2018 Dec 2018

Bhimtal Lake



Sep 2018 Dec 2018

Naukuchiatal Lake

Figure 3: Piper Diagram for Bhimtal and Naukuchiatal lakes for Sep 2018 and December 2018

Future Plan: as per activity schedule

The work as per activity schedule is as follows:

(1) Water budget study of for Both lakes
(2) Study on sedimentation and soil erosion for both lakes catchment
(3) Isotopic and water quality analysis
(4) Analysis of sediment samples

PROJECT REFERENCE CODE: SP-35/2018-2020/HID

Title of the Project:	Unravelling Submarine Groundwater Discharge (SDG) zones along the Indian subcontinents and its islands
Project team:	Sudhir Kumar (PI), MS Rao (Co-PI), S.M. Pingale (Co-PI)
Collaborating RC's:	RC, Kakinada and RC, Belagavi
Type of Study:	Sponsored, NCESS, **(**Ministry of Earth Sciences, GoI)
Date of Start:	1st April, 2019
Date of Completion:	31st March, 2020
Budget :	Rs 46.44 Lakhs **(NIH Component)**

Study area: The SGD study area allotted (i.e. WG7& WG8) for NIH Roorkee group are shown in Fig. 1.

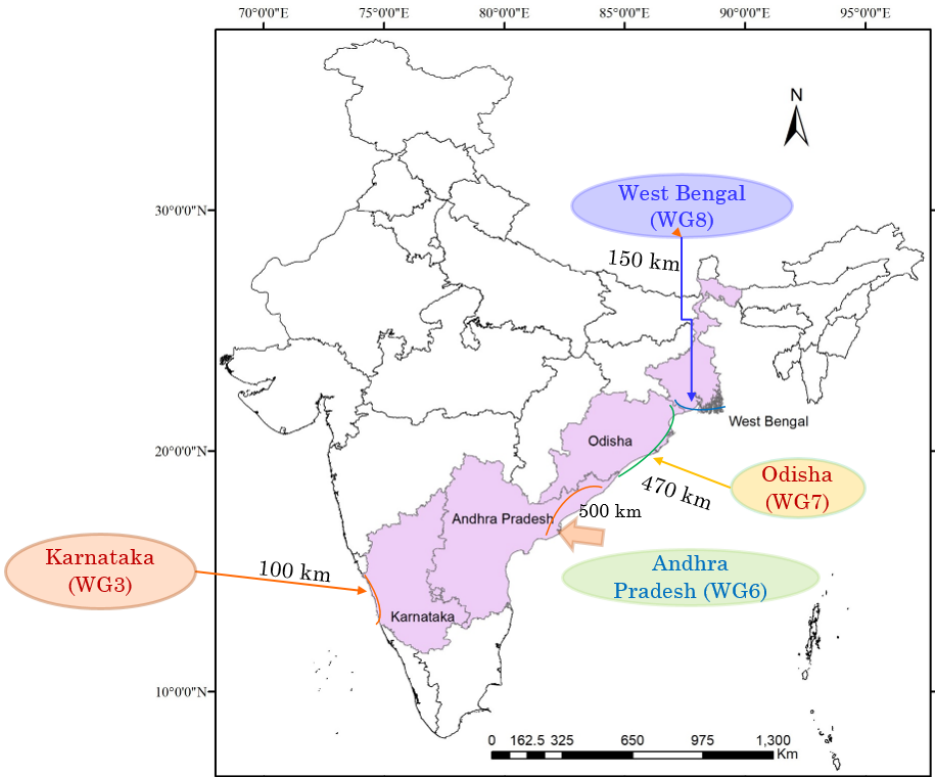


Fig. 1 Location of the study area.

Objectives:

i. To collect archival data of groundwater (GW level, GW chemistry, aquifer properties, lithology etc.) in the potential SGD zones in the coastal aquifers.

ii. To investigate the SGD zones using Landsat 8 thermal infrared images.

iii. To collect water samples from open/bore wells at every average 1 km along the coast at selected intervals.

iv. To measure salinity and temperature of sediment pore water, groundwater and seawater

v. To collect data on water temperature, salinity, Alkalinity, DO, pH, DIC, DOC, Silicon and Nutrients, dissolved inorganic nutrients: Silica (Si); nitrate and nitrite (N+N); ammonium (NH4); and phosphate (PO4), Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging or hydrogeological surveys.

Methodology:

i) Literature survey on SGD and archival information and collection of regular monitoring data from CGWB.

ii) Collection and processing of Landsat 8 thermal infrared images for selected locations.

iii) **Field work & sample analysis:** Groundwater samples will be collected at uniform frequency for isotopic and chemical analysis.

iv) **Data synthesis**: Field data and archival data will be converted into thematic layers on GIS environment. This will be used to identify the potential SGD zones in the coastal aquifers.

v) **Management Measures:** Data will be interpreted in terms of augmentation of SGD zones in the coastal aquifers.

vi) **End use:** Identification of recharge areas, adoptive management strategies for artificial measures, knowledge dissemination and preparing field implementable programs.

Work accomplished Till Oct 2019:

- ✓ Literature survey have been completed on SGD
- ✓ Water sampling from some of locations for chemical and stable isotope analysis have been completed (Fig.2).
- ✓ Collected different data related with groundwater.
- ✓ Digital Elevation Model (DEM) [Shuttle Radar Topography Mission (SRTM)(30m) (http://srtm.usgs.gov/)] was downloaded (Fig. 3) and Landsat 8 remote sensing data (https://earthexplorer.usgs.gov/) for the month of May and November, 2019 have been procured and processed (Fig.4).
- ✓ Developed instrument for collection of soil sediment water pore samples along the coastal aquifers (Fig.5).
- ✓ Some of the data related with groundwater and hydrogeology have been collected from CGWB.

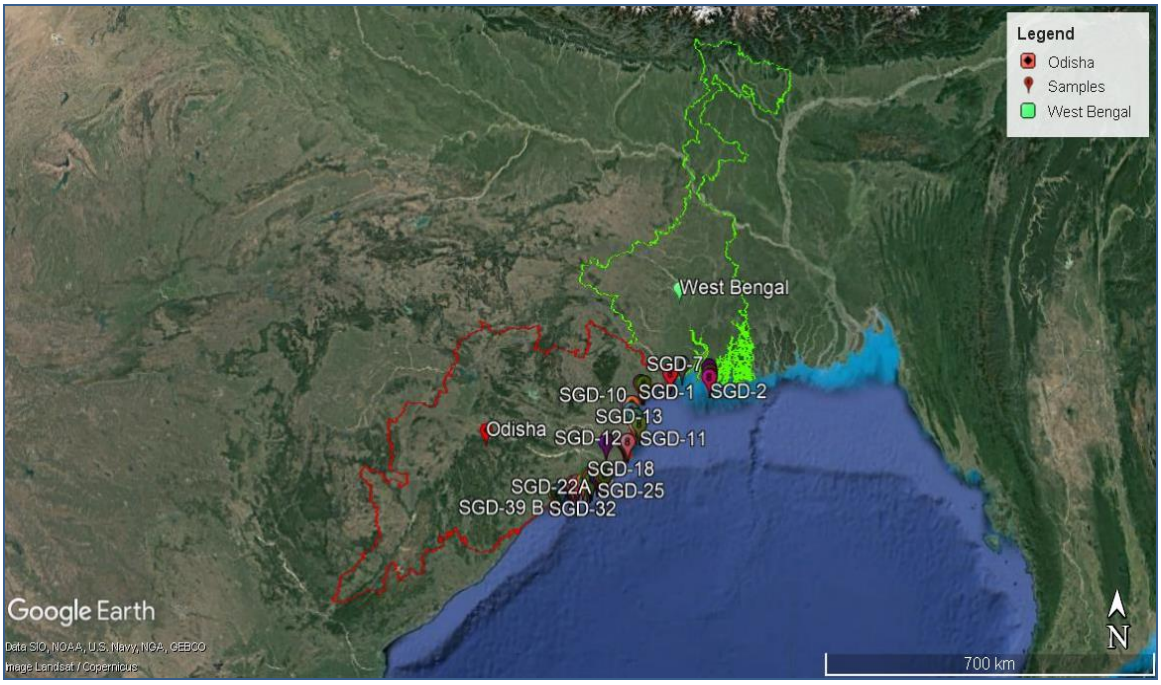
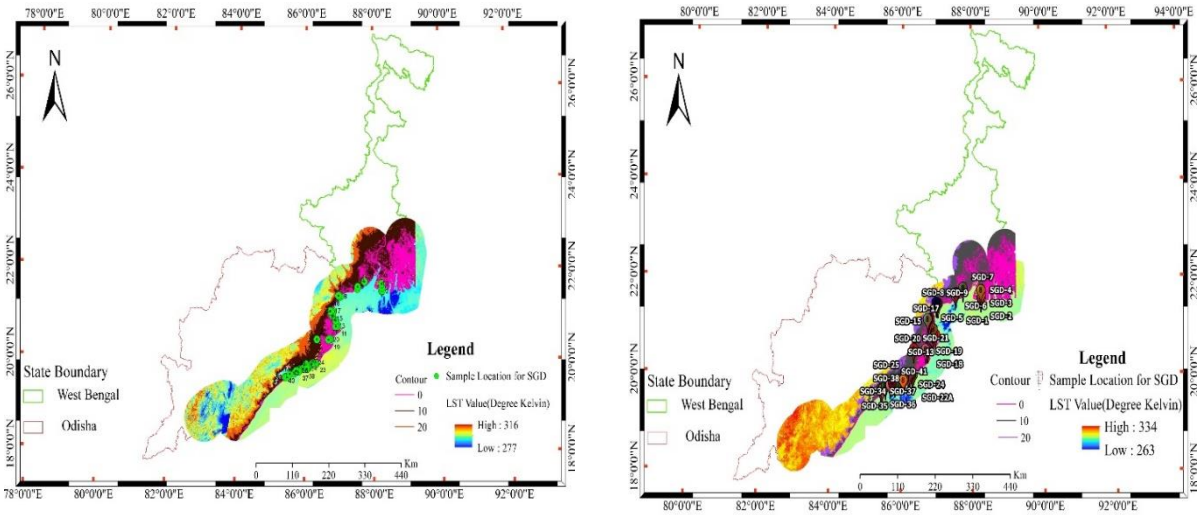
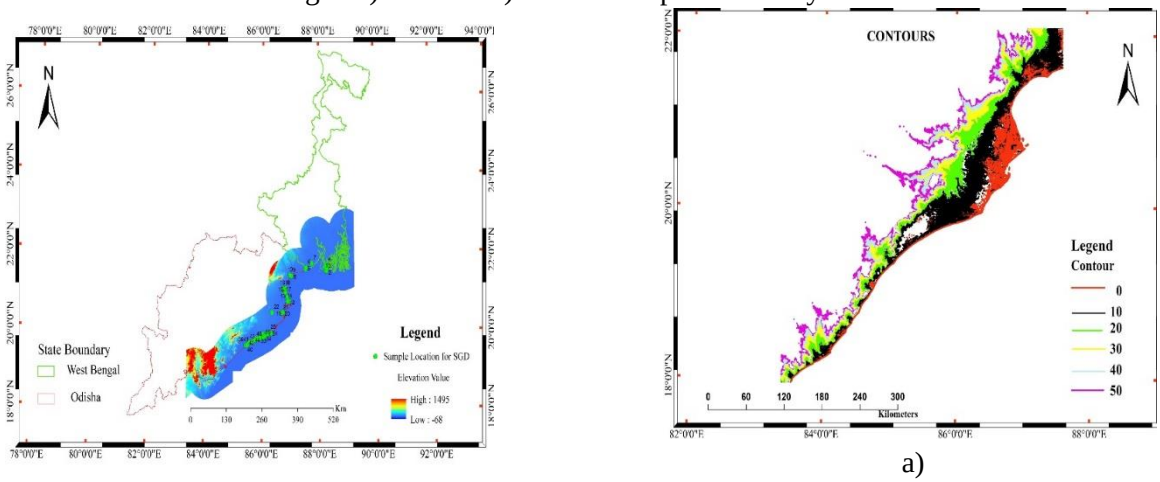


Fig. 2 SGD sampling location.



a) b)

Fig. 3 a) DEM & b) Contour map of the study area



a)

b)

Fig. 4 Landsat 8 thermal image for the month of a) May (WB) and b) Nov, 2018 (Odisha)

Fig. 5 Soil sediment water pore sampler developed for SGD sample collection

Future Plan: Work Plan & Activity Chart for the period 2019-20

- Collection of groundwater data from CGWB and State Govt. dept.
- Field surveys for primary data collection on hydrogeology and hydrochemistry of coastal aquifers.
- Procurement of rainfall and temperature data for SGD analysis

- Deployment of field staff for water sample collection at specified interval for isotopic and chemical analysis.
- Soil sediment water pore sampling from coastal aquifers.
- Thematic maps of the study area in GIS frame work.

PROJECT REFERENCE CODE: SP-42/2019-2021/HID

Title of the Project:	Unravelling Submarine Groundwater Discharge (SDG) zones along the Indian subcontinents and its islands
Project team:	Sudhir Kumar (PI), MS Rao (Co-PI), S.M. Pingale (Co-PI)
Collaborating RC's:	RC, Kakinada and RC, Belagavi
Type of Study:	Sponsored, NCESS, **(**Ministry of Earth Sciences, GoI)
Date of Start:	1st Jun, 2019
Date of Completion:	31st May, 2020
Budget:	Rs 46.44 Lakhs **(NIH Component)**

Statement of the problem

Many streams that feed into the Ganges river are converting from perennial to seasonal, thus limiting stream water flow in non-monsoon periods. This is due to the combined effect of climate change (by delaying and shortened monsoons) and anthropogenic factors (mismanagement of water resources). As a result, the groundwater levels in the Ganges basin are falling down sharply, and are affecting the rural communities who depend on groundwater for domestic and irrigation water supply. Village wells are running dry, and women are forced to go far distances to fetch water, leading to social and economic stress and loss of school time for girls, while fetching water.

Objectives:

The main research objective is to identify hot-spots for decentralized and distributed groundwater recharge networks. The sub-objectives supporting the main research objective are to:

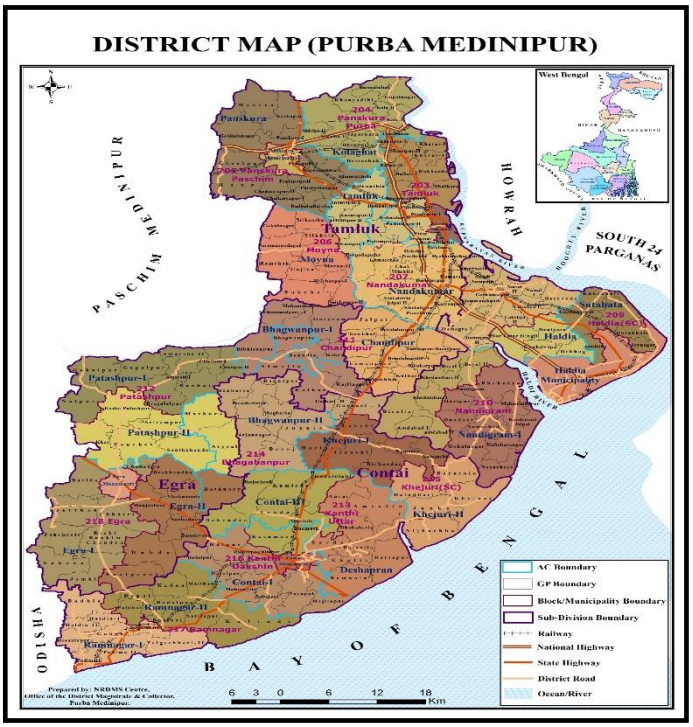
- Identify change in drinking water supply sources for rural, marginalized and women communities
- Identify socio-economic stress due to poor groundwater quality and quantity
- Identify loss of labor time and education time due to water fetching activities
- Identify health issues in consuming polluted water and long term impacts
- Identify limitations in groundwater recharge due to centralized water supply schemes
- Provide scientifically validated management plans for up-scaling distributed groundwater recharge networks.

Methodology

By constructing groundwater recharge structures in a decentralized/distributed approach, the villages can easily store the rainwater and allow it to recharge the groundwater levels. This will allow monsoon rainfall to be stored in the soil layers and delay runoff into the rivers, thus leading to sustained well water levels in dry periods and reduction in peak floods in the main channel. To install these groundwater recharge structures, vulnerability assessment maps and feasibility location maps are needed. The feasibility location maps will take into account physical factors (e.g. geology, hydrology, climate, and distance to wells), social (e.g. representation of and near to marginalized community wells) and economic factors (e.g. procuring land, mobilization of village communities). Village surveys will be conducted along with collection, cleaning and analysis of government groundwater data for producing social-economic inputs to the maps. High resolution – free satellite imagery will be used to identify key locations based on the physical factors.

Study area

Purba Medinipur District, with population of about 51 lakh is the 8th most populous district, of West Bengal and has geographical area of 4713 km^2. Population density of the district is 1081 persons per km^2. There are 25 sub districts in the district, among them Kolaghat is the most populous sub district with population of about 2.9 lakh and Haldia is the least populous sub district with population of about 98 thousand.



Considering the relevance and budget limitation, the study area is a part of the Haldia sub-division of the Purba Medinipur district, highlighting the problem of groundwater table decline at alarming rate. Central Ground Water Authority has notified the area and has imposed embargo on further exploitation of fresh water from the aquifer occurring within the depth of 120 – 300 m bgl.

Major Problems in the area are (i) Groundwater depletion, (ii) Water quality (salinity in the upper aquifers) , and (iii) Lack of proper implementation of existing legislative acts for guiding the groundwater extraction.

Deliverables:

- Field report containing qualitative and quantitative data
- Conceptual model based on data collected
- Groundwater vulnerability maps
- Potential Groundwater recharge zone map

ANNEXURE-I

HYDROLOGICAL INVESTIGATIONS DIVISION

WORK PROGRAMME FOR 2019-2020

SN.	Project Title	Study Team	Duration	Remarks
INTERNAL STUDIES:				
1	Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand	S M Pingale (PI), Sudhir Kumar S. D. Khobragade Soban Singh Rawat Rajeev Gupta	3 years (04/19-03/22)	New Study
2	Isotope fingerprinting of precipitation over Indian Region	Nidhi Kalyani (PI) Sudhir Kumar MS Rao Scientists from RC's	3 years (04/19-03/22)	New Study
SPONSORED PROJECTS:				
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	Suhas Khobragade (PI) Sudhir Kumar Rajesh Singh M. Arora R. J. Thayyen S.K. Verma	5 Years (04/16-03/21)	Continuing Study under NMSHE Project
2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar (PI) S.K. Verma	3 Years (06/16 -05/19) ***Proposed to be extended till Mar 2020***	Continuing Study Project with GBPIHE
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	MS Rao (PI) Sudhir Kumar C.K. Jain S.K. Verma	3 Years (06/16 -05/19)	Continuing Study IAEA under CRP
4.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) C.K. Jain M. Someshwar Rao S.K. Verma	3 ½ year (1/18 – 6/21)	Continuing Study PDS under NHP
5.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M. Someshwar (PI), Sudhir Kumar, S.K. Verma A. R. Senthil Kumar V. S. Jeyakanthan	3 ½year (1/18 – 6/21)	Continuing Study PDS under NHP
6.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Suhas Khobragade Sudhir Kumar	3 Years (1/18 – 12/20)	Continuing Study PDS under NHP

7.	Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study	Sudhir Kumar MS Rao SM Pingale BK Purandra YRS Rao	1 year (04/19 – 03/20)	MoES through NCESS
8.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	Sudhir kumar MS Rao SM Pingale	2 years (06/19 – 5/21)	IIT Bombay, Mumbai

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Rakesh Kumar	Scientist G & Head
2	Dr. A K Lohani	Scientist G
3	Dr. R P Pandey	Scientist G
4	Dr. S K Singh	Scientist F
5	Dr. Sanjay Kumar	Scientist E
6	Dr. Archana Sarkar	Scientist D
7	Dr. L N Thakural	Scientist C
8	Sri J P Patra	Scientist C
9	Dr. Ashwini A. Ranade	Scientist C
10	Sri Sunil Gurrapu	Scientist C
11	Sri N K Bhatnagar	Scientist B
12	Sri Waikhom Rahul Singh	Scientist B
13	Sri Om Prakash	SRA
14	Sri Jatin Malhotra	SRA
15	Sri T R Sapra	RA

Work Program for the Year 2019-20

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/16-21	Hydrological modeling in Alaknanda basin and assessment of climate change impact (NMSHE)	A.K.Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	5 years (April 2016 to March 2021)
2.NIH/SWHD/17-20	Water efficient Irrigation by using SCADA system for medium irrigation Project (MIP) Shahnehar (PDS-NHP)	R.P. Pandey J.P. Patra Rajesh Singh N.K. Bhatnagar	3 years (Dec 2017 to Dec 2020)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
3.NIH/SWHD/19-22	Development of drought monitoring system for early warning and preparedness for a selected region in India	R.P. Pandey D.S.Rathore Ravi Galkate Sunil Gurrapu Suman Gurjar	3-years (May 2019 to March 2022)
4.NIH/SWHD/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
5. NIH/SWHD/18-20	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2 years (Nov 2018 to October 2020)
6.NIH/SWHD/15-19	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	4 years (April 2015 to March 2019) Proposed to be extended up to March 2020
7.NIH/SWHD/17-20	Development of regional methods for design flood estimation in Uttarakhand	J.P. Patra Rakesh Kumar Pankaj Mani Sanjay Kumar	3 years (April 2017 to March 2020)
8.NIH/SWHD/18-21	Evaluation of seasonal extreme rain events across river India in 3D global temperature change	Ashwini Ranade Archana Sarkar	3 years (April 2018 to March 2021)
9.NIH/SWHD/18-21	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent	Sunil Gurrapu Ashwini Ranade J.P. Patra	3 years (Nov 2018 to March 2021)
10.NIH/SWHD/18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. thakural Reena Rathore	2 years (Oct 2018 to sept. 2020)

1. Hydrological modelling in Alaknanda basin and assessment of climate change impact

PROJECT REFERENCE CODE: NIH/SWHD/16-21

1. Project Title: **Hydrological modelling in Alaknanda basin and assessment of climate change impact**	**DST Sanction No:** **SP-06**
2. PI (Name & Address): Dr. A.K. Lohani, Scientist-G, Surface Water Hydrology Division, NIH Roorkee	
3. Co-PI (Name & Address): Dr Sanjay Kumar Jain, Scientist G, Head WRS Div. NIH Roorkee	
4. Approved Objectives of the Proposal • To model stream flow/snow melt runoff in Alaknanda Basin. • To investigate the impact of likely future changes in climate on stream flow in the study area using future climate scenarios. • To estimate seasonally varying Temperature Lapse Rate (TLR) using LST data estimated from thermal satellite image in Alaknanda basin.	
Date of Start: January, 2016	Total cost of Project: 42.296 (Rs. in Lakh)
Date of completion: December, 2020	

5. Brief Methodology/Work Plan etc :

Brief Methodology

The present sub-project proposes to focus on snowmelt runoff modelling in Alaknanda basin and study of impact of climate change. It is also envisaged to develop disseminate knowledge and results of the study in the concerned Central, State and other departments/agencies. The stepwise methodology to be adopted is as follows: a) Collection/procurement of available long-term hydro-meteorological and hydrological data for the study area from different Organizations (say, IMD, SASE, CWC, State Departments etc.). b) Procurement of satellite data of different dates for preparing snow cover area maps, collection of DEM data for preparation elevation area maps and drainage network. c) Development of seasonally varying Temperature Lapse Rate (TLR) using LST data estimated from thermal satellite image in Alaknanda basin. d) Processing and analysis of hydrological and hydro-meteorological data. Calibration and validation of snowmelt runoff model. e) Development of future climatic scenarios and investigation of the impact of likely future changes in climate on stream flow in the study area. f) Organization of workshops for the departments dealing with water resources planning and management.

Activity	1st year		2nd year		3rd year		4th year		5th year	
	I	II	I	II	I	II	I	II	I	II
Collection of hydrological and hydro-meteorological data from various agencies and entry in SWDES software	←							→		
Generation/import of spatial data layers for the study area and reference database from different sources		←			→					
Processing and analysis of data in SWDES and HYMOS software			←			→				

Evaluation of various components of hydrologic cycle in different spatial and temporal scales, trend and correlation analysis					←	—	—	—	→	
Analysis and design of observation network					←	—	—	—	→	
Development of project web site including linkage with web-based hydrological information system	←	—	—	—	—	—	—	—	—	→
Capacity building			←	—	—	—	—	→		

6. Salient Research Achievements (summary of progress):

Progress

- Various maps such as basin map, drainage map, landuse map, DEM (Fig. 2), snow cover area maps of the basin have been prepared.
- Grided rainfall data of the study basin have been collected and processed.
- Snowmelt runoff model is being setup for the study basin.
- Flow data is required for the calibration and validation of the model.
- Available G& D data in the basin has been identified and efforts are being made to collect these data.

Variable Infiltration Capacity Model: The distinguishable features of this model are

- Grid based macro-scale hydrological model (1 km)
- Sub-grid variability in land surface vegetation classes
- Sub-grid variability in the soil moisture storage capacity
- Drainage from the lower soil moisture zone (base flow) as a nonlinear recession
- Inclusion of topography that allows for orographic precipitation and temperature lapse rates resulting in more realistic hydrology in mountainous regions

WIN-SRM Model

- Both spatial and temporal Input data for WIN-SRM model has been prepared
- WIN-SRM Model is being applied for the Alaknanda Basin.
- Preliminary runs have been made
- Calibration and Validation of the model is in progress

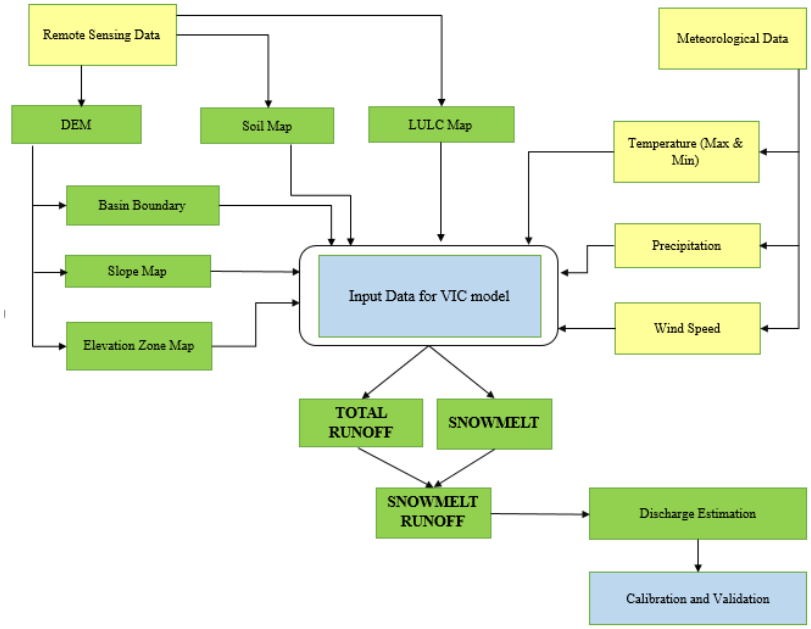
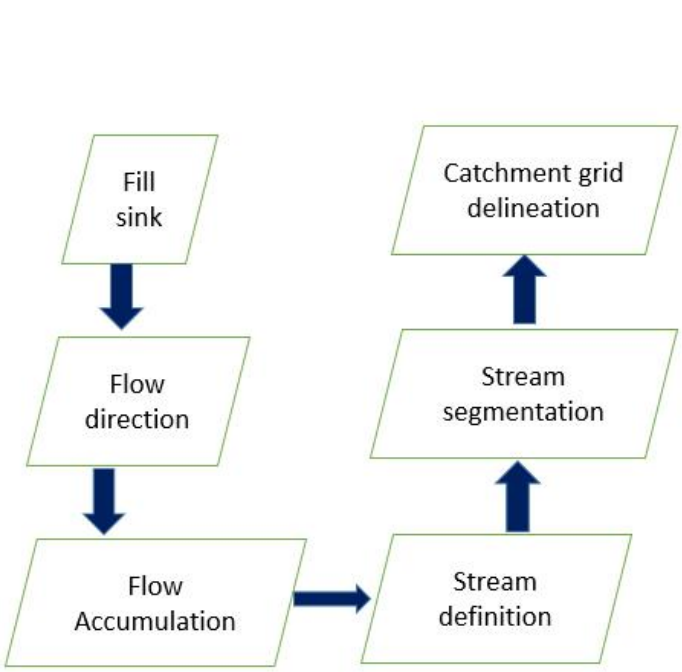
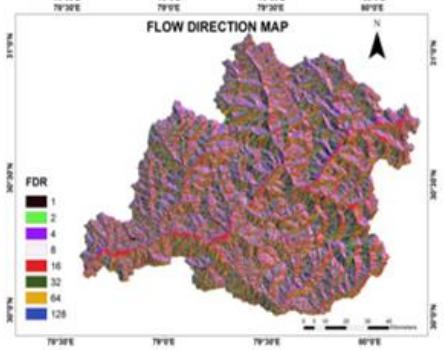


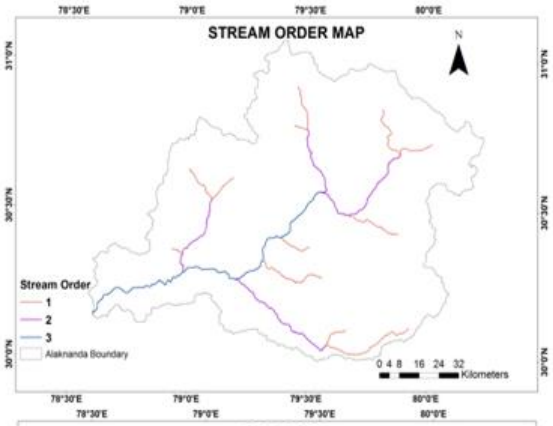
Figure 1: Process Flow chart of VIC Model

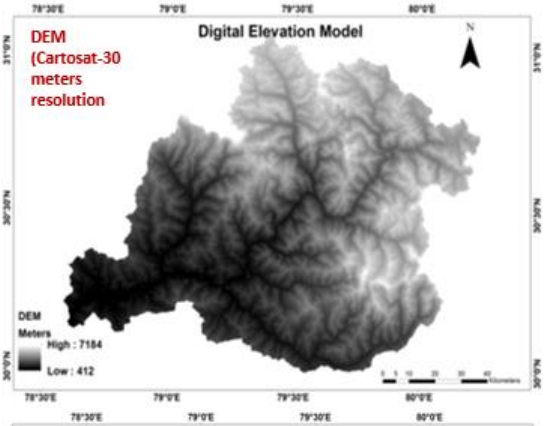
Hydro-processing

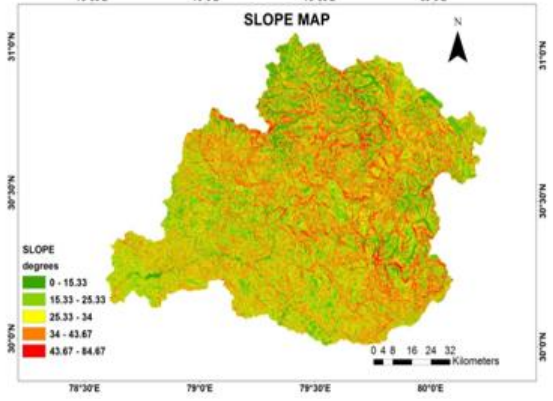


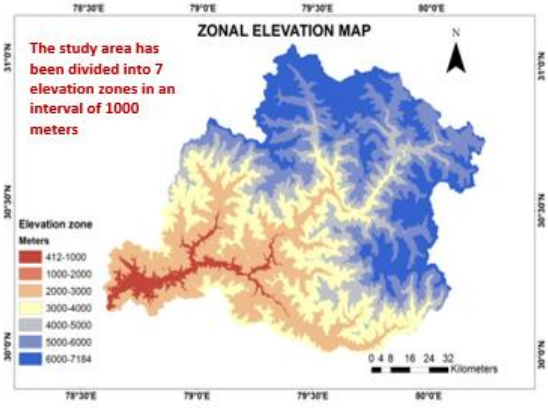


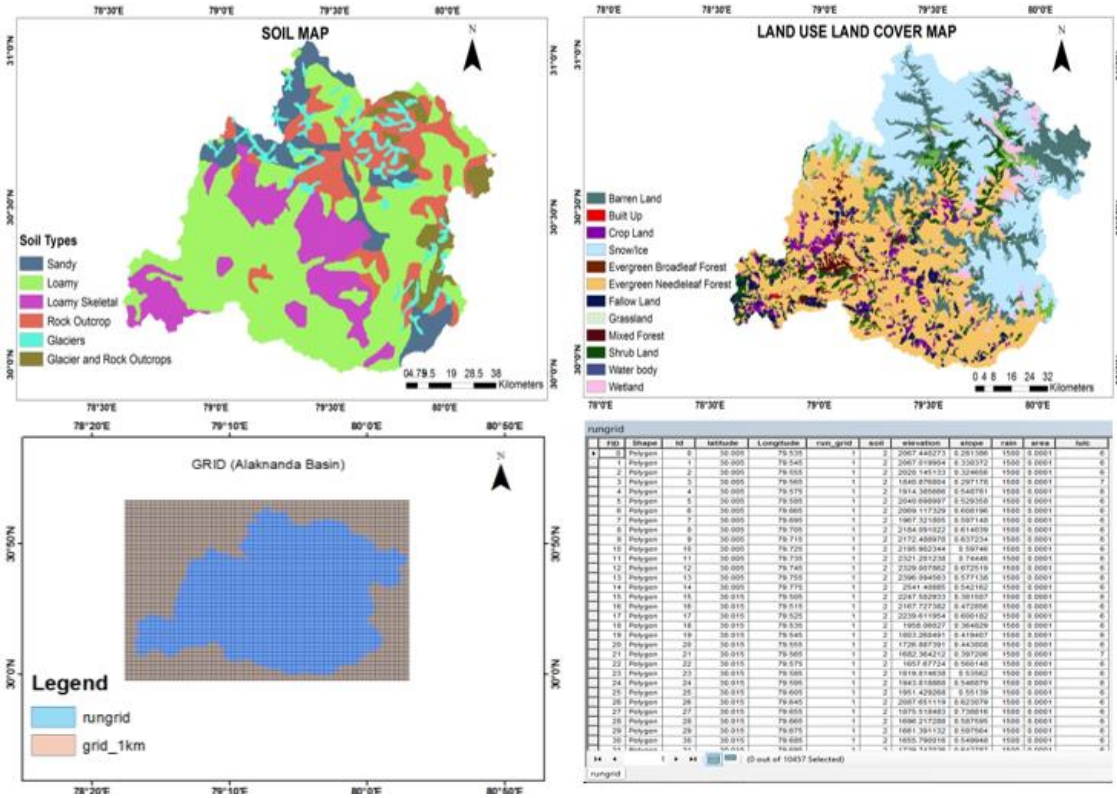
Flow Direction map











Temporal Data Preparation

- Maximum temperature
- Minimum temperature
- Daily rainfall
- Wind speed
- **Indian Meteorological department (IMD)** Gridded datasets has also been used for VIC simulation . The temperature datasets were available at a resolution of **1°x1°** and rainfall at a resolution of **0.25°x 0.25°**
- **ERA-Interim** datasets from ECMWF of **0.75 °** interpolated to **0.125 °** has been downloaded and processing is being done.

2. Water Efficient Irrigation by using SCADA system for medium Irrigation Project (MIP) Shahnehar

PROJECT REFERENCE CODE: NIH/SWHD/17-20

Title of the study : **WATER EFFICIENT IRRIGATION BY USING SCADA SYSTEM FOR MEDIUM IRRIGATION PROJECT (MIP) SHAHNEHAR**

Project team

Name of PI: **Dr. R.P. Pandey, Scientist G**.

Name of Co-PI: **Er. Jagdish Prasda Patra, Scientist C**
Dr. Rajesh Singh, Scientist C,
Sh N. K. Bhatnagar, Scientist B

Type of study: PDS

Collaborating Institutions

Department of Irrigation & Public Health Engg. (I&PHE), Hydrology C&M Division, Tutikandi, Shimla-4. Himachal Pradesh	**National Institute of Hydrology Roorkee -247667**

Total Project Cost: Rs.75.0 lakh (**Funded by NHP)**
NIH Cost Allocation Rs. 15.0 lakh

Project Duration: **3-years**

Date of start: **December, 2017**

Scheduled Date of Completion: **December, 2020**

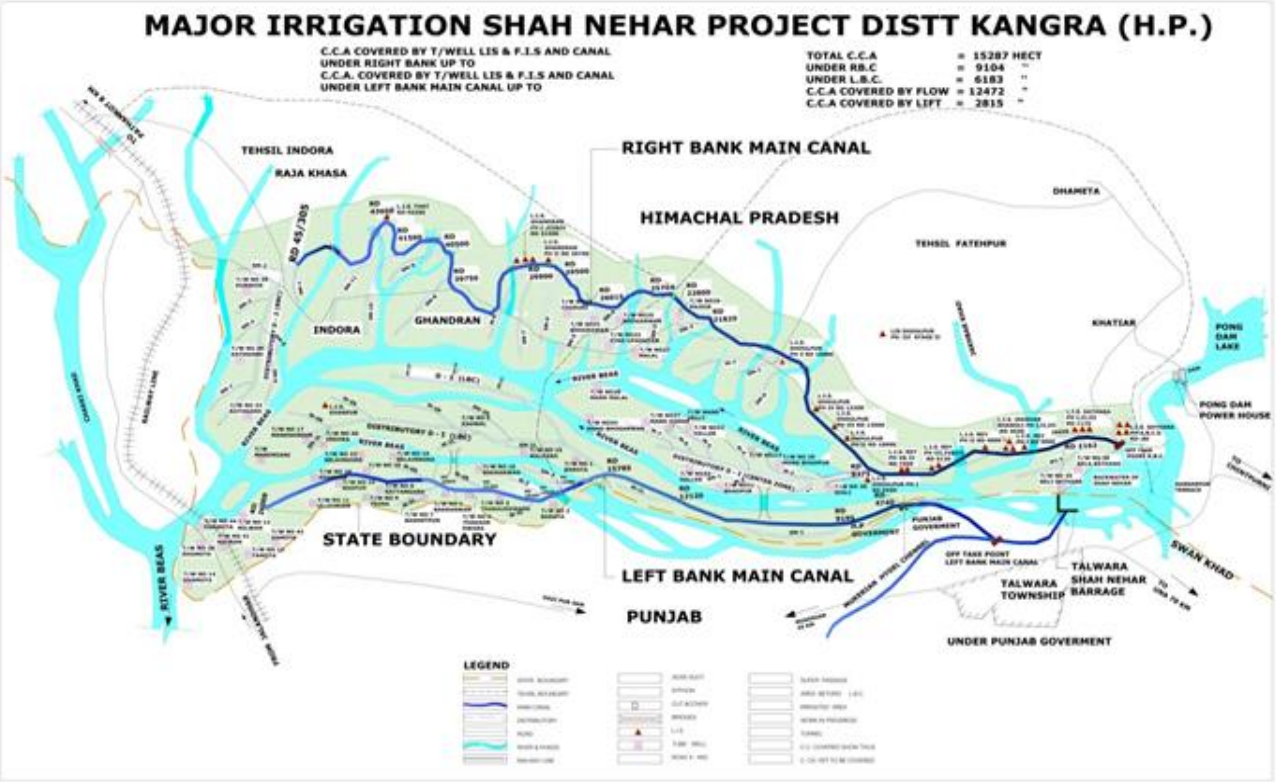
OBJECTIVES OF THE STUDY:

The primary objectives of this study is to **Devise a suitable approach to improve irrigation water use efficiency in Shah Nehar Project.** The specific objectives of the study are as follows:

- To develop monitoring, supervisory control and modernize system for Agriculture Irrigation water.
- Paradigm shift in the approach from a supply-based system to a demand-based sustainable system.
- Real time monitoring of water availability at head works.
- Performance evaluation of Left Bank Canal and Right Bank Canal of MIP Shah Nehar Project.
- Identify issues that need to be addressed to improve project performance
- Suggest measures to improve water use efficiency & sustainability up to farm level.
- Integrating Warabandi with SCADA system.

Study Area : <u>Shah Nehar Command Area, Himachal Pradesh</u>

Shah Nehar Irrigation Project in District Kangra, Himachal Pradesh is first Major Irrigation Project of the state amounting to Rs.143.32 crore was approved by the HP Govt to irrigate 15287 hectares of land of 93 villages situated on right and left bank of river Beas by constructing two numbers of main canals on each bank with a length of 45.30 and 25.69 km respectively. The water was fetched from outfall of Pong Dam by signing agreement between Govt. of HP and Punjab Govt. on 4/8/1983.The index map of Shah Nehar project command area is given in Figure below.



Whole of the Right bank canal enroots through the jurisdiction of Himachal Pradesh whereas about 4.0 Km of LBC out of 25.69 km falls in the state of Punjab. Out of total cost of Rs 143.32 crore the Govt. of Punjab was to share Rs 88.49 crore and remaining Rs 54.83 crore was to be borne by the Govt. of H.P. Later on due to price escalation revised DPR was prepared and approved to the tune Rs 387.17 crores at price level 2010 in 110th meeting of advisory committee of CWC. The project was included under Accelerated Irrigation Benefit Program (**AIBP**) with 90% Central Aid and balance 10% had to be shared by Govt. of Punjab and HP in the ratio of 61.74% and 38.26%.

Description of the Problem

At present the Shah Nehar project experiences improper distribution of water into the agricultural fields resulting into low yield of crops and therefore necessity of water efficient irrigation system by using SCADA. The primary objectives of the proposed study are to enhance water use efficiency, minimize water losses and to increase productivity in the command area of Shah Nehar project. The Shah Nehar project is first major Irrigation project in Himanchal Pradesh. Presently, water is being supplied to 93 villages comprise of 15287 hectares Culturable Command Area (CCA) through several outlets provided in the main canal. From each outlet the water is transported by gravity or lift scheme to each chak proposed in the command area development. The water demand of each outlet is based on the cropping pattern proposed in the respective chak. The roster of water demand is based on the warabandi schedule prepared by the Irrigation & Public Health Department in consultation with Krishi Vikas Sangh/Water User Associations.

It is proposed to quantify available water at the head-works of the canal system during cropping period, estimation of irrigation water requirement for existing cropping pattern, assessment of losses at the conveyance, distribution and application of water in the command area. The study will be helpful in identification of the potential area which requires appropriate land and water management intervention for improvement of water use efficiency. Further the study will be useful in quantifying the potential of improvement in irrigation water use efficiency in the Shah Nehar command area.

The HP IPH Department has listed the problems of irrigation water management in the Shah Neha Project based on input received from the farmers, observations made during their field visits and consultation with specialized agronomists as follows:

- ✓ Non availability of water during peak demand of crops at the tail end of command area.

- ✓ No check over theft of water from the main canals.
- ✓ Irrigation systems play vital role for sustainable agricultural development in Himachal Pradesh, but major problem of which is rather low efficiency of water use.
- ✓ No accountability due to absence of water accounting & audits.
- ✓ Poor and low consistency management of the irrigation systems efficiency.
- ✓ Lack of reliable monitoring network and supervisory control for irrigation systems.
- ✓ Non availability of effective decision making tool to improve irrigation management.
- ✓ Huge water loss due to random irrigation process.
- ✓ Lack of awareness about modern and water efficient irrigation methods.

Proposed Methodology

The purpose of the proposed study is to examine the present status of the Shah Nehar Irrigation Project water use efficiency, quantify the water losses in the main canal system & distributaries, water courses and field application. Determination of time based crop water demand and supply for existing cropping pattern and identification of irrigation system components needing water management interventions to improve water use efficiency of system and maximize the benefit from the Shah Nehar project. The work component will include the following:

1. Monitoring of supply and distribution of water in conveyance, distributary outlets and the on form irrigation application at selected experimental sites.
2. Assessment of the real time availability of water at head works, at various outlets in the main canal and tail ends of distribution system during the Rabi, Kharif and Zaid crop period.
3. Assessment of site specific water requirement for suitable time-steps during cropping periods in different seasons
4. Devising a methodology regarding equitable distribution of water to the farmers in each crop period from head to tail reaches by using SCADA.
5. Develop a system of water supply database of quantum of water used to each beneficiary so the charges can be levied accordingly.
6. Devising a possible system of change in cropping pattern owing to real time monitoring of available water at various reaches of the canal.
7. Identification and evaluation of intervention to minimize water losses throughout the canal and distribution system, water courses and in the field application to enhance the water use efficiency.

From the data collection and analysis of the data, Water efficient Irrigation by using SCADA System will be provided so that water can be used more efficiently and hence it will increase the effectiveness of the Irrigation Project.

Progress of Work

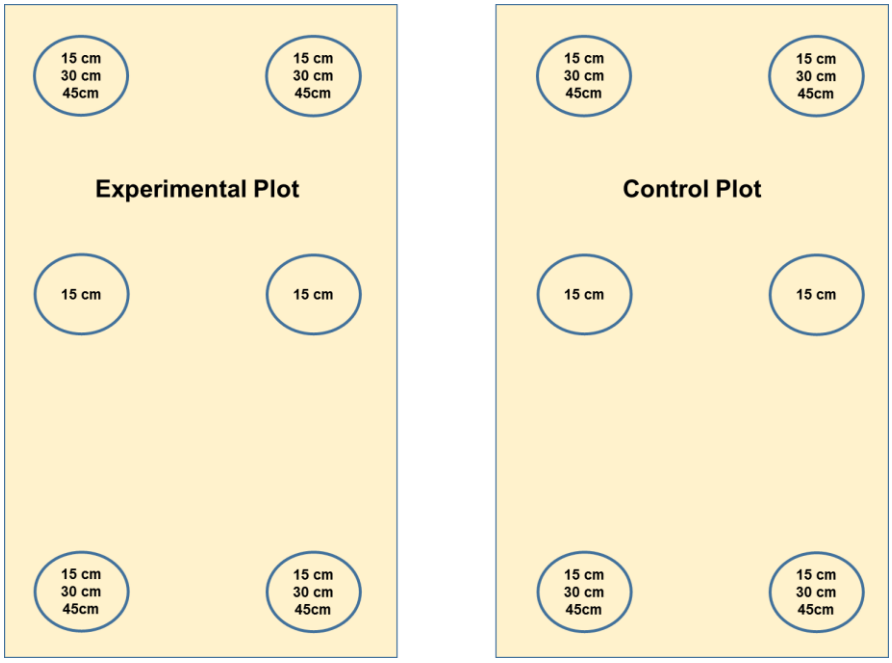
The team NIH Scientist visited study area and conducted detailed survey of Shahnehar Project Command Area, along with Himachal Pradesh I &PHE department officials. Detailed plan for the selected experiment sites was prepared after discussion with I&PHE officials. after field survey to finalize the project modalities and work plan for the study. The pilot sites for detailed experimentation have been identified. Field investigation and instrumentation for field experimentation for the study has been finalization after meeting with the project team of the lead organization (I&PHE, Shimla) to setup monitoring schedule.

The irrigation command site for SCADA implementation has been finalized.

1. The meteorological data for the assessment of present irrigation requirement has been collected from BBMB meteorological station at pong dam site.
2. The estimation of Pet and the crop water requirement for the study has been worked out.
3. The Himachal Pradesh I &PHE department has been further requested to obtain data from Kangra Agriculture College/other stations in the vicinity of the project site.
4. Base maps for the study sites have been prepared.
5. The experimental sited identified are as follows:
6. Lift Irrigation Scheme (LIS) Sthana, Terrac Sub-Division—for SCADA experimentation.

7. Selected sites/field plots in distributary-1 (D-1) command area –Badukhar Sub-Division -- for experimentation-1 in middle reaches.

8. Selected sites/field plots in distributary-2 (D-2) command area- for experimentation-2 in tail reaches.
9. Field investigations have been carried out and the layout of the experimental plots for installation of moisture sensors for measurement of crop root-zone moisture at the three sites have been prepared as follows.



S.N. (1)	Instrument/ Sensor (2)	At one Site (3)	For Three Site (4)=(3)*3
1	Moisture and temperature sensor		
	• at 15, 30, 45 cm depth	8	24
	• at 15 cm depth	4	12
2	Flow meter (Discharge measurement)	3	9
3	Data logger/transmitter	1*	3*

10. Department of I & PHE, Shimla, Govt. of Himachal has processed for procurement of discharge & Moisture measurement sensor and installation in the field. The procurement is under process at present.
11. Installation of sensors and telemetry system for soil moisture monitoring and data transmission. (Work in progress).
12. Estimation of Irrigation requirement for different crops in the Shahnehar Command areas using meteorological data has been carried out and it will be presented in the working group meeting for comments/suggestion, if any. The summary do the estimated crop water requirement is as follows.

    Crop Water Requirement (CWR), Potential Evapotranspiration (ETo) and Irrigation scheduling in the subtropical humid region are crucial in efficient use of irrigation supply, water resources assessment, hydrology and designing the irrigation projects as the supply of water through rainfall varies in space and time. In this context, dependable monthly rainfall at 80% and 50% probability level during the period 1982-2018 has been to assess distribution of effective rainfall and the minimum expected rainfall during the crop growing period in Shahnahar command area. FAO (Food and Agriculture Organisation) CROPWAT 8.0 crop simulation model has been used to

estimate refernce evapotranspiration (ETo), effective rainfall, crop water and irrigation requirement and irrigation scheduling for the Rice and Wheat crop. It is found that the average annual ETo is 4.11 mm/day and varies with highest value of 6.67 mm/day in the month of June and lowest value in January (1.99 mm/day). From the observation of probability analysis at P80 and P50, it is also found that the maximum deficit can be in the order of of 33.02 mm in month of July and minimum deficit of 1.32 mm rainfall in the month of November. For seasonal agricultural planning, the 80% dependable rainfall level may be considered for safer and better irrigation management planning in the study area.

Further Proposed Work Plan for next year

1. Application of field irrigation under measured and controlled conditions. (replication at three sites).
2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.
3. To evolve irrigation scheduling (revision) considering the crops, soil moisture and prevailing climatic conditions.
4. Demonstrations and conducting workshops on OFWM practices for all the stakeholders including farmers.
5. To review the role of existing Water Use Associations (WUA) and suggest suitable
6. To extend the improved/scientific modifications for encouraging the better OFWM practices and equitable water distribution among the farmers.
7. Review of the existing Cropping patterns during different sowing seasons and suggest suitable crops for each season to enable optimum utilization of available water.

Deliverable:

1. Estimates of water availability at headwork's and irrigation water requirements for various crops a different growth stages & time period.
2. Quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application methods.
3. Identification of components of irrigation system needing intervention to enhance water use efficiency.
4. Experimental assessment of SCADA based approach in the enhancement of water use efficiency.

3. Development of Drought Monitoring System for early warning and preparedness for a selected region in India

PROJECT REFERENCE CODE: NIH/SWHD/19-22

Title of the study: Development of Drought Monitoring System for early warning and preparedness for a selected region in India**.**

Project team

Name of PI: **Dr. R.P. Pandey, Scientist G**.
Name of Co-PI: **Er. D.S. Rathore, Scientist F**
Er. Ravi Galkate, Scientist E
Dr. Sunil Gurrapu, Scientist C
Ms. Suman Gurgar, Scientist C

Type of study: Internal project

Total Proposed Project Cost: Rs. 95.0 lakh

Project Duration: 3-years

Date of start: May 01, 2019

Scheduled Date of Completion: March , 2022

Objectives

The main purpose of the proposed project is to develop a scientific tool for regular drought monitoring, early warning and preparedness in drought affected region The specific objectives of the project are as follows:

1. To collect historical information, hydro-meteorological data, crop data, water supply provisions etc.
2. Identification of key hydro-meteorological indicators/indices for monitoring and assessment of drought and severe water scarcity condition.
3. Development of base showing physiographic information, i.e. DEM, soil map, crop map and land use map including demarcation of rainfed and irrigated areas in study region.
4. Preparation of inventory report of past drought events including period of occurrence, severity level and their qualitative/quantitative impacts on regional water availability, water supply, agriculture, migration etc.
5. Development of systematic database setup and computation programs for different drought indices/techniques.
6. Development of composite program and dashboard with menu driven generic system for various drought indicators/indices linked with common data base.
7. Customization of drought monitoring system for district/sub-district level assessment.
8. Evaluation and result verification with field observation.
9. Hosting of the drought monitoring system in NIH web site.

Description of the problem

Drought management including monitoring, early warning, preparedness and mitigations have emerged as priority areas to cope with risk to drought and enhance resilience. Drought as one of a few risks that could lead to high loss and damage in light of the growing number of poor people getting exposed to extreme droughts linked to climate change. Drought preparedness, regional efforts to reduce drought risk, and tools to boost the resilience of people and ecosystems to drought are particularly high on the agenda of many countries in the world.

Monitoring and collecting pertinent weather and climate data is vital to making timely and informed

decisions. The Ministry of Agriculture and Formers Welfare (MoAFW), Govt. of India.is nodal agency in India for drought monitoring and Management. The MoAFW has prepared a Manual for Drought Management (MoAFW 2016) incorporating multiple Indices /indicators based on meteorological, agricultural and hydrological variables as follows

Mandatory Indicators		**Impact Indicators**			
Rainfall Indices		**Agriculture**	**Remote Sensing**	**Soil Moisture**	**Hydrology**
Rainfall Deviation (RFdev) or SPI	**Dry Spell**	**Crop Area Sown**	**VCI or NDVI Deviations**	**PASM / MAI**	**SFI / RSI / SGW**
States may consider any three of the four types of the Impact Indicators (one from each) for assessment of drought.					

The assessment of drought condition using above techniques requires specialized skills. Therefore, development of a regular drought system will be very useful for timely identification of onset of drought, early warning and preparedness.

Proposed Study Area:

It is proposed to take up this study initially for one or two drought affected districts in the Bundelkhand region. Once the system is developed it can be extended to state/region and subsequently entire country may be covered.

Proposed Methodology

The brief methodology of the study will be as follows.

1. Liaising with related departments in the proposed study areas for acquisition of long term hydro-meteorological and other relevant records including climatic data, land use, surface and groundwater and irrigation data.
1. Assessment of existing surface and ground water resources in the study areas.
2. Preparation of GIS maps of drainage, land-use, cropping systems, DEM, water availability including demarcation of rainfed and irrigated areas.
3. Development of an inventory of drought events and their impact and identification of indigenous knowledge (ITKs) on drought mitigation in the study areas.
4. Analysis of meteorological and hydrological data and agricultural records for establishing regional drought indicators/indices, assessment of dry spells and studies of water scarcity regimes.
5. Evaluation of proposed indicators/indices with the past as well as the current information/records and verification of indices and drought assessment criteria.
6. Development of the drought monitoring system and hosting it in the Web-site.
7. Organization of training programs, workshop and demonstrations for capacity building of stakeholders.

Progress of Work

1. The hydro-meteorological data has been collected from different sources which includes, long term rainfall records for different districts in Bundelkhand region.
2. The reservoir storage data has been obtained from CWC.
3. The ground water level records have been obtained from some districts. For the other districts persuasion process is continue.
4. Base maps like DEM, soil map, land use map, and drainage map has been prepared for the study area has been prepared.
5. Preparation of district wise crop map is in progress.

Expected outcomes and benefits

The proposed study is envisaged to bring out an improved understanding of drought indicators and the applicability of various indices to monitor drought for early warning and preparedness. An integrated

tool consisting of multiple indices will be developed to identify drought conditions in near real time. It will ascertain methods for drought risk assessment and resource assessment for preparedness to cope with drought. The identification of drought hotspots and the classification of land suitability zones will be used to make recommendations with regard to crop types, adjustment of cropping patterns, cultural practices (i.e. adjusting sowing dates to coincide with emerging patterns) and social coping mechanisms and strategies.

Deliverables

The developed tool in the form of software will be hosted in the NIH web site for suitable dissemination of drought related information with selected accessibility to the stakeholders.

Note: Detailed Progress will be presented in the working group meeting.

4. Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)

PROJECT REFERENCE CODE: NIH/SWHD/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
Rakeh Kumar Sc-G, Co-PI
J. P Patra Sc 'C'
Pankaj Mani, Sc 'E'

3. Location Map:

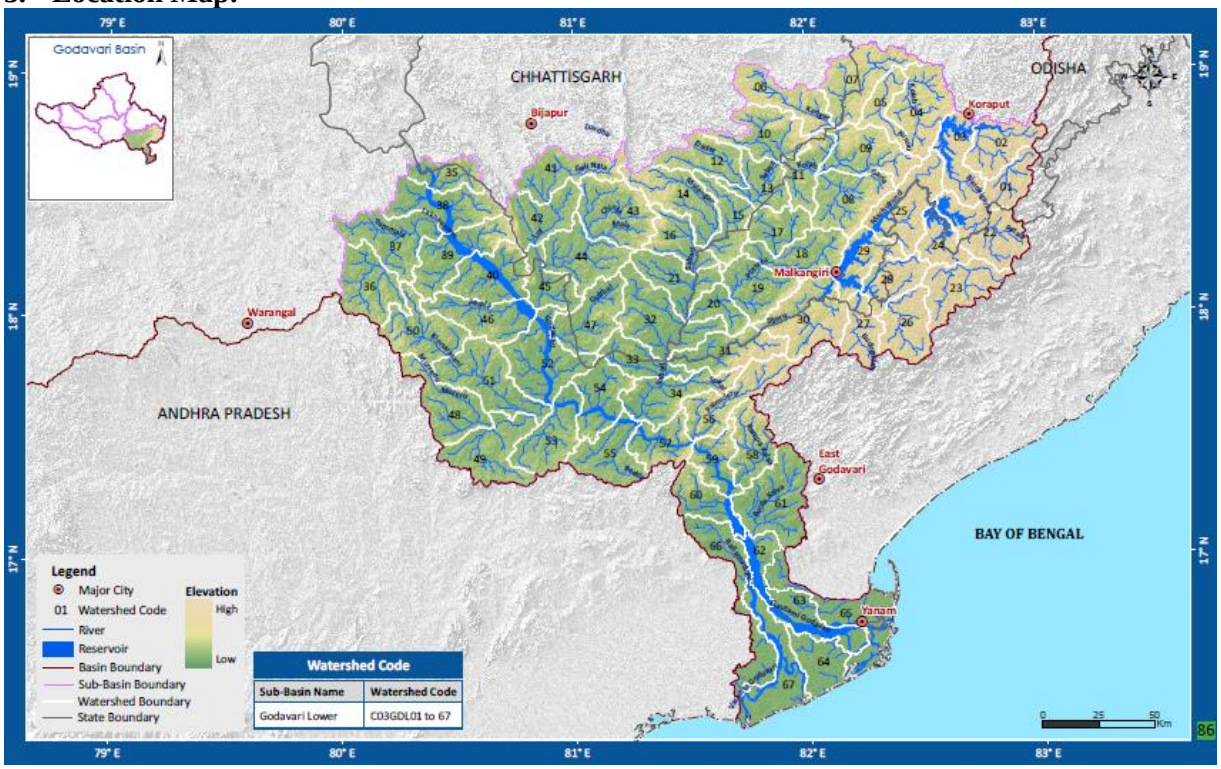


Fig 1: Location Map of the study Area

4. 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.
(v) Impact of climate change on flood estimates.

5. 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. The impact of climate change on flood estimates would also be evaluated.

6. 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. Downscaled climate change projections would also be used for evaluation of impact on flood estimates.

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 for estimation of floods of various return periods for un-gauged catchments.
- Regional relationships for Nash and Clark IUH model parameters.
- Impact of climate change on flood estimates.
- Research papers and Report

7 Progress

L moments for annual maximum series at different sites have been estimated for at-site frequency analysis. Parameters of different distributions have been estimated for these sites. Flow duration curves at various sites have been estimated and their regionalization is in progress. Trends in annual maximum series are being examined to investigate the impact of climate change. CWC is requested to provide hydro-metrological data available with them for the lower Godavari basin for objective 3 &4. NAM calibration and validation for some gauged basins and its application in un-gauged basin was also investigated. Secondary data from other sources such as Flood Estimation Reports, PMP atlases and similar studies, is also being collected.

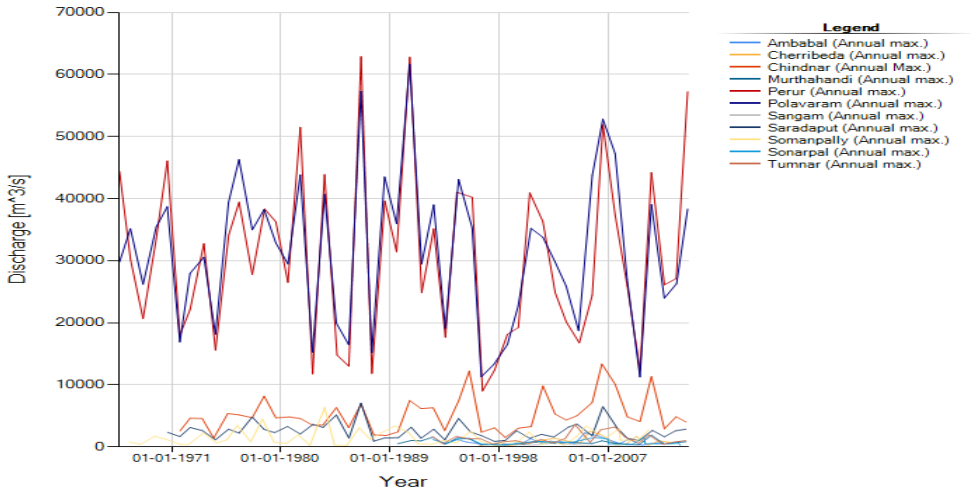


Fig 2: Observed Annual Maximum Flood Series

Table1: L moments of Annual Maximum Series at Various Gauging Sites

Site Name	L Moments			
	L_1	L_2	L_skewness	L_Kurtosis
Ambabal (Annual max.)	803.76	265.09	0.41	0.25
Cherribeda (Annual max.)	847.71	369.69	0.27	0.13
Chindnar (Annual Max.)	5,169.20	1,540.46	0.24	0.18
Murthahandi (Annual max.)	749.77	225.99	0.31	0.15
Perur (Annual max.)	30,675.35	7,939.15	0.1	0.07
Polavaram (Annual max.)	31,506.85	6,890.04	0.03	0.09
Sangam (Annual max.)	320.89	106.93	0.41	0.38
Saradaput (Annual max.)	2,550.70	736.86	0.25	0.18
Somanpally (Annual max.)	1,503.15	697.17	0.32	0.12
Sonarpal (Annual max.)	767.4	236.84	0.18	0.03
Tumnar (Annual max.)	1,318.56	471.3	0.32	0.17

Table2: Parameter of GEV distribution for various sites

Site Name	Parameter of GEV Distribution		
	Location	Scale	Shape
Ambabal (Annual max.)	536.06	246.71	-0.344
Cherribeda (Annual max.)	507.58	457.7	-0.145
Chindnar (Annual Max.)	3780.31	1982.05	-0.112
Murthahandi (Annual max.)	535.26	260.73	-0.201
Perur (Annual max.)	24683.54	12577.64	-0.112
Polavaram (Annual max.)	26916.11	11795.6	0.228
Sangam (Annual max.)	213.03	100.08	-0.34
Saradaput (Annual max.)	1885.09	944.88	-0.115
Somanpally (Annual max.)	835.04	784.17	-0.22
Sonarpal (Annual max.)	567.41	335.97	-0.018
Tumnar (Annual max.)	865.21	524.59	-0.227

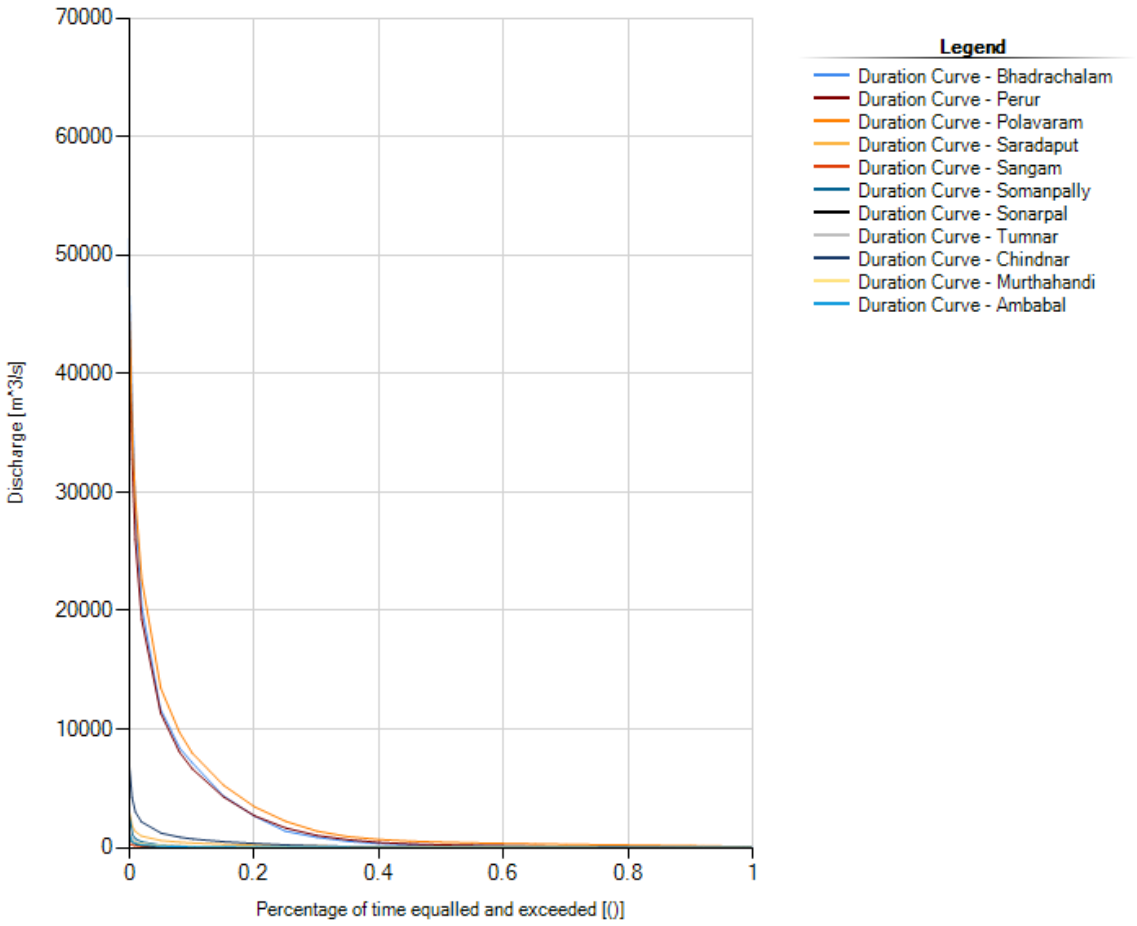


Fig: Flow duration curves at various sites

5. Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin

PROJECT REFERENCE CODE: NIH/SWHD/18-20

Title of the Study

Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin

Study Team

Dr. Archana Sarkar, Sc D, SWHD (PI)
Dr. Surjeet Singh, Sc E, GWHD (Co-PI)
Ms. Suman Gurjar, Sc C, GWHD
Mr. Sunil Gurrapu, Sc C, SWHD

Type of Study

Internal

Date of Start

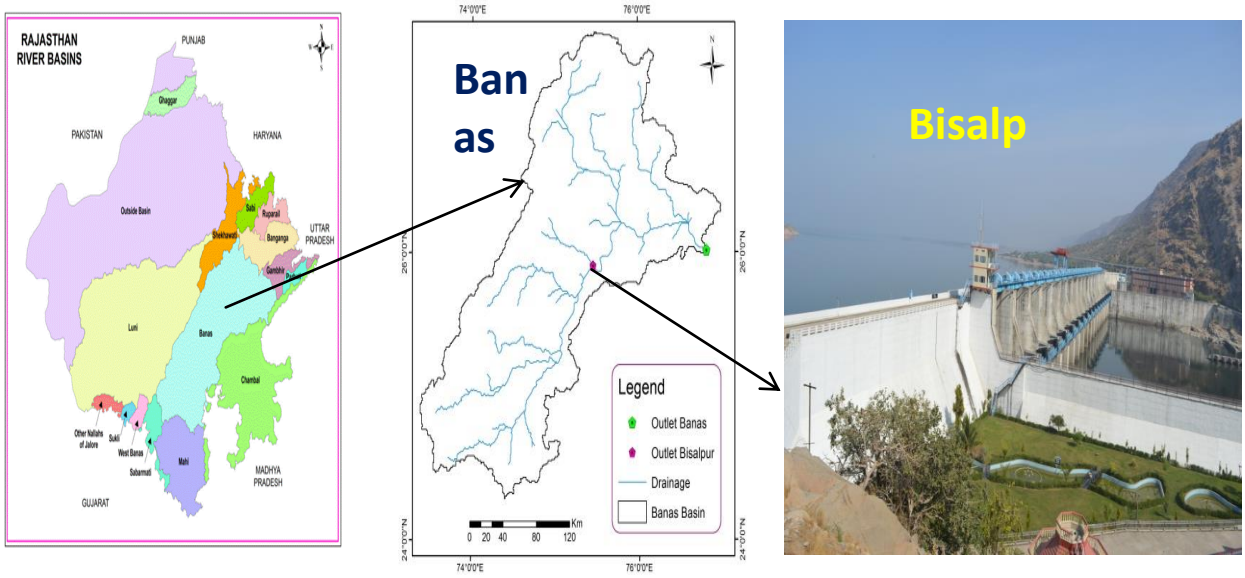
1 Nov. 2018

Scheduled date of completion

31 Oct. 2020

Study Area:

The study area is the Banas river basin up to the Bisalpur Dam and command area in Rajasthan.



River Banas is located in east-central part of Rajasthan State in India. It originates in the Khamnor hills of the Aravali range and flows in Rajasthan. Banas is a major tributary of the River Chambal, which is again a tributary of River Ganga. The total catchment area is about 51,779 km2 with a length of about 512 km. The Banas River passes through the 13districts namely, Sawai Madhopur, Jaipur, Ajmer, Tonk, Rajsamand, Banswara, Chittaurgarh, Udaipur, Bhilwara, Dausa, Sikar, Nagaur and Karauli. The Banas Basin may be classified as tropical grassy plains, semi-arid and hot, on the basis of Koppen's classification of climatic patterns. Orographically, the western part of the Basin is marked by hilly terrain belonging to the Aravali chain. East of the hills lies an alluvial plain with a gentle eastward slope. Ground elevations in the western hilly part range approximately 900 meters, while the alluvial plain elevations range approximately from 650 meters. The mean annual rainfall

over Banas Basin is around 585 mm of which about 95% falls during the four Monsoon months (June-September). The average temperature in the basin varies from 19°C to 33°C with the maximum going above 45°C during summers.

Study Objectives:

1. Analysis of the historical & future patterns of rainfall and temperature in Banas basin up to Bisalpur Dam and command area.
2. Rainfall-runoff modelling in the catchment of Bisalpur dam.
3. Estimation of inflow and water availability in Bisalpur reservoir.
4. Assessment of irrigation demands in the command area of Bisalpur dam.
5. Scenario analysis of future water availability under climate change and measures to address the gaps in supply-demand scenario.

Statement of the problem

The Banas River Basin is the largest river basin (45833 km^2) within the Rajasthan State of India. Banas is a seasonal river that dries up during the summer, but it is nonetheless used for irrigation. Bisalpur drinking water cum irrigation project is constructed across river Banas in 1991 with an ultimate irrigation potential of 55224 hectare (irrigation during the months of October to March for the Rabi crop), besides providing 458.36 million m^3 of drinking water for Jaipur, Ajmer, Beawar, Kishangarh, Nasirabad and other enroute cities, towns and villages. An estimated 150 million USD of extra agriculture was produced in 2014-2015. An increase in temperature in this region has been observed from historical data. This may lead to shortening of the crop growth period, increase in crop water requirement and reduction in crop yield. The water availability in this reservoir in coming years will play a crucial role in the overall economy of the entire region including other socio-economic issues.

Approved Action plan and timeline

S. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collection of information and Hydro-meteorological data from field, Preparation of base maps								
2	Trend analysis of historical data								
3	Downloading and bias correction of GCM data								
4	Input data preparation for Rainfall runoff model and CROPWAT								
5	**Preparation of Interim Report**								
6	Calibration and Validation of rainfall runoff model								
7	Assessment of crop water requirement for the present cropping pattern using CROPWAT								
8	Inflow forecasting for the Bisalpur Dam								
9	Climate change scenario analysis for future water availability								
10	Climate change scenario analysis for future crop water requirement								
11	Recommendations to address the gaps in future water availability-demand scenario								
12	Preparation & Submission of **Final report**								

Progress

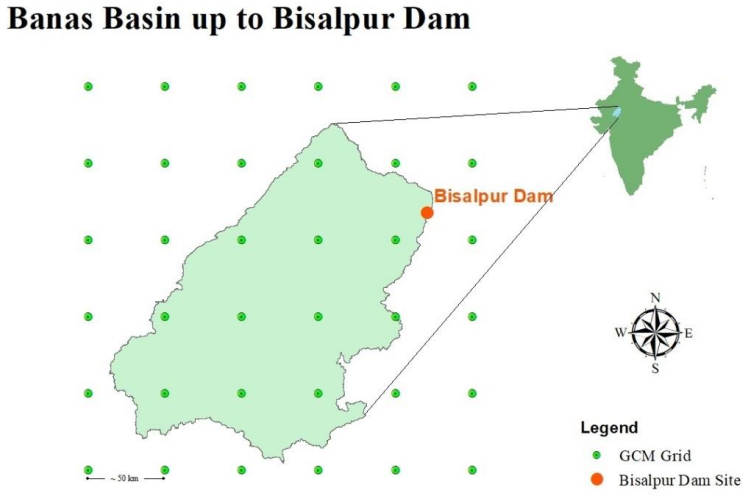
Objectives	Achievements
May 2019- Oct 2019	
Collection of information and Hydro-meteorological data from field, Preparation of base maps	Continued
Trend analysis of observed historical data	Continued
Downloading and bias correction of GCM data	In progress
Input data preparation for Rainfall runoff model and CROPWAT	Initiated

Analysis and Results

Data Used

Essential climate variables of 19 GCMs (Table below) at 0.5 degrees grid (Figure below) are being extracted from the Climate data store of COPERNICUS. These ECVs are available on a daily time interval for a period up to year 2100 for two climate change scenarios, i.e., RCP4.5 and RCP 8.5.

Institute	GCM Name	Scenario	Resolution: Grid Lat	Resolution: Grid Long
CSIRO-BOM	ACCESS1-0	historical, rcp4.5, rcp8.5	1.25	1.875
CSIRO-BOM	ACCESS1-3	historical, rcp4.5, rcp8.5	1.25	1.875
BNU	BNU-ESM	historical, rcp4.5, rcp8.5	2.7906	2.8125
IPSL	IPSL-CM5A-MR	historical, rcp4.5, rcp8.5	1.2676	2.5
IPSL	IPSL-CM5A-LR	historical, rcp4.5, rcp8.5	1.8947	3.75
IPSL	IPSL-CM5B-LR	historical, rcp4.5, rcp8.5	1.8947	3.75
MPI-M	MPI-ESM-MR	historical, rcp4.5, rcp8.5	1.8653	1.875
MPI-M	MPI-ESM-LR	historical, rcp4.5, rcp8.5	1.8653	1.875
MOHC	HadGEM2-ES	historical, rcp4.5, rcp8.5	1.25	1.875
MOHC	HadGEM2-CC	historical, rcp4.5, rcp8.5	1.25	1.875
NCC	NorESM1-M	historical, rcp4.5, rcp8.5	1.8947	2.5
NOAA-GFDL	GFDL-ESM2G	historical, rcp4.5, rcp8.5	2.0225	2.5
GFDL-ESM2M	GFDL-ESM2M	historical, rcp4.5, rcp8.5	2.0225	2.5
NOAA-GFDL	GFDL-CM3	historical, rcp4.5, rcp8.5	2	2.5
CNRM-CERFACS	CNRM-CM5	historical, rcp4.5, rcp8.5	1.4008	1.40625
INM	INM-CM4	historical, rcp4.5, rcp8.5	1.5	2
BCC	BCC-CSM1.1	historical, rcp4.5, rcp8.5	2.7906	2.8125
BCC	BCC-CSM1.1(m)	historical, rcp4.5, rcp8.5	2.7906	2.8125
ICHEC	EC-EARTH	historical, rcp4.5, rcp8.5	1.1215	1.1215



Results

Python scripts have been written for extraction of the data available in NetCDF to CSV format. The extracted data is being downscaled for the Banas catchment using the DBS method. Daily rainfall data of 28 raingauge stations for a period of 30 years similar to the historical data of GCM data has been processed and it will be used for downscaling of the precipitation data from various GCM. Similarly, daily gridded temperature data of IMD at $1^{o}X1^{o}$ of 30 years (1986-2015) for the Banas River basin has been processed for downscaling of Temperature data from GCM.

Hydrological data (river stage and discharge) has been collected from the WRD office in Jaipur during field visit. Crop related information has been collected from the KVK in Tonk district and the Agriculture department office in Jaipur. Information regarding the Bisalpur reservoir operation has also been collected from the Dam office in Deoli during the field visit.

Expected Adopters

Water Resources Department, Agriculture Department, Govt of Rajasthan.

The methods and results generated in the present study will help the Water Resources Department and Agriculture Department of Rajasthan State for the assessment of impacts of climate change in the basin and develop policies accordingly for the improved water resources management and best agricultural practices.

Deliverables

Research papers, report, stakeholder engagement

Data Procured and/Generated during the Study

Daily rainfall data of 28 raingauge stations in the Bisalpur River basin for a period of 30 years (1987-2016). Gridded temperature data at $1^{o}X1^{o}$ for the Banas basin from IMD (previously procured for other study), Essential climate variables (precipitation, temperature) at 0.5deg resolution from ECMWF

Future Plan

As per the approved action plan.

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

PROJECT REFERENCE CODE: NIH/SWHD/15-19

1. Title of the Project - Study of hydrological changes in selected watersheds in view of climate change in India.

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
	Mr. Tanvear Ahmad¸ Sc-B
	Dr. Sanjay Kumar Jain, Sc-G
	Dr. Sharad Kumar Jain, Sc-G

3. 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.

4. Present state-of-art

The climate of earth has never been stable for any extended period but varying naturally on all time scales. Climate change has greatly affected the characteristics of climatic variables globally. These changes are not uniform but vary from place to place or region to region. Probable climate change and its perilous impacts on the hydrologic system pose a threat to global fresh water resources and aquatic ecosystems worldwide.

The present study is envisaged in this context to take up the study on the assessment of hydrological changes in different watersheds in India under changing environment.

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. 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 four river basins namely Ramganga, Bina, Chaliyar and Dhadhar have been processed to meet out different objectives of the study. The various inputs for the hydrological model such as Digital Elevation Model (Dem), landuse/landcover, soil map etc. have been prepared.

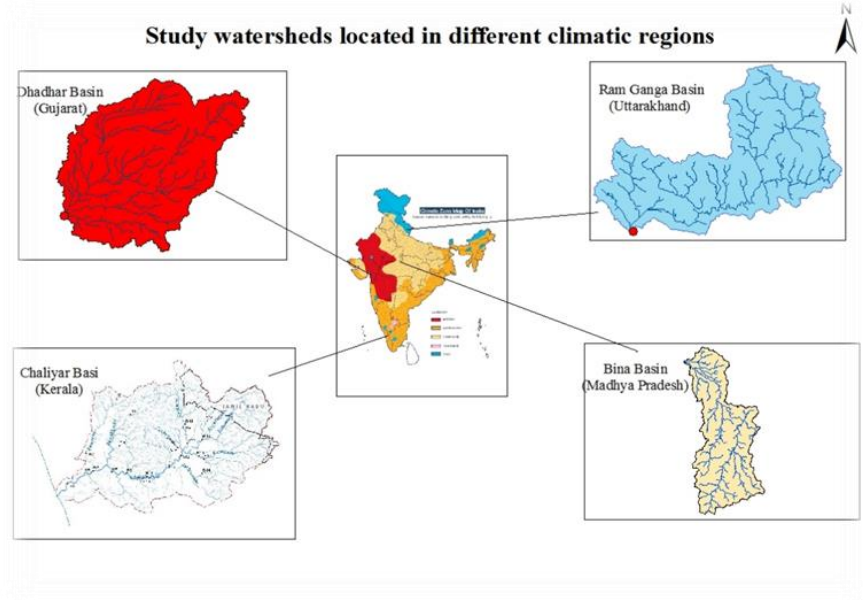


Figure 1: Study watersheds located in different climate regions of India

Digital elevation models (DEMs) are grid-based GIS coverages that represent elevation. Downloaded DEM was processed for removal of sinks, thereafter the filled DEM has been used to generate the flow direction, flow accumulation maps in the GIS environment for the delineation of drainage networks and watershed boundaries for the four watersheds. Moreover, land use/land cover, soil map etc. thematic maps esstential for the modeling have also been prepared for the study areas. Statistical methods for spatio-temporal temporal analysis of meteorological data using parametric and non-parametric approach have been applied to determine the trends in the rainfall time series. Moreover, spatial variation of ground water levels along with drought characterization for the river basins have been carried out. The hydrological models (NAM and SWAT) have been setup for the river basins. Input databse namely Landuse/landcover, DEM, Soil/Satellite data for the Dhadhar basin has been completed. The hydrological model have been calibrated and validated for the Dhadhar river basin. Grided data of rainfall and temperature of IMD of four watresheds have been prepared for downscaling using SDSM. Moreover, downloaded Canadian Earth System Model (CanESM2) scenarios for the study area. Statistical downscaling of meteorological data namely daily rainfall, minimum, maximum and average temperature for the Dhadhar, Bina and Rāmgangā basin using statistical downscaling model (SDSM). SDSM is based on multiple linear regression (MLR) technique. The model has been calibrated and validated based on rainfall and temperature of period 1961-1995 and 1996-2005 respectively with large-scale predictors of National centre for Environmental Prediction (NCEP) reanalysis data.

8. Progress since last working group

Statistical downscaling of meteorological data namely daily rainfall, minimum, maximum and average temperature for the Chaliyar basin using statistical downscaling model (SDSM). SDSM is based on multiple linear regression (MLR) technique. The model has been calibrated and validated based on rainfall and temperature of period 1961-1995 and 1996-2005 respectively with large-scale predictors of National centre for Environmental Prediction (NCEP) reanalysis data. The Bias correction of the rainfall and Temperature for future scenario for the Dhadhar and Chaliyar basin has been also done to assess the impact of changing climate on runoff using SWAT model.

7. Development of regional methods for design flood estimation in Uttarakhand.

PROJECT REFERENCE CODE: NIH/SWHD/17-20

1. Title of the study: Development of regional methods for design flood estimation in Uttarakhand.

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

3. Duration of study: 3 Years (April 2017 to March 2020) : Ongoing

4. Type of study: Internal.

5. Location map

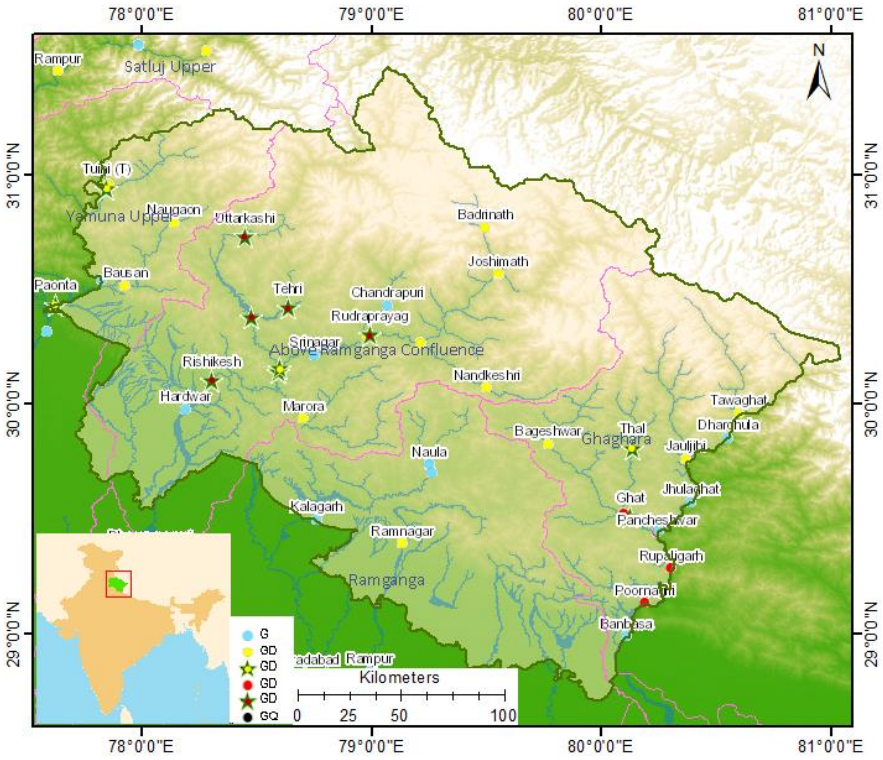


Fig. 1: Location map of study area.

6. Study 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, Clark IUH model parameters and GIUH-based flood estimation.
g) Estimation of floods of various return periods for Ganga basin in Uttarakhand.
h) Development of flood frequency relationships under climate change scenarios.

7. Statement of the problem

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. Flood estimation reports for various sub zones have been prepared with joint efforts of Central Water Commission (CWC), India Meteorological Department (IMD) and Research Design and Standards Organisation (RDSO) of Ministry of Railways and Ministry of Surface Transport (MOST) for estimating design floods of 25, 50 and 100 year return periods for design of waterways, bridge, culverts etc having small and medium catchments where hydrological data are inadequate or totally absent. Recently, PMP atlas for various basins of India has been developed by CWC and IMD for assessment of design storm as required in the assessment of design flood for any water resources development project. The point rainfall at various raingauge stations are analysed and rainfall of various return periods have been estimated by fitting a two parameter Gumbel frequency distribution. Various new techniques of flood frequency analysis are being developed by various researchers for selecting candidate frequency distribution, parameter estimation etc. (L-Moments, PWM etc.). 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

8. Approved action plan and timeline

S.N.	Work Element	1st Year	2nd Year	3rd Year	Status
1	Collection of hydro meteorological data, satellite images, thematic maps etc.				Under Progress
2	Compilation, statistical analysis of rainfall and river discharge				Under Progress
3	At-site frequency analysis for point rainfall and gridded rainfall data				Under Progress
4	Regional frequency analysis for point rainfall and gridded rainfall data				Under Progress
5	Preparation of isopluvials maps for various return periods.				Under Progress
6	At-site and regional flood frequency analysis for gauged catchments				Under Progress
7	Estimation of catchment characteristics and parameters of UH				Under Progress
8	Development of regional relationships for peak floods with catchment characteristics.				Under Progress
9	Rainfall frequency relationships under climate change scenarios				Yet to start
10	Report				

9. Role of team members

S. N.	Role / Action	Member/(s)
1	Collection of hydro meteorological data, satellite images, thematic maps etc.	JPP, RK, SK, TRS
2	Compilation, statistical analysis of rainfall and river discharge	JPP, SK , TRS
3	At-site frequency analysis for point rainfall and gridded rainfall data	JPP, RK
4	Regional frequency analysis for point rainfall and gridded rainfall data	RK, JPP, SK

5	Preparation of isopluvials maps for various return periods.	JPP, RK ,PM
6	At-site and regional flood frequency analysis for gauged catchments	RK, JPP,SK
7	Estimation of catchment characteristics and parameters of UH	PM, JPP, SK
8	Development of regional relationships for peak floods with catchment characteristics.	RK ,JPP,SK
9	Rainfall frequency relationships under climate change scenarios	RK ,JPP,SK
10	Report	JPP, RK, PM, SK

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

10. Brief Methodology

This study aims at development of at-site and regional flood frequency relationships using L-moments approach for Uttarakhand state (Figure 1), perticularlly in Ganga basin up to Rishikesh. 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.

This study will also investigate the consequences of using a stationary assumption as well as the alternative: a non-stationary framework that considers temporal changes in statistics of extremes base on characteristic of time series. The estimates for various return periods using non-stationary i.e. General Extreme Value distribution with time-dependent parameters will be analysed. In addition, it is planned to analyse an ensemble of reference periods (past and future events) for rainfall frequency analysis. The future periods would be obtained various downscaled models. The NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset comprised of downscaled climate scenarios derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5) and across RCP 4.5 and RCP 8.5 from the 21 models. The spatial resolution of the dataset is 0.25 degrees (~25 km x 25 km) and the periods from 1950 through 2005 (Retrospective Run) and from 2006 to 2099 (Prospective Run). The World Climate Research Programme (WCRP) Coordinated Regional Climate Downscaling Experiment (CORDEX) dataset for South Asia region are derived from the Atmosphere-Ocean coupled General Circulation Model (AOGCM) runs conducted under the CMIP5 for RCP 4.5 and RCP 8.5. The

CORDEX South Asia dataset includes dynamically downscaled projections from the 10 models for about 50 km regional climate change projections.

11. Results achieved with progress/present status

The peak annual maximum flood series data of ten gauging sites are collected from CWC (Figure 2). The box plot of annual peak flood at ten gauging sites is shown in Figure 3. At site flood frequency analysis is carried to estimated design floods of various return periods at these locations using L-moments approach. The estimated floods of 50 year and 100 year return period along with observed maximum discharge plotted against catchment area for three locations is shown in Figure 4. Further, power equation in the form of $Q_T = a_T \times A^{b_T}$ is also fitted to estimate T-year design flood (Q_T) with catchment area of known A. Daily station rainfall data of 33 raingauge stations are collected from IMD along with gridded rainfall data from 1901 to 2013. The location of raingauge stations and box plot of 1day annual maximum rainfall is shown in Figure 5. These datasets are being analysed for various statistical properties and annual maximum rainfall series are extracted for rainfall frequency analysis. The APHRODITE monsoon Asia Precipitation grided daily data from 1951 to 2007 are also downloaded. Both at site and regional rainfall frequency analysis is in progress using a stationary assumption.

The annual maximum discharge series are also being analysed for both Stationary and Nonstationary Extreme Value Analysis. The sample results at Rudraprayag gauging site in of Alaknanda River is shown in Figure 6. It is observed that there is a significant increasing trend in the annual maximum discharge (with or without consideration of 2013 event). Various combinations of time dependant EV1 and GEV parameters (location and scale) are estimated using Maximum Likelihood Method. The EV1 distribution with linear time dependant location parameter is select to be best model based on lower Akaike Information Criterion (AIC). The design flood corresponding to year 2050 and 2100 are estimated based using the fitted non-stationary EV1 distribution. The design flood for 25, 50, 75 and 100 year return period flood estimated using stationary assumption would become about 7, 13, 20 and 26 year return period in the year 2050 considering non-stationary. Further, in year 2100 the corresponding return periods are estimated to be 2, 3, 5 and 7 year respectively. However, it is to be noted that the 100 year return period flood estimated using L-moments approach (GLO as robust distribution) is 6030.4 m^3/s in comparison to 5937.7 m^3/s estimated in year 2100 using non-stationary EV1 distribution. The results shows that along with non-stationarity various other aspects like selection of parameter estimation method, goodness of fit criteria, uncertainty of parameter estimations, covariates etc. should be studied while estimating design flood in respect to design life of the structure.

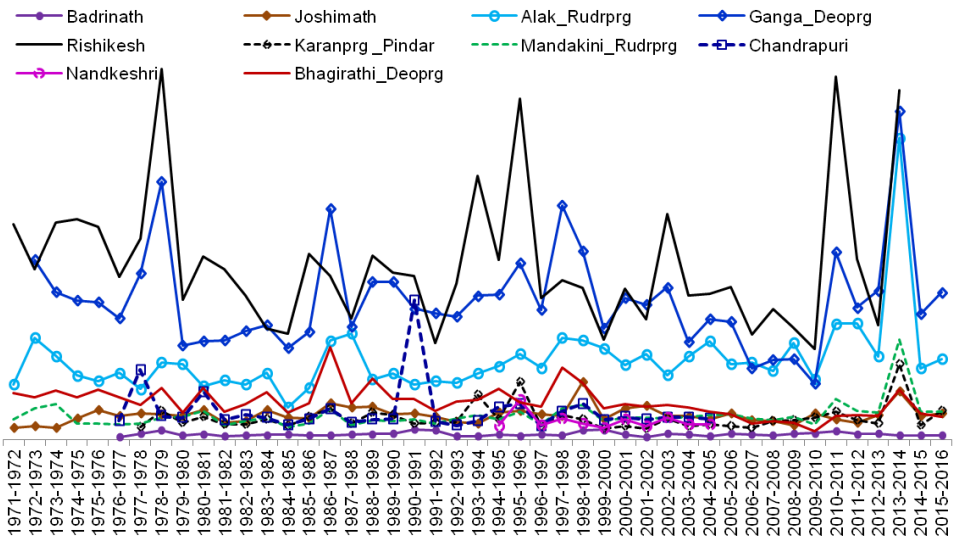


Fig. 2: Observed annual maximum flood series.

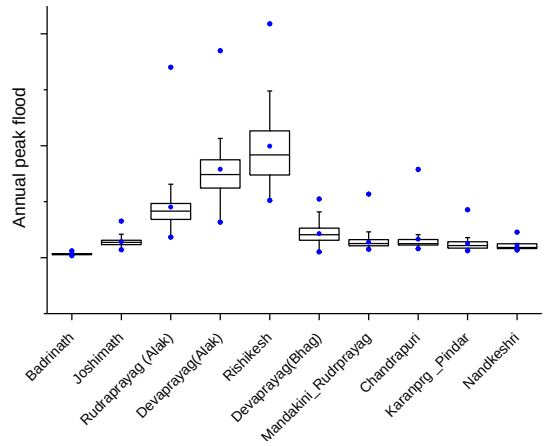


Fig. 3: Box plot of annual peak flood

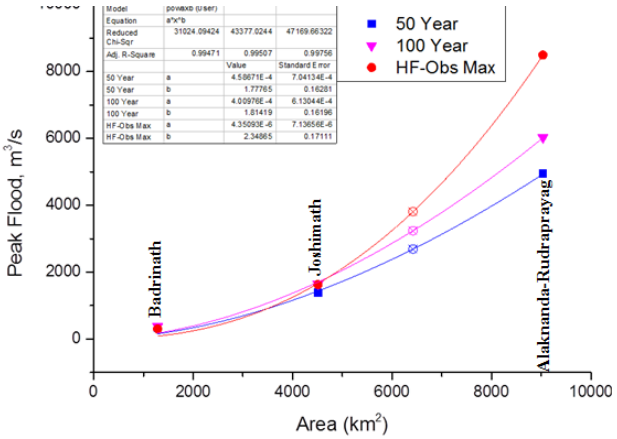
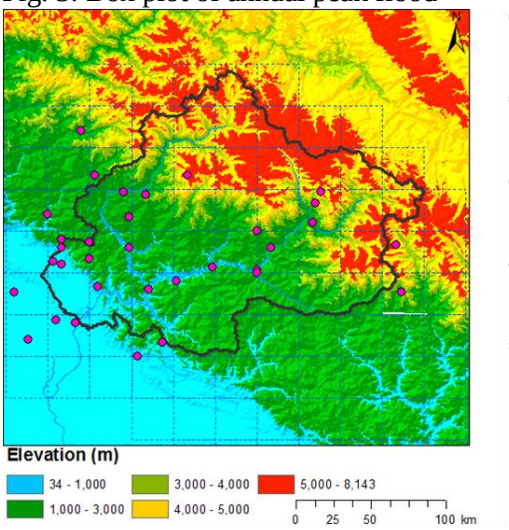


Fig. 4: Floods of various return periods



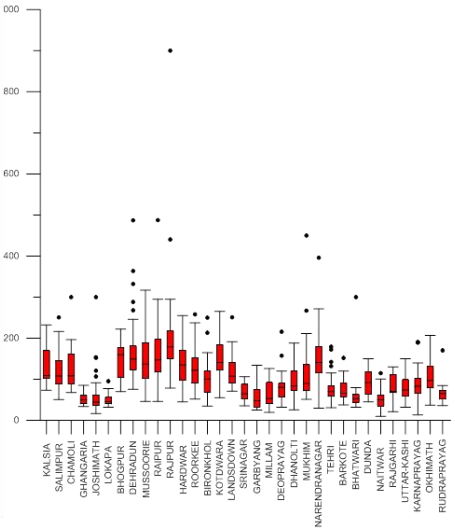


Fig. 5: Location of raingauge stations and 1 day annual maximum rainfall

Sites	MK: Z	Signific.	Sen Slope	MK: Z	Signific.	Sen Slope
Badrinath	0.84		0.472	1.73	+	0.928
Joshimath	0.58		1.210	0.02		0.060
Alak_Rudrprg	3.00	**	18.577	2.77	**	19.102
Mandakini_Rudrprg	2.57	*	6.106	1.89	+	4.672
Bhagirathi_Deoprg	-4.10	***	-15.597	-4.14	***	-17.298
Ganga_Deoprg	-0.33		-6.556	-0.93		-16.036
Karanprg _Pindar	0.17		0.703	-0.42		-1.341
Nandkeshri	-0.16		-0.650			
Chandrapuri	-0.32		-1.376			
Rishikesh	-2.28	*	-44.270	-2.77	**	-49.529

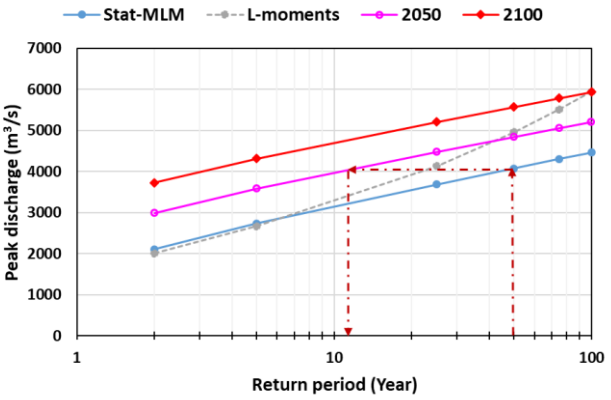


Fig. 6: Nonstationary Extreme Value Analysis using at Rudraprayag

12. Action taken on comments of previous working group meeting

There were no specific comments.

13. List of deliverables

- Design floods of various return periods at river gauging locations.
- Isopluvial maps of various return periods (Viz. 10 year, 25 year, 50 year, 100 year etc.) 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.

14. Data collected/generated

- ♦ DEM of the study area is 90 m SRTM and 30 m CartoSat.
- ♦ Peak annual maximum flood series for ten gauging sites.
- ♦ 0.25 x 0.25 deg grided daily rainfall data from 1901 to 2013 from IMD
- ♦ 0.5° and 0.25° grided, daily data from 1951 to 2007 from APHRODITE monsoon Asia Precipitation data.
- ♦ Daily rainfall data of 33 raingauge stations.

15. Involvement of end users/beneficiaries

The study has been proposed with after discussion with Irrigation department of Uttarakhand. It is expected that outcome of study will be helpful for estimation of design floods for various water resources projects.

8. Evaluation of seasonal extreme rain events across river India in 3D global temperature change

PROJECT REFERENCE CODE: NIH/SWHD/18-21

Title of the Project: **'Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario'**

Project team: Dr. Ashwini Ranade, Scientist 'C'(PI)
Dr. Archana Sarkar. Scientist 'D'(Co-PI)

Type of Study: Internal

Status: ongoing

Duration: 3 years

Date of Start: 1 April 2018

Scheduled date of completion: 31st March 2021

Objectives

Sr. No.	Objectives	Status
1.	Updation of longest instrumental area-averaged monthly rainfall series (1813-2000) of 11 major and 9 independent minor river basins of India and to document climatological and Fluctuation features of annual, seasonal and monthly rainfall	Completed
2.	Identification of different types of seasonal extreme rain events concerning rainfall amount, rainfall intensity and duration over seven homogenous rainfall zones of India during 1951-2015.	Ongoing
3.	Evaluation of 3D global atmospheric parameter changes conducive to the occurrence of large-scale extreme rain events over seven homogeneous rainfall zones during different seasons.	Ongoing
4.	Time series modeling of the longest instrumental monthly rainfall series (1813-2015) of major and independent minor river basins for their extrapolation for 2 to 10 years	Ongoing

Statement of the problem

Heterogeneous changes in global tropospheric temperatures over the last few decades have been observed to make changes in the spatiotemporal distribution of rainfall across the globe. Annual, seasonal, and monthly rainfall across India shows strong spatiotemporal variation and large departures from normal. Many of the studies show an overall decreasing trend in monsoonal rainfall over a major part of the country. However, in our earlier studies, we did not find any significant long term trends in wet season parameters of 11 major and 36 minor basins but noticed a declining tendency in wet season rainfall in some major basins of Central India. In a monsoon season, extreme events occur surprisingly even during large-scale drought years also. So there is pressing need in hydrology, to better understand the ongoing changes in hydro-meteorological extremes in order to comprehend the impact of climate change on water resources in different parts of the country. Recent understanding through global climate models predicts that the hydrological cycle will accelerate as climate warms, and leads to changes in patterns of extreme floods and droughts. We have seen that the small-scale, short-duration EREs are embedded in large-scale, long-period intense wet spells, and rainwater generated during the main monsoon wet period is highly correlated with the Asia-Pacific monsoon intensity. Abrupt warming and cooling in the atmosphere drastically modulate the monsoon circulation and intensify the associated weather systems causing heavier rains over a region. Types of weather systems and general and monsoonal circulation associated with the occurrence of extreme rain events in different parts of the country could be different. Keeping in mind recent changes in global surface temperature, monsoon

circulation pattern, and occurrence of EREs, the objectives of the present study are to understand the nature of short-term to long-term rainfall variability across river basins of India using the area-averaged longest instrumental basin-scale rainfall dataset (1813-2015); to determine the causal factors of the dominant modes of its variability; identify the seasonal extreme rain events across the country and to understand the dynamism and causes for the occurrences of extremes in different parts of the country.

Dataset used and Study area:

For the present report classification of the country's river systems into major and minor basins by K. L. Rao (1975) is adopted. 11 Major basins and 9 independent minor river basins are selected for the updating of monthly rainfall series up to 2015. The longest instrumental area-averaged monthly rainfall series for 11 major river basins and 36 minor river basins earliest from 1813-2000 is used and updated up to 2015 using 1 degree gridded daily rainfall data from India Meteorological Department from 1951-2015. Atmospheric variables (Temperature, Geopotential height, mean sea level pressure, precipitable water, etc.) from 'Climate System Forecasting (CFSR) reanalysis dataset.

Analysis and results:

In this work, an attempt has been made to understand the meteorological changes associated with the most extreme wet and dry monsoon months (June to September) in the recent 37 years (1979-2015) over India. Longest instrumental area-averaged monthly rainfall series of All India available from 1813-2000 constructed using 316 well-spread rain gauge stations has been updated by using 1-deg gridded daily rainfall data up to 2015. Composite anomalies in the temperature, geopotential height at 12 isobaric levels and mean sea level pressure across the globe during most extreme four wet and dry years for India have been constructed. Further the anomalies are averaged for 11 subzones and 54 geo-domains across the globe in order to comprehend the result.

- ***Identification of most extreme wet and dry months***

The years with greatest and least rainfall for each month during the 1979-2015 monsoon period (June to September) have been identified. Composites of percentage departure from normal in monthly rainfall for four extreme wet and dry months have been prepared. It has been seen that the most extreme June rainfall occurred during the years 2001, 2008, 2011 and 2013 when monthly rainfall was 38.8% above normal. While extreme July and Aug rainfall was 19.9% above normal and occurred during 1981, 1988, 1994, 2013 and 1988, 1993, 1994, 2011 respectively. The most extreme September rainfall was 36.3% above normal during 1983,1998,2007,2010. The most extreme dry years in monthly rainfall with their percentage departure are as below: June: 1987, 2009, 2012 & 2014 (-41.1%); July: 1982, 1987, 2002, 2004 (-30.8%); Aug: 1993, 2005, 2009, 2015 (-25.7%); September: 1982, 1986, 2001, 2015 (-33.2%).

- ***Division of globe in 11 subzones and 54 geo-domains:***

Departure from normal in atmospheric parameters have been averaged for 11 geographical subzones viz. northern and southern hemisphere (NH & SH), north and south Pole (NP & SP), north and south midlatitude (NMLAT & SMLAT), north and south subtropics (NSBT & SSBT), north and south tropics (NTP & STP), Tibet (TBT). In order to comprehend the results, each subzone is further divided into 6 parts named as geo-domains. Thus the whole globe has been divided into 54 geo-domains based upon the locations of highs and lows, development of weather systems, rainfall pattern and topography.

- ***Departure in atmospheric parameters over 11 subzones:***

Composite values of monthly averaged tropospheric temperature and thickness for extreme wet and dry months over 11 climatic zones are calculated. Results show that, during wettest months, the tropospheric of NH was warmer and thicker in June (0.2°C/7.62m) cooler and thinner in July (-0.04°C/-1.2m) and August (-0.05°C/-1.14m) and again warmer and thicker in Sept (0.2°C/8.4m). The SH troposphere was warmer and thicker in June (0.1°C/4.5m), cooler but thicker in July (-0.01°C/0.4m), cooler and thinner in Aug (-0.1°C/-2.6m), and again warmer and thicker in Sept (0.2°C/8.6m). This lead to positive interhemispheric (NH-SH) temperature contrast during June, Aug and negative during July and Sept. During driest months, the tropospheric of NH was warmer and thicker in June (0.13°C/6.6m) cooler and thinner in July (-0.1°C/-5.4m), warmer and thicker in

August (0.1°C/5.6m) and again cooler and thinner in Sept (-0.2°C/-7.5m). The SH troposphere was warmer and thicker in June (0.2°C/9.2m), cooler and thinner in July (-0.1°C/-3.9m), warmer and thicker in Aug (0.1°C/4.9m), and cooler and thinner in Sept (-0.1°C/-4.5m). This lead to negative interhemispheric contrast during June, July, and September and positive during August. Overall, during extreme wet years most of the subzones show positive departure in temperature and thickness field. However there are variations from June through September.

Broad features of departure fields in tropospheric temperature and thickness during wet and dry monsoon months over 11 subzones are as follows (figure 1): During wettest June, tropics, subtropics and mid-latitude regions of both hemispheres were warmer and thicker than normal. While SP is cooler and thinner. NP and NSBT are thick but no temperature change has been seen. In driest June month, the anomalies are more or less same, except NSBT, where no change is seen. During extreme wet July, NTP, STP, and SMLAT are cooler and thinner, while NSBT, NMLAT, SSBT, and SP are warmer and thicker than normal. Cooling of tropics may be due to the wide coverage and excessive rainfall in the month of July, while during driest month, NSBT, NMLAT, SMLAT, and SP are cooler and thinner, while NTROP and NP are warmer and thicker. Cooling of NSBT and NMLAT during July is an indicator of the weaker monsoon circulation and hence subdued rainfall. During extreme wet August, both tropics and SSBT are cooler and thinner while both poles and NMALT are warmer and thicker. During extreme driest month of August, both tropics and SSBT are warmer and thicker while both poles and mid-latitudes are cooler and thinner. In wettest September month, almost whole globe is warmer and thicker while during driest September, whole globe is cooler and thinner except SMLAT, which is warmer and thick than normal.

During extreme wet years, although significant changes in departure field have not noticed across the globe, NSBT and TBT show comparatively intense departure field than other subzones. Tibet is warmer by 1.1° and thicker by 43.9m than normal in June, 0.54°C/23.6m in July, 0.2°C/7.9m in Aug and 0.04°C/7.8m in Sept. NH-SH contrast also did not show much variation during extreme wet years. During extreme dry years, majority of the subzones show negative departure field compare to normal. Tibet is cooler by -0.22°C and thinner by 10m in June, -0.32°/-19.7m in July, -0.25°C/-7.3m in Aug and -0.54°C/-24.8m in Sept as compare to its normal values. It has been seen that even small changes on terrestrial scale may produce vigorous changes on local-scale.

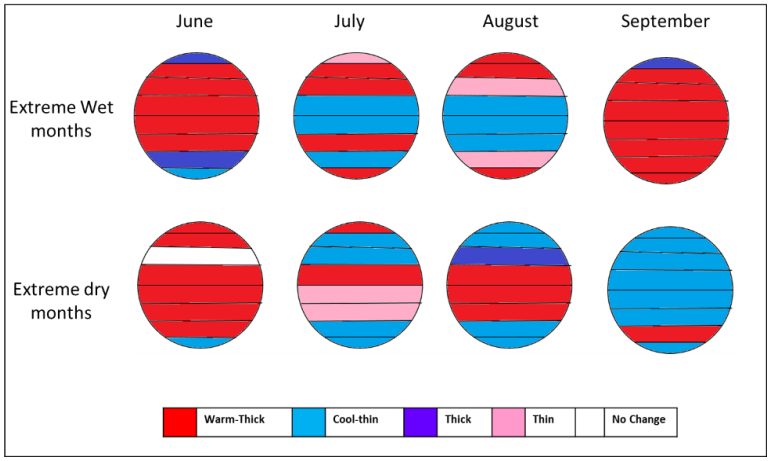


Figure 1. Combined tropospheric temperature and geopotential thickness anomalies over global climatic zones during extreme wet and dry months in monsoon season.

- **Spatial distribution of Atmospheric anomalies:**

Global distribution of composite anomalies for four extreme wet and dry months in atmospheric parameters (temperature and geopotential height at 12 isobaric levels, tropospheric temperature, thickness, and MSLP) is observed. It has been seen that, during extreme wet June, prominent warm anomalies are observed across north and south tropics-subtropics with a hot core over Middle East and western Tibet and another over western Russia. North Pole and south multitude appear to be

cooler than normal. During extreme dry June, although whole north tropics and south tropics are warm, the Middle East and western Tibet are showing cool anomaly.

During extreme wet July, the whole north and south tropics are cool but the warm anomaly is extending from Middle East to eastern Tibet and China. North Pole is cool but South Pole is warmer than normal. During driest July, the Middle East, the whole Tibet and Indian Ocean are showing negative anomaly. North Pole is warmer while South Pole is cooler than normal.

In extreme August month, warm anomaly core is observed over Central and western Tibet. Another core is observed over Japan and North America. The whole Indian Ocean is warmer than normal, while Pacific and Atlantic are cooler than normal. During extreme Dry August, cool anomaly is observed starting from Middle East to Japan, Magnolia extending northwards up to North Pole. Surprisingly whole tropics of north hemisphere and Southern hemisphere are warmer than normal and south pole cooler than normal.

During extreme wet September, most parts of the globe in both hemispheres are under warm anomaly with the core over Japan-Magnolia. Although central and eastern Pacific and North Pole are cooler than normal. During driest September, opposite picture can be seen. The most part of the globe is under cool anomaly. Middle East and Tibet-Himalaya are also anomalously cooler than normal. While eastern part of equatorial and north pacific and some parts of south mid-latitude are under positive anomaly conditions.

- **Conclusions:**

Anomalies in the atmospheric parameters during extreme wet and dry monsoon months during 1979-2015 are observed. The important findings are as follows:

1. During wettest June, tropics, subtropics and mid-latitude regions of both hemispheres were warmer and thicker than normal with a hot core over the Middle East and western Tibet and another over western Russia. In driest June, anomalies are more are less same except over Middle East and western Tibet cooler than normal.
2. During wettest July, NTP, STP, and SMLAT are cooler and thinner, while NSBT, NMLAT, SSBT, and SP are warmer and thicker than normal with the hot core over eastern Tibet and Japan- Mongolia. During driest month, NSBT, NMLAT, SMLAT, and SP are cooler and thinner than normal.
3. During extreme wet August, both tropics and SSBT are cooler and thinner while both poles and NMALT are warmer and thicker. The anomalous hot core is observed over central and western Tibet. During driest month both tropics and SSBT are warmer and thicker while both poles and mid-latitudes are cooler and thinner.
4. In wettest September month, the almost whole globe is warmer and thicker with a hot core over Japan Mongolia while during driest September, most part of the globe is cooler and thinner including Middle East and Tibet-Himalaya.

Deliverables

It is expected that the results from this study will be useful in order to understand the effect of climatic changes on rainfall pattern across India

Adopters of the results of the study and their feedback:

From hydrology and water resources sectors

Major items of equipment procured: None

Lab facilities during the study: None

Specific linkages with Institutions/beneficiaries: None

Shortcomings/Difficulties:

1. Shortage of observed station rainfall data for the updating the longest instrumental monthly rainfall series
2. Shortage of manpower

Future Plan:
To understand the effect of climatic changes in global atmospheric parameters and circulations on extreme rainfall of river basins of India

9. Evaluation of the influence of low-frequency atmosphere- ocean oscillations on annual floods in the watersheds of the Indian subcontinent

PROJECT REFERENCE CODE: NIH/SWHD/18-21

Title of the Project: Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent

Project team: Mr. Sunil Gurrapu, Scientist C (PI)
Dr. Ashwini Ranade, Scientist C
Mr. Jagadish Prasad Patra, Scientist C

Type of Study: Internal

Status: On-going

Duration: 3 years

Date of Start: 1st November 2018

Scheduled date of completion: 31st October 2021

Objectives:

1. Analyze annual peak flows in the rivers of Indian subcontinent.
    a. The main objective of this study is evaluate the stationarity assumption made in flood frequency studies.
    b. Evaluate the trends in the historically observed annual peak flows and to identify step-change in the data, if any.
2. Evaluate the influence of various low-frequency atmosphere-ocean oscillations on flood magnitude and frequency.
    a. Pacific Decadal Oscillation (PDO) and El Nino Southern Oscillation (ENSO) are large-scale climate patterns occurring over the Pacific Ocean.
    b. They are quantified into indices at a monthly scale, based on the varying sea surface temperature and pressure over the equatorial Pacific Ocean.
    c. Such indices are available from various institutes across the world including
        i. Joint Institute for the study of Atmosphere and the Ocean (JISAO), USA
        ii. Climate Research Unit (CRU), University of Eastern Anglia, UK
        iii. National Oceanic and Atmospheric Administration (NOAA), USA
    d. In this objective, we evaluate correlations between these indices and annual peak flow. We also aim to quantify their influence on annual floods and provide a correction factor to account for the non-stationarity.
3. Sensitivity analysis of probable maximum precipitation (PMP) estimation methods in design flood studies.
4. Prepare a status report on the impact of changing climate on PMP in India.

Statement of the problem:

Globally, floods are ranked among the largest and costliest natural disasters having major impact on various economic sectors. In India, flooding is one of the three prominent climate extremes, other two being droughts and cyclones. Majority of flooding in Indian watersheds occurs during summer monsoon months due to uneven distribution of rainfall. For example, recent devastating floods in Kerala were in response to the abnormally high rainfall received within a short period of 3 days, i.e. during 15th to 17th August 2018. Summer monsoon rainfall being the major source of water input to the Indian subcontinent, optimal design and operation of water resources infrastructure (e.g. major

dams) is very much essential. Planning and design of such structures require a great depth of knowledge on the magnitude and frequency of extreme floods. Traditionally, the frequency of extreme floods is derived based on the analysis of historically observed annual maximum flows assuming they are independent and identically distributed (*i.i.d*) and the system fluctuates within a fixed envelope of variability, i.e. stationarity assumption. However, several studies across the globe highlight the potential inadequacy of traditional flood frequency analysis (FFA) and argue that the *i.i.d.* assumption can no longer be considered valid. Moreover, Indian summer monsoon is influenced by several low-frequency atmosphere-ocean oscillations including Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), El Niño-Southern Oscillation (ENSO) etc.

The failure probability of large hydraulic structures such as large dams and spillways, should be as low as possible. BIS specifies that the design flood for a large structure (i.e. gross storage > 60 MCM) is the probable maximum flood (PMF). The design flood for such structure is estimated based on the probable maximum precipitation (PMP). PMP is the maximum precipitation that is physically possible over a region for a given duration. PMP can be estimated either from meteorological or statistical methods. However, due to lack of standard approach for estimating PMP, it's use in the design and analysis of flood related studies is criticized. In this study, we propose to first analyze the annual floods (i.e. maximum flows) with the hypothesis that they are influenced by the low-frequency atmosphere oscillations originating in the equatorial Pacific and Indian Oceans. Secondly, we propose the evaluate the PMP estimation methods in flood frequency studies and prepare a status report on the impact of climate change on PMP.

Study Area (Preliminary):
The preliminary study is being carried out on several sub-basins of River Godavari and River Narmada. We chose several streamflow gauging stations with a minimum of 30 years observed daily streamflow data. Based on the preliminary survey of available streamflow data, we chose 19 gauging stations from Godavari and 12 stations from Narmada watersheds, with at least 30 years of data.

Datasets:

1. Observed daily streamflow data for the selected gauging stations is obtained from India-WRIS website.
2. Pacific Decadal Oscillation (PDO) indices is obtained from Joint Institute for the study of Atmosphere and Ocean (JISAO), University of Washington.
3. El Niño-Southern Oscillation (ENSO)is quantified by Southern Oscillation Index (SOI) and is obtained from Climate Research Unit, University of Eastern Anglia.
4. Indian Ocean Dipole is quantified by the Dipole Mode Index (DMI) and is obtained from Earth Systems Research Laboratory (ESRL), National Oceanic and Atmospheric Administration (NOAA), USA.

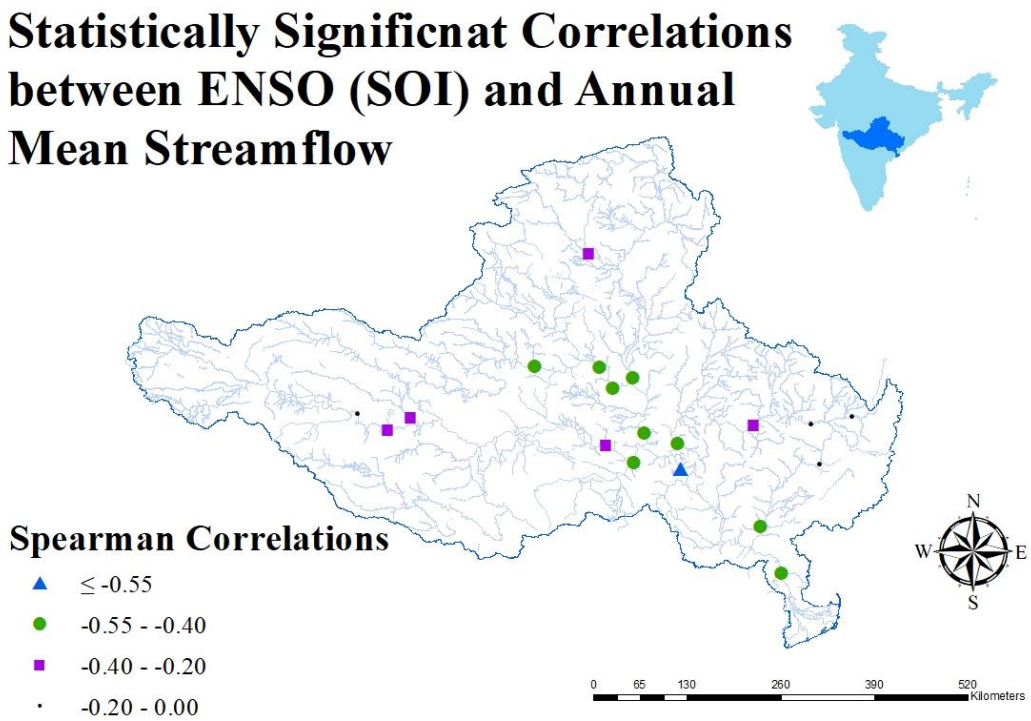
Current Status:
This study was motivated by the observation that the influence of low frequency oscillations upon flood risk is not yet a key ingredient in the planning and design of regional infrastructure, despite several studies showing strong correlations between monsoon rainfall and low frequency oscillations such as ENSO, PDO etc. The preliminary analysis was done on several gauging stations located on the stream networks of Godavari and Narmada River basins. Results from preliminary analysis are as follows;

We obtained the daily streamflow data for several gauging stations (19 in Godavari basin and 12 in Narmada basin) from India-WRIS. These stations were selected based on the length of the record, i.e. at least 30 years of observed data. Annual peaks were extracted for the water year (1st June to 31st May of the following year), with a condition that at least 200 days of flow data is available during both southwest (June – September) and northeast (October – December) monsoon seasons, i.e. a maximum of 14 days of missing data is allowed during the water year. Despite the risk of missing out on few peaks, we adopted this condition to include as many stations as possible in the study.
Godavari River Basin: Annual Mean flow in 15 gauging stations out of 19 are influenced by the El Niño-Southern Oscillation (ENSO), Figure 1. The correlations between ENSO index (SOI) of

February and annual mean streamflow show statistically significant spearman correlations, as strong as 0.54. These correlations indicate that the annual mean streamflow in the Godavari watershed is more during the positive (i.e. El Niño episodes) phase of ENSO and less during the negative (i.e. La Niña episodes) phase of ENSO. In addition, we observed that the annual peak flow in 12 gauging stations is significantly influenced by the ENSO. Similarly, annual streamflow in nearly 12 gauging stations in this watershed showed statistically significant correlations with the August and September month PDO index. Up to 50% of the variability in annual streamflow at these stations can be explained by the PDO index.

Narmada River Basin: In contrast to the Godavari watershed, Annual streamflow in the Narmada watershed did not show any significant correlations with both ENSO and PDO. However, the correlations are significant at few stations (nearly 5 out of 12).

We are further evaluating the spatial and temporal variability of these correlations. Although the correlations are significant for majority of the stations, they are not evident at all the stations. One major shortcoming is the length of the available data, because the periodicity of PDO is approximately 20 – 30 years, although it is nearly 10 years for ENSO. Also, majority of these gauging stations are regulated and hence the anthropogenic influence might be disturbing the natural signal of these teleconnections. Longer duration datasets and those on naturally flowing streams would help identifying the signal clearly. Currently, we are identifying more gauging stations with longer datasets and more specifically looking for stations on naturally flowing streams. Eventually, we will de-trend the streamflow datasets of anthropogenic influence (naturalization) and perform the analysis again to get a clearer picture. Consecutively, we will also evaluate the impact of other teleconnection. We are also reviewing the available literature to evaluate the PMP estimation methods in the context of the changing climate and a status report will be prepared for the same.



Deliverables:

1. Research papers based on the established relations between low-frequency climate oscillations and flood magnitude and frequency.
2. Status report on the impact of climate change on probable maximum precipitation (PMP) in India.

10. Evaluation of Water Quality of Government Schools in Roorkee Block, District - Haridwar

PROJECT REFERENCE CODE: NIH/SWHD/18-20

Title of the Study: Evaluation of Water Quality of Government Schools in Roorkee Block, District Haridwar

Study Group: PI: N. K. Bhatnagar, Scientist B
Co-PI: Dr. M. K. Sharma, Scientist D
Dr. L. N. Thakural, Scientist C
Smt Reena Rathore, Deputy Education Officer, Roorkee Block
Sh Hukam Singh, Sc B

Role of Team Members:

S. No.	Name of the person	Role
1	N. K. Bhatnagar	• Meetings with School authorities: List of Schools, fixing the schedules of schools visit for sampling, discussions about mass awareness programmes for schoolchildren and villagers etc • Preparation of study area map • Preparation of route map for sampling • Literature review including the work of NIH in district Haridwar • Pre- and Post-monsoon Groundwater Sampling • Processing of data • Organization of Mass Awareness Programme • Preparation of report
2	M. K. Sharma	• Guidance, Supervision and review of the work • Pre- and Post-monsoon Groundwater Sampling • Water quality analysis • Processing of data • Organization of Mass Awareness Programme • Preparation of report
3	L. N. Thakural	• Guidance, Supervision and review of the work • Data base preparation in GIS environment • Organization of Mass Awareness Programme • Preparation of report
4	Smt Reena Rathore Deputy Education Officer, Roorkee Block	• Providing support, supervision and help regarding Schools. • Organization of Mass Awareness
5	Sh Hukam Singh Scientist B	• Lab and field work.

Type of Study : Applied research

Date of start : October 2018

Scheduled date of completion: September 2020

Duration of the Study: 2 Years

Objectives of the Study: i) Groundwater quality monitoring in pre-monsoon (April-May) and post-monsoon (OctoberNovember) season at identified school locations. ii) To map

degraded ground water quality zones and possible sources of pollution and identify specific parameters not conforming to drinking water quality standards. iii) To examine the suitability of ground water quality for drinking purpose using Water Quality Index. 145 iv) To suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking. v) To organize Mass Awareness Programme for school and villagers regarding Drinking Water Quality and Water Conservation.

Statement of the Problem: Groundwater is one of the vital resources, which meets the requirements of daily livelihood especially in rural areas of India. Growing demand of water in various sectors viz; agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the groundwater resource, continuously declining groundwater levels, sea water ingress in coastal areas, and groundwater pollution in different parts of the country. There is a major possibility that School Children of Roorkee Block are bound to drink contaminated water as informed by Deputy Education officer, Roorkee Block during a talk. In view of this, a study was conceptualized to evaluate the groundwater quality status of Government Schools of Roorkee for drinking purpose.

Action Plan/Methodology: i) Literature survey on assessment of groundwater quality and issues in the region. ii) Meetings with School authorities: List of Schools, fixing the schedules of schools visit for sampling, discussions about mass awareness programmes for schoolchildren and villagers etc iii) Preparation of study area map iv) Preparation of route map for sampling v) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations. vi) Analysis for physico-chemical parameters: pH, EC, TDS, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (HCO3, Cl, SO4, NO3), Minor Ions (F, PO4,) and Toxic (Heavy) Metals: As, Cd, Cr, Pb, Cu, Ni, Fe, Zn, Mn in the collected water samples. vii) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose. viii) Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking. ix) Suggesting ameliorative measures to control/ restore the groundwater quality.

Timeline:

Year	1 st Quarter	2 nd Quarter	3 rd Quarter	4 th Quarter
2018-19			Literature Survey	Meetings with School authorities, Preparation of Maps, Interim report.
2019-20	-. Field visit, Sampling.	Sample Analysis and processing of the data.	Field visit, Sampling.	Analysis and processing of the data, Interim Report.
2020-21	Mass Awareness Programme	Preparation of Final Report.		

List of deliverables: Technical Report and Research

Lab facilities during the study: Water Quality and Remote Sensing/GIS Laboratory of NIH

Data generated in the study: Hydro-chemical and statistical data of Roorkee block.
Study Benefits/Impact: Water quality analysis of every school will be helpful to provide pure potable drinking water to schoolchildren and they wouldn't be bound to drink contaminated

water that will be helpful them not to fall ill because of water born diseases. Directly the health of children will improve and, consequently, the attendance too.

Specific linkages with Institutions/beneficiaries: Villagers, Education Authority of District Haridwar and District Administration /Difficulties: None.

Expected Budget

Sr. No.	Sub-Head	I Year	II Year	Total
1	Travelling expenditure	100000	100000	200000
2	Infrastructure / Equipment / Consumable	100000	100000	200000
3	Experimental charges	350000	350000	700000
4	Misc. Expenditure	50000	50000	100000
5	Grand Total	600000	600000	1200000

Progress after last working Group:

As scheduled in timeline, Literature survey on water quality of Haridwar has been done, study area map with the help of GIS is under preparation, pre monsoon water sampling has been done and test in water quality lab has been completed. Testing of metal ions in water samples is under progress.

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Sanjay K Jain	Scientist G & Head
2	Dr. M K Goel	Scientist G
3	Mrs. Deepa Chalisgaonkar	Scientist G
4	Er. D S Rathore	Scientist F
5	Dr. Renoj Thayyen	Scientist E
6	Dr. Manohar Arora	Scientist D
7	Dr. P K Singh	Scientist D
8	Er. Manish Nema	Scientist C
9	Dr. P K Mishra	Scientist C
10	Dr. Vishal Singh	Scientist C
11	Sri P K Agarwal	Scientist B
12	Sri Deepak Singh Bisht	Scientist B
13	Sh. Yatveer Singh	SRA

WORK PROGRAMME FOR THE YER 2019-2020

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
Completed Internal Studies				
	Development of window based software for hydrological data processing and Unit Hydrograph Analysis	D. Chalisgaonkar A. K. Lohani M. K. Goel	1 year (04/18-03/19)	
Ongoing Internal Studies				
1.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain Sanjay K. Jain Renoj J.Thayyen P. K. Mishra	5 years (12/14-12/19)	
2.	Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework	P. K. Singh P. K. Mishra M. K. Goel Suman Gurjar	2 years 2018-2020	
3.	Real time flood modelling using HEC-RTS modelling framework	Vishal Kumar A. K. Lohani Sanjay K. Jain	2 years 2018-2020	
4.	Development of window based software for Flood Estimation	D. Chalisgaonkar A. K. Lohani M. K. Goel	1 year (04/19-03/20)	
Ongoing Sponsored Studies				
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	Renoj J. Thayyen Farooq Azam P.G. Jose A.P. Dimri	3 years (03/16-02/19) Extended up to March 2020	SERB (65.14)
2.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel M. Arora; A. K. Lohani D. S. Rathore; D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra	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 D. Chalisgaonkar V. S. Jeyakanthan L. N. Thakural	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 A. K. Lohani Sudhir Kumar P. Thakur (IIRS)	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 Sanjay K. Jain Sharad K. Jain P. K. Mishra M. Arora AP Dimri (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	Sharad K. Jain Renoj J.Thayyen Sanjay K. Jain	5 years (01/16-12/20)	DST (54.07)

	(Sub-project – 5)	Surjeet Singh M. K. Nema; P. K. Mishra; P. K. Agarwal AP Dimri (JNU)		
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra M. K. Nema Renoj J. Thayyen P. Kumar	5 years (01/16-12/20)	DST (90.99)
8.	Dynamics of Himalayan Ecosystem and its impact under changing climate scenario-Western Himalaya	Renoj J.Thayyen P. K. Mishra	3 years (03/17-03/19) Extended up to March 2020	NMHS-MoEF (58.76 lakh)
9.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema Renoj J. Thayyen Sharad K. Jain Sanjay K. Jain P. K. Mishra AP Dimri (JNU)	3 years (2016-19) Extended up to December 2020	MOES (Rs. 98 Lakh)
10.	Sustaining Himalayan Water Resources in a Changing Climate (SusHi-Wat)	Sanjay K. Jain (PI) Sharad K. Jain CSP Ojha (PI, IITR)	3 years (2016-2020)	MOES-NERC, Newton-Bhabha project (11.59 Lakh)
11.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore L. N. Thakural Sanjay Kumar B. Venkatesh M. K. Jose T. Chandramohan	3 years 2017-2020	PDS under NHP (50.23 Lakh)
12.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years 2018-2021	NIH/ DST
New Internal/ Sponsored Studies				
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Sanjay K. Jain P. K. Singh M. Arora Renoj J. Thayyen A. K. Lohani Vishal Kumar Suman Gurjar	3 years (11/19-11/22)	NMHS-MoEF (143 Lakh)
2	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Renoj J. Thayyen A. P. Dimri (JNU) Sanjay K. Jain	3 years (11/19-11/22)	NRDMS-DST (46.39 Lakh)
3	Permafrost mapping and characterisation of Ladakh Region	Renoj J. Thayyen A. P. Dimri (JNU) G. Jeelani (KU) V. Agnihotri (GBPNI)	3 years (11/19-11/22)	NMHS-MoEF (197 Lakh)

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/01

1. **Title :** Development of window based software for hydrological data processing and Unit Hydrograph Analysis

2. **Study Group :** Deepa Chaligaonkar, Sc 'G'
   Dr. A. K. Lohani, Sc 'G'
   Dr. M. K. Goel, Sc 'G'

3. **Duration:** April 1, 2018 to March 31, 2019 (One Year)

4. **Statement of The Problem:**

Unit hydrograph approach is a simple, versatile and popular technique, which is being widely used for the estimation of floods for design of hydraulic structures, drainage system, small bridges, culverts etc. Right from the inception of NIH, a number of software/computer program have been developed at NIH for these analyses. However, they were written in FORTRAN/Basic languages which did not provide user-friendly environment to the field users. In view of this, a WINDOWS based software is being developed to carry out hydrological data processing and unit hydrograph analysis for the estimation of flood for gauged as well as ungauged catchments of small and medium size.

5. **Methodology:**

The software is being developed in VB.NET plateform which supports the development of user friendly environment for carrying out the various computations involved in the hydrological data processing unit hydrograph analysis. The software has following main modules:

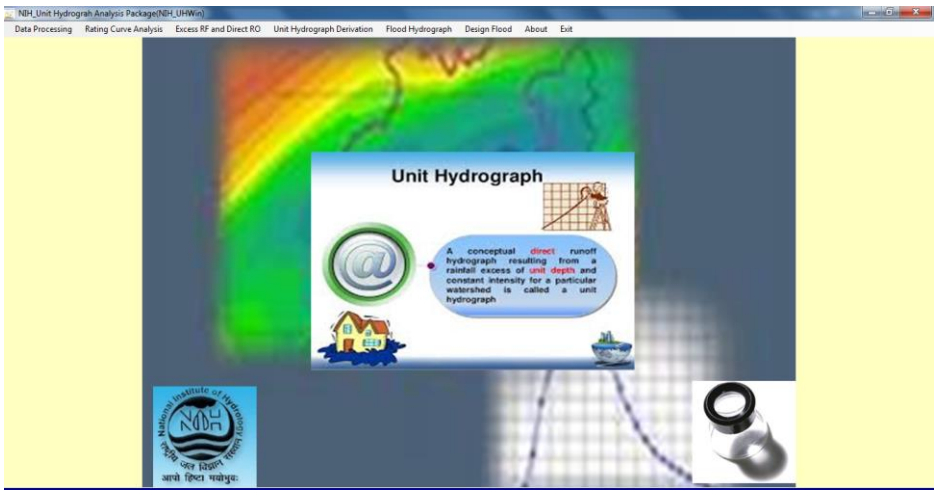
- **Data Processing**
  - Filling up of Missing Data
  - Consistency Check Using Mass Curve,
  - Computation of Areal Average Rainfall,
  - Computation of Variation of Depth with Area
  - Distribution of Daily to Hourly Rainfall
- **Rating Curve Analysis**
  - Discharge from Velocity
  - Development of Rating Curve & Discharge Computation,
  - Discharge from Stages
- **Excess Rainfall (ERH) & Direct Surface Runoff (DRH)**
  - Base flow Separation & Computation of ERH Volume
  - Separation of Base flow using Straight Line Tech.
- **Unit Hydrograph Derivation,**
  - Unit Hydrograph for Gauged Catchments
    a. Collins Method,
    b. Clark Method,
  - Unit Hydrograph for Ungauged Catchments,
  - S Hydrograph Computation,
  - UH of Changed Duration using Superimposition Method,
  - UH of Changed Duration using S-Curve Method,
  - Development of Dimensionless Hydrograph,

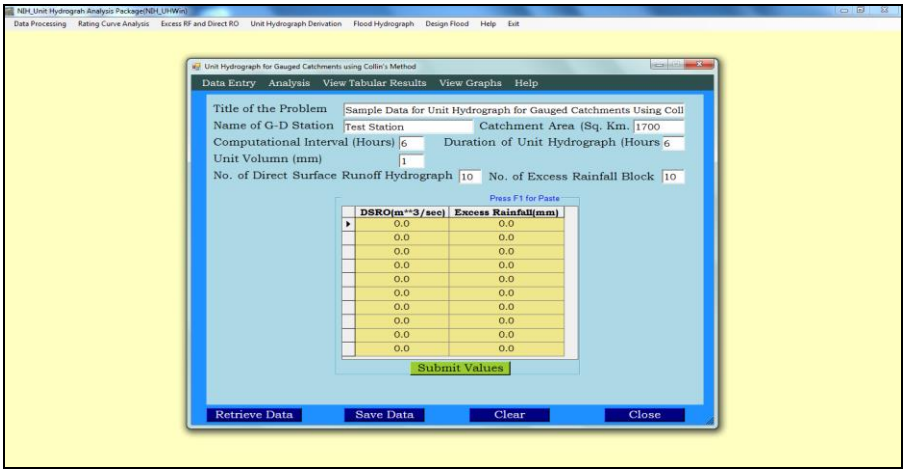
- Development of UH form a Dimensionless Hydrograph

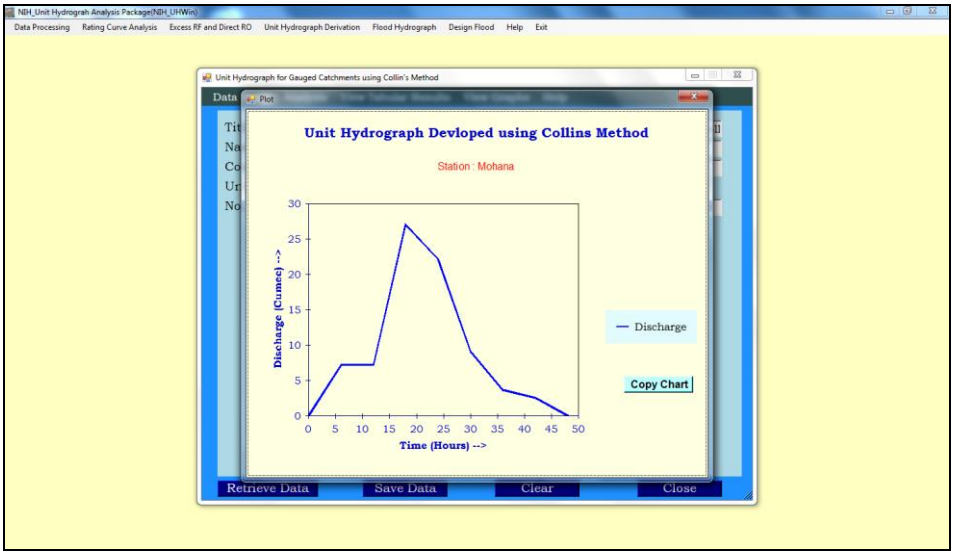
- **Flood Hydrograph**
  - Computation of Direct Surface Runoff (DRH),
  - Computation of DRH & Error Functions
- **Design Flood**

For carrying out these analysis forms have been developed for easy data entry for all the modules. The online help has been provided at each stage of running the package and the results are presented in tabular as well as graphical form.

A setup file will be prepared which will help in easy installation and transfer the software package. When the user will click the setup file, it will automatically create the respective folders, install the software and will create in icon for the software on the desktop. This icon will help in easy execution of the software.
The software is being prepared in vb.net platform. Descriptive data formats have been prepared for easy preparation of data files. Some of the screenshots are shown below:







7. Research Outcome of the Project:

A WINDOWS based Software package for hydrological data processing and Unit Hydrograph analysis is being developed. It is expected that the field engineers will find it useful.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/01

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:	Mr**.** Manish Kumar Nema, Scientist 'C'
b. Project Co-Investigators:	Dr. Sharad K. Jain, Director,
	Dr. Sanjay K. Jain, Scientist 'G', Head, WRSD
	Dr. Renoj J. Thayyen, Scientist 'E' and
	Dr. P. K. Mishra, Scientist 'C'

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. **Present state-of-art**

Watershed is supposed to be the basic unit at which the hydrologic processes are studied and is central to most of the concepts in hydrology. Managing agricultural or forested watersheds for water quality and quantity improvement and productivity requires a detailed understanding of functional linkages between eco-hydrological processes and management practices. Various watershed studies are being conducted to understand the fundamental hydrologic and biogeochemical processes and their linkages with soils, vegetation, topography, climate, and management practices worldwide. These studies mainly involve modelling the natural processes but the vibrancy of experimental hydrology broadly across the areas of subsurface and surface hydrology and hydrometeorology still have a unique place of importance and no alternative.

In view of the state of affairs of existing models and studies addressing the problems of watershed hydrology, the major limitations might be characterized as mainly twofold. First, study basin designs have been limited by the black box concept and many misconceptions (e.g., the linearity, non-heterogeneity, additivity of hydrologic systems etc.). Second, operation has been substantially bounded by the hydraulic conception of these watersheds as isolated hydrological systems (Wei-Zu et al. 2013). Most of the watershed studies monitor only total runoff at the stream-outlet and the subsurface responses of the watershed are only estimated by hydrograph separation, etc. These characteristics undermine the formulation of a unified theory of watershed hydrology (Sivapalan et al. 2005) and the development of watershed models (Kirchner, 2006; Mcdonnell et al., 2007). There is a clear need to move beyond the status quo and expand from this narrow hydrological perspective to generate hypotheses governing general behavior across places and scales, with the ultimate aim to advance the science of hydrology.

6. **Methodology**

(A) Study Area:

A small Himalayan hilly watershed Hinval up to Jijli in the upper Ganga basin in the state of 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 other one 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 Himalayan subtropical forests yield to a belt of temperate broad leaf and mixed forest mainly comprises of pine forest. The total area under study is of 100 km^2 approximately (20 km^2 forested catchment and 80 km^2 the other one) with an elevation range of 999-2676 m. The location map of the watershed and their digital elevation model from SRTM is given in the figure 1.0 for reference. The stream in the forested sub-catchment is the source of drinking water for 87 nearby villages. This stream is being pumped 24x7 by the state authorities at its outlet at Dev Nagar. A study of the topography and land use of the proposed watershed shows that the watershed is representative of the surrounding areas.

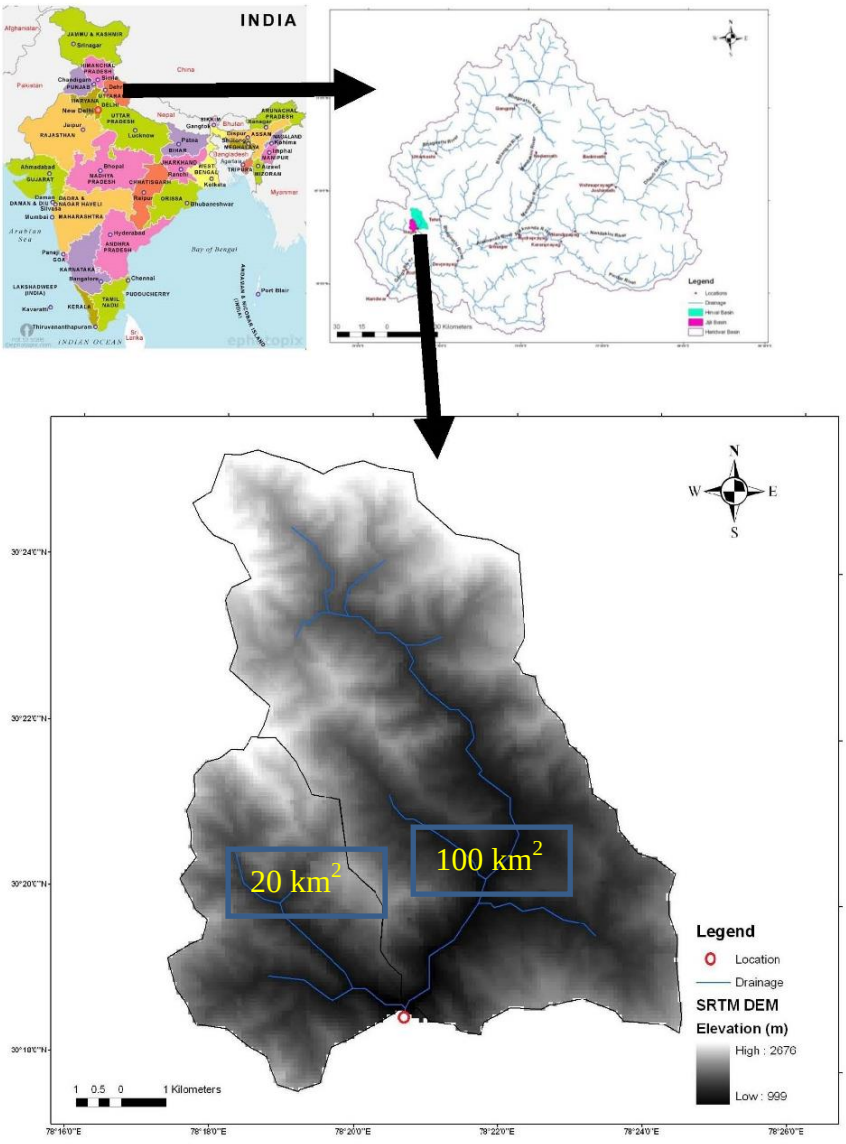


Fig. 1.0 Location of the Hinval watershed up to Jijli within India

(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.

7. 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.

8. 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.

9. Quarterly Break up of cost estimate for Year: 2017-18

SN	Sub-head	Amount (in Rupees)			
		AMJ (Q1)	OND (Q2)	JAS (Q3)	JFM (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	320000.00	320000.00	320000.00	320000.00
4.	Experimental charges	0.00	0.00	0.00	0.00
5.	Misc. expenditure	37500.00	37500.00	37500.00	37500.00
	Sub- Total:	575500.00	575500.00	575500.00	575500.00
	Grand Total:	2302000.00			

10. 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:

S No.	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 acquisi																				
5.	Data analysis and modelling																				
6.	Final Reporting																				

10. Progress till date:

Majority of the instrumentation towards establishing a classical hydro-meteorological field observatory in the Lesser Himalayan environment has been completed. Some of the data analysis and results pertaining to ET estimation by empirical formulas, SEBAL method has been presented in the earlier working group meetings. For this working group meeting the analysis of ET estimation by METRIC method and Eddy covariance method is being presented. Some modification in the METRIC method, based on the soil moisture content in the absence of rainfall event has been done which enhances the efficiency of the METRIC model.

Eddy Covariance Flux Analysis: Analysis of very high frequency data of Eddy Covariance fluxes has also been performed using *Easyflux* software and a python module named *Fluxpart* for carbon-di-oxide and water fluxes. This highly frequency (10 Hz) data from eddy covariance flux towers are usually reported half-hourly with the objective to collect data 24h a day and 365 days a year. However, the average data coverage during a year is only 65% due to system failures or data rejection. And as there is no universal method has emerged for filling of missing or rejected data. The ET_{EC} Flux is under estimates as compare to ET_{PM} when the missing data excluded and no data gap filling was done. After that mean Diurnal variation method was adopted for data gap filling using, which was evolved for CO_2 Gap filling and the correlation of these two ET estimation methods improves significantly.

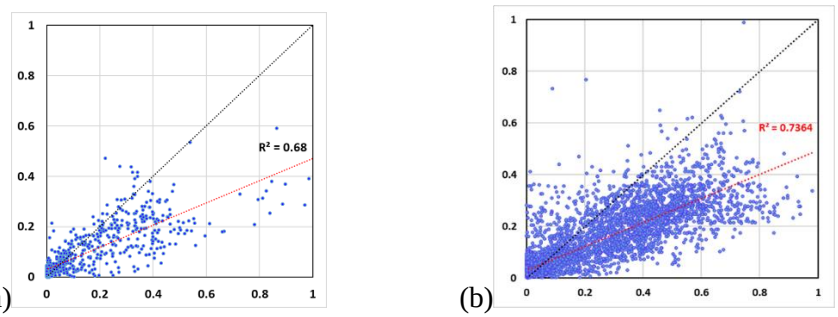


Figure. 1. $ET_{EC\ Flux}$ Vs ET_{PM} (a) when the missing data excluded and no data gap filling was done (b) Mean Diurnal variation data gap filling method was adopted

Variation of $ET_{EC\ Flux}$ and ET_{PM} for the month of DEC-2018 and Diurnal variation of $ET_{EC\ Flux}$ and ET_{PM} for 20th December 2018 is shown in the Figure 2. The minor fluctuations can be observed in the Figures 2 & 3 that indicates that the eddy flux estimates are more realistic as compared to ET_{PM}.

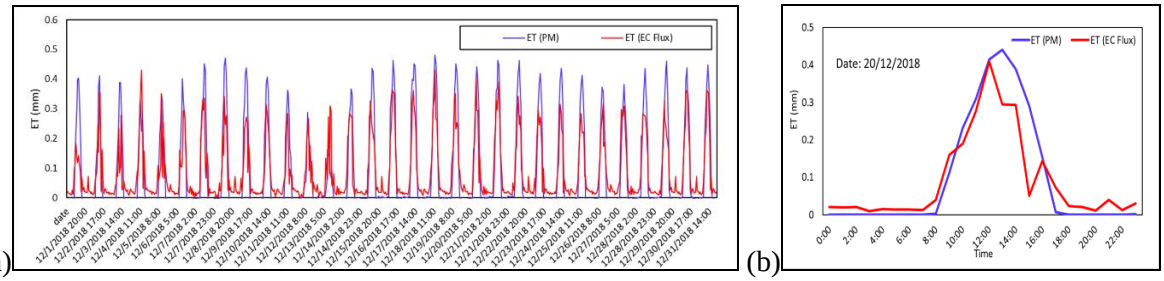


Figure 2. (a) variation of $ET_{EC\ Flux}$ and ET_{PM} for DEC-2018 (b) Diurnal variation of $ET_{EC\ Flux}$ and ET_{PM} for 20th December 2018

<u>METRIC ET Estimation:</u> **M**apping **E**vapo**T**ranspiration at high **R**esolution with **I**nternalized **C**alibration (METRIC) etc. are a remote sensing based models similar to SEBAL that estimate ET as a residual of the surface energy balance to produce ET information over a larger area of interest. Using the original form, METRIC under-predicted the ET values considerably as compared to ET_{PM} values, especially after the period of significant rainfall. A modification is proposed in the original METRIC model for better representation of the effect of rainfall on the ET process. The proposed modification reduces the average error in METRIC ET(ET_{MT}) estimation by more than 50%. For the study area, mean absolute error is reduced from 0.95 mm/day to 0.44 mm/day when METRIC model is used with proposed modification.

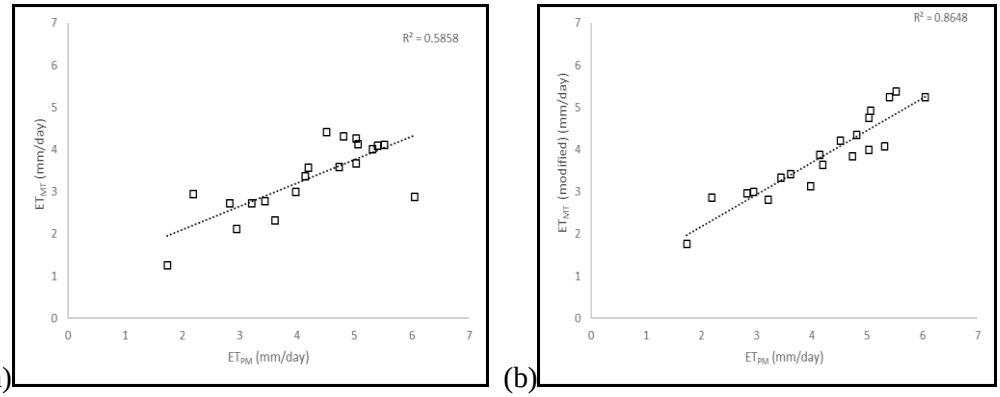


Figure. 3. Comparison of FAO Penman-Monteith (ET_{PM}) estimates with (a) METRIC ET (ET_{MT}) estimates (b) ETMT values estimated using METRIC with proposed modifications.

Since the project is about experimental hydrology, so once we collect some long-term data then only conclusive inferences can be drawn. Continuous monitoring and visits by the project team is going on to the project site to attend different objectives.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/02

1. Thrust Area under XII five year Plan
Food security and the sustainable management and use of water resources

2. Project team:

a. Project Investigator:	Dr. P K Singh, Scientist 'D', WRS
b. Co-PI Project Co-Investigator(s):	Dr. P K Mishra, Scientist 'C', WRS
	Dr. M K Goel, Scientist 'G', WRS
	Er. Suman Gurjar, Scientist 'C', GWH

3. Title of the Project– Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework

4. Objectives-The major objective of this study is to apply newly developed WA+ framework for Subarnarekha river basin in India. The objectives of this study includes assessment of:

1. Agricultural water consumptions using green water and blue water concept
2. Total water withdrawals and their partitioning in to surface and groundwater withdrawls
3. Land productivity and water productivity for food security
4. Consumed and non-consumed water along with beneficial and non-beneficial consumptions
5. Water scarcity and develop water allocation plans from water demand and water supply statistics
6. Available, exploitable, utilized and utilizable water resources

5. Present state-of-art

Water accounting (WA) has emerged in recent years as a key approach to understanding water scarcity and identifying gaps and in-efficiencies in water resources management. Various efforts have been made by United Nations (UN), Food and Agricultural Organisation (FAO), International Water Management Institute (IWMI) and the Australian government to develop standard water accounting (WA) frameworks.

FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, and has the advantage of consistency and standard terminology. However, AQUASTAT falls short of giving enough detail about the interaction between land use and water use. One major point pertinent to water scarce basins is that AQUASTAT focuses on water withdrawals, and does not distinguish between consumptive use and non-consumptive use.

The United Nations Statistics Division has proposed a WA framework called System of Environmental Economic Accounting for Water (SEEA-WATER). However, its applicability for water stock accounting is in question mainly because key required data are unlikely to be available (Perry, 2012). The essential difference in green and blue water resources (Falkenmark and Rockstr¨om, 2006; Rockstr¨om andGordon, 2001) is not recognised in the SEEAW framework.

The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) as part of the National Water Initiative (NWI) is based on several aspects of the SEEAW. The framework accounts for water withdrawals rather than consumptive use.The AWAS considers irrigated agriculture, industrial and domestic users and does not provide any information on rainfed systems and natural evapotranspiration (ET) processes.

The International Water Management Institute (IWMI) developed a WA procedure (Molden, 1997) with the aim of tracking water depletion rather than withdrawals to avoid errors when neglecting recycling, and to account for ET. The IWMI WA framework has been applied by IWMI in many irrigation system studies (e.g., Bhakra system inIndia (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and atthe national scale (e.g., India: Amarasinghe et al., 2007; SriLanka: Bastiaanssen and Chandrapala, 2003). However, only a few countries have adopted these WA mechanisms usually due to the lack of data needed to implement these approaches.

6. Methodology

The Water Accounting Plus system (WA+) is based on open access remote sensing data -in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be understoodby people with technical and non-technical backgrounds alike.

The WA+ framework is developed by IHE-Delft in partnership with IWMI, FAO, and the World Water Assessment Program (WWAP). WA+ is based on a mass water balance approach (at the pixel level) and uses Budyko theory (Budyko, 1974) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certainarea of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies landuse lancover (LULC) in to 80 classes. These 80 LULC classes are further grouped under four main Water Management Classes (WMC), i.e., Protected Land Use (PLU), Utilized Land Use (ULU), Modified Land Use (MLU), and Managed Water Use (MWU). WA+ framework uses the Budyko theory (Budyko, 1974) for measurable ET separation in to ETgreen and ETblue. The Budyko theory is based on the coupling of (a) Water Balance approach and (b) Energy Balance approach. The water balance is performed individually for green and blue pixels, respectively. Following this, WA+ procedure develops eight fact sheets and spatial maps. The eight fact sheets are listed here:

1. Resource Base
2. Evapotranspiration
3. Agricultural Services
4. Utilized Flow
5. Surface Water
6. Groundwater
7. Ecosystem Services
8. Sustainability

In the present study, all the data will be generated for the study basin using open source data. Then WA+ Framework will be applied to achieve the desired objectives.

7. Research outcome from the project

There are eight fact sheets, which will yield many outputs (spatial and temporal estimates) at the pixel level. Estimates of the following will be achieved through this study:

- Exploitable, reserved, utilized, utilizable and non-utilizable flows at river basin scale
- Consumed, non-consumed and recoverable & non-recoverable flows
- Land productivity and water productivity
- Man-made and natural water withdrawls in the basin
- Water supply and demand scenarios and allocation plans
- Surface water availability and surface water storage in the basin
- Groundwater recharge in the basin

8. Work schedule

a. Probable date of commencement of the project:
b. Duration of the project: 02 Years
c. Stages of work and milestone: Shown below

Project Year	**Jan 2019-Dec 2019**				**Jan 2020-Dec 2020**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. Data downloading, processing, and generation of data base	←	—	→					
b. Basic data analysis in WA+ framework, Ground truthing surveys for LULC and data collection from CWC, and state govt. departments		←	—	→				
c. WA+ framework application and testing			←	—	→			
d. Calibration and validation of the WA+ framework					←	—	→	
e. Sensitivity analysis of the WA+ models, finalization of results and writing research papers					←	—	→	
f. Final report writing and research paper publications							←	— →

9. Present progress

Waterpix model and Development of Sheet 4, Sheet 5 and Sheet 6

We have applied the WaterPix model of the WA+ Framework to carry out the water balance at pixel level. Major data inputs for running the WaterPix model are:

(i) Precipitation (P), (ii) Evapotranspiration (ET), (iii) Green and blue ET (Etg and ETb), (iv) Leaf area index (LAI), (v) soil moisture (GLDAS) at the beginning, end and mean of the month, (vi), GLDAS- runoff ratio (surface runoff/base flow), (vii) rainy days (n), (viii) saturation soil moisture, and (ix) and GRACE data. The method uses modified SCS-CN method for estimation of surface runoff. The model yields the monthly and yearly estimates of supply, WUE, percolation, base flow, total runoff, and root depth soil moisture.

These datasets are further utilized in development of Sheets 4, 5 & 6 which will yield the information related to supplies and demands (man-made and natural) and quantification of surface water availability and groundwater recharge and extractions.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/03

1. Thrust Area under XII five-year Plan
Flood modeling and inundation mapping

2. Project team:
Dr. Vishal Singh, Scientist C
Dr. A K Lohani, Scientist G
Dr. Sanjay K Jain, Scientist G

3. Title of the Project -
Real time flood modelling in Southern River basin using HEC-RTS modelling framework.

4. Objectives-

The present research work shall explore the flood discharge and their inundation in the Southern river basin. During extreme high rainfall events, the frequency of flood events increases. The high amount of flood discharge may cause severe flood conditions in the downstream portion of the river basin. A destructive flood hazard has been recently happened in the Kerala state of India (2018) during monsoon season. Therefore, the purpose of this research work is to provide the advance research and engineering guidelines as per the adopted approaches and methodologies for the hydrological and hydrodynamic assessment of the flood discharge and inundation in the Southern river basin under extreme scenarios. Based on current research needs, following are the research objectives defined:

1) To process and accuracy assessment of the rainfall dataset over the selected river basin by utilizing satellite-based rainfalls (e.g. TRMM+GPM) and measured rainfalls (e.g. IMD gridded rainfalls).
2) Construction of the hydrological model (i.e. HEC-HMS) to generate stream flows at different sections of the river channels.
3) Climate change assessment on Periyar river flood flows utilizing GCMs/RCMs and Statistically downscaled multi-model CMIP5 GCMs datasets.
4) Generation of flood discharges at different sections of rivers and the development of flood inundation maps in a stochastic manner including multiple return periods (e.g. 20 year, 50 year, 100 year, 500 year and 1000 year).
5) Construction of the 2D Flood model by the coupling of hydrological model (i.e. HEC-
6) HMS) and hydrodynamic model (i.e. HEC-RTS) named as HEC-RTS framework.

5. Study Area –

For the present research work, the Periyar river basin has been selected as shown in Figure 1.

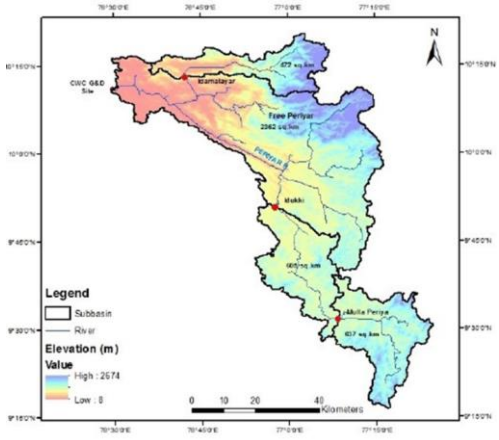


Figure 1: Periyar river basin highlighting the locations of targeted reservoirs (in red circle point).

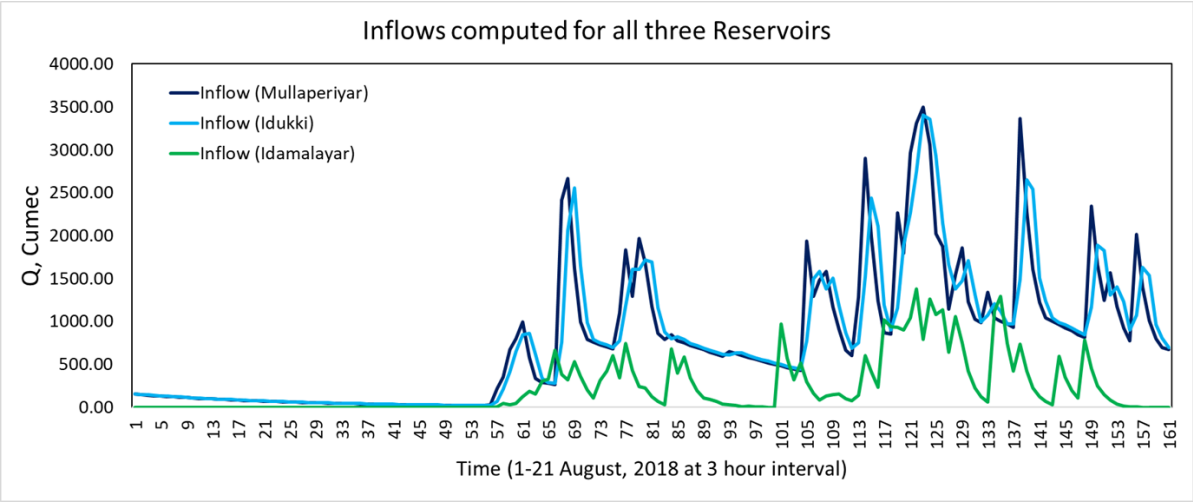
6. Methodology

6.1 Dataset to be utilized

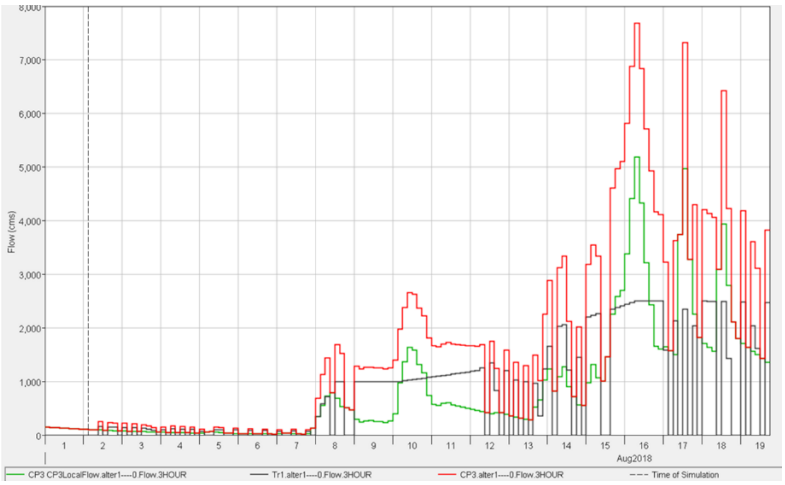
For the proposed study, the real time time-series rainfall datasets with high spatial resolution along with other meteorological variables (e.g. temperature, humidity, radiation, wind etc.) will be utilized from different sources such as Indian Meteorological Department Rainfalls, APHRODITE rainfalls, TRMM rainfalls etc. Similarly, other meteorological variables will also be acquired from these organizations. The high resolution digital elevation model (DEM) and other thematic layers such as landuse/landcover (LULC), Soil map will also be utilized. The hydrodynamic parameter/datasets will be collected from the nodal agencies and on the field as per their requirements. The overall methodology (Figure 2) has been classified into three components as given below:

7. Progress till date

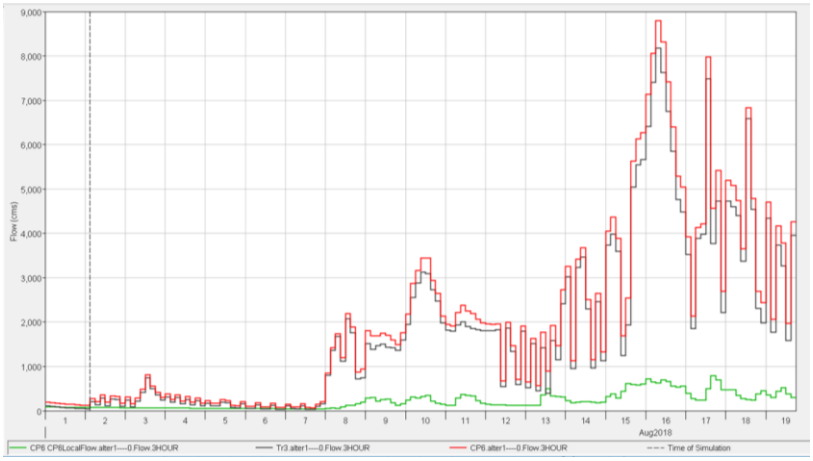
1. Computation of inflows to reservoir



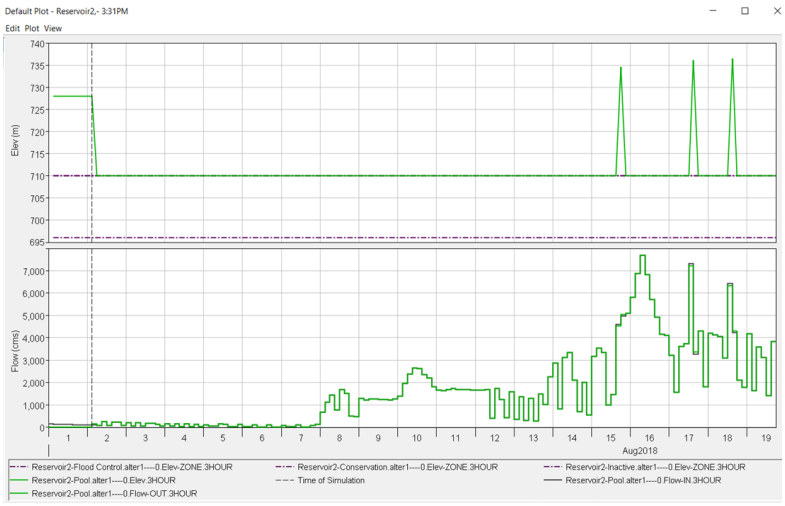
2. Inflow to Idukki



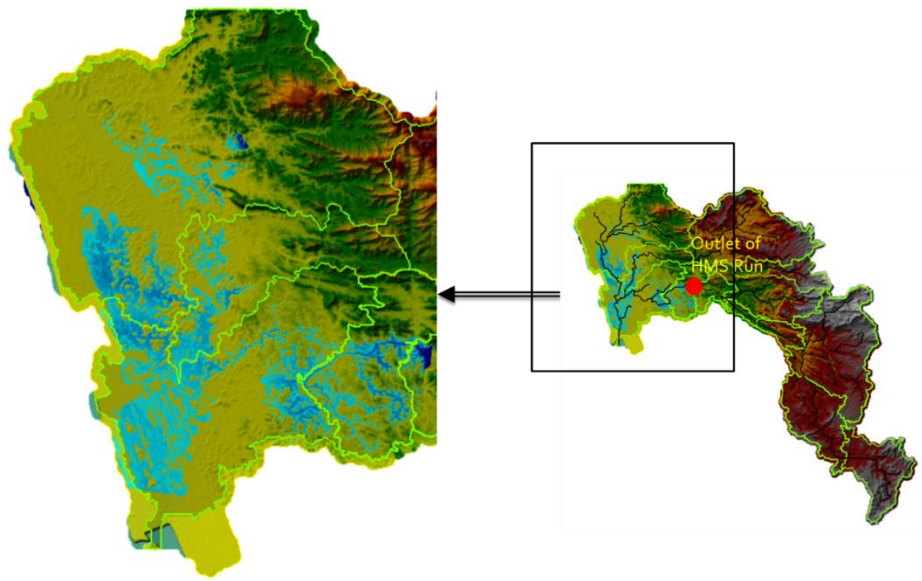
3. Flood flows released from Idukki



4. Reservoir optimization with new rules at Idukki reservoir



5. Flood Inundation Map as per the Flood Event "1st Aug to 18 Aug, 2018.



8. Work to be done in next step

1. Long Term Reservoir simulation for Idamalayar, Idukki and Mullaperiyar dams
2. New Rule curves and optimization of all reservoirs for historical flood event (2018).
3. Simulation of final flows for the historical event (2018) at each catchment using HMS incorporating reservoir parameters and elevation-area-storage-discharge function.
4. Simulation of GCMs/RCMs based flood flows
5. RAS model setup and generation of flood flows
6. Flood frequency analysis and computation of different return period flood maps.
7. The real time data for reservoir operation (e.g. elevation-area-storage-discharge) is still not available.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/04

1. **Title :** Development of window based software for Flood Estimation
2. **Study Group :** Deepa Chaligaonkar, Sc 'G'
   Dr. A. K. Lohani, Sc 'G'
3. **Duration:** April 1, 2019 to March 31, 2020 (One Year)
4. **Statement of the Problem:** The flood fright has always remained a cause of concern for the planners of various water-based projects. The estimation of flood for small or large catchments is pre-requisite for the success of any water resource project. Overestimation of flood could result in construction of uneconomical while underestimation of floods could lead to failure of project. Right from the inception, a number of computer program have been developed at NIH for flood studies. However, they were written in FORTRAN/Basica languages which did not provide user-friendly environment to the field users. In view of this, it is proposed to develop a WINDOW based software to carry out flood estimation.

5. **Objective**: To develop a WINDOWS based Software package for flood estimation.

6. **Methodology:** The software will have a user friendly environment for carrying out the various computations involved in flood estimation. The software will include following main components:
   - Channel Routing Parameters Estimation
     - Estimation of Muskingum Parameters using Graphical Method
     - Estimation of Muskingum Parameters using Method of Moments
     - Estimation of Muskingum Parameters using Optimimtion Technique
     - Routing of Inflow Hydrograph using Available Muskingum Parameters
     - Routing of Inflow Hydrograph using Muskingum Cunge method
   - Reservoir Routing
     - Reservoir Routing using Mass Curve Method
     - Reservoir Routing using Modified Plus Method
     - Reservoir Routing using Goodrich Method
     - Reservoir Routing using Coefficient Method
   - Unit Hydrograph Development
     - Processing and analysis of rainfall data
       - Filling up of Missing Data
       - Consistency Check of a Record using Double Mass Curve technique
       - Computation of Areal Average Rainfall
       - Computation of Variation of Depth with Area
       - Distribution of Daily Rainfall into Hourly Rainfall
     - Rating Curve Analysis and Computation of Discharge
       - Computation of Discharge from Velocity Measurements
       - Development of Rating Curve
       - Conversion of Stage Values to Corresponding Discharge Values
     - Excess Rainfall and Direct Surface Runoff Computations
       - Baseflow Separation and Computation of ERH Volume
       - Separation of Baseflow using Straight Line Technique
     - Unit Hydrograph Derivation
       - Unit Hydrograph for Gauged Catchments
         - ✓ Conventional Method
         - ✓ Unit Hydrograph using Collin's Method
         - ✓ Unit Hydrograph using Conventional Nash Model (Method of Moments)

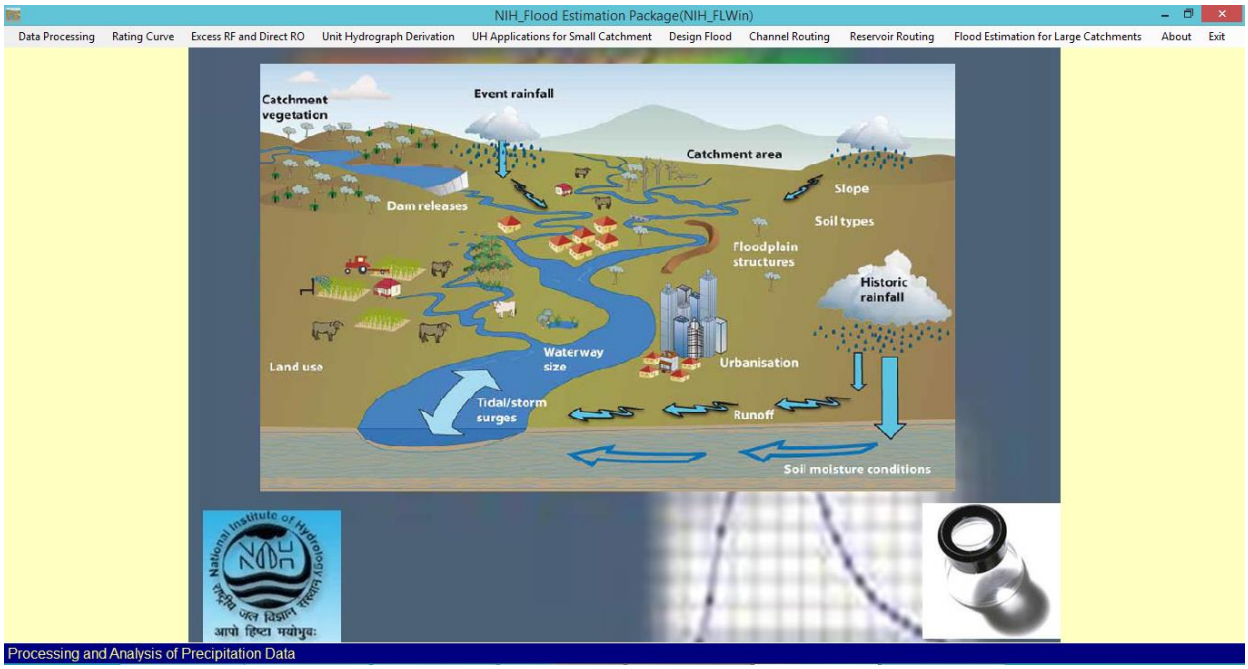
- ✓ Unit Hydrograph using Conventional Nash Model (Optimisation)
- ✓ Unit Hydrograph Given Parameters of Conventional Nash Model
- ✓ Unit Hydrograph using Integer Nash Model
- ✓ Unit Hydrograph using Clark Model (Optimisation)
- ✓ Unit Hydrograph using Given Parameters of Clark Model

▪ Unit Hydrograph Derivation for Ungauged Catchments

- ✓ Unit Hydrograph using Snyder's Method
- ✓ Unit Hydrograph using Regional Formulae Developed by CWC
- ✓ S hydrograph Computation
- ✓ Unit Hydrograph of Changed Duration using Superimposition Method
- ✓ Change of Unit Duration of Unit Hydrograph using S - Curve Method
- ✓ Development of Dimensionless Hydrograph
- ✓ Development of Unit Hydrograph from a Dimensionless Hydrograph

- UH Application on Small Catchment for Flood estimation
  - Computation of Direct Surface Runoff Hydrograph
  - Computation of Direct Surface Runoff (DRH) and Error Functions
  - Computation of Design Flood
- Flood Estimation for Large Catchments

The software will be capable of presenting the results in tabular as well as graphical form. Descriptive data forms will be prepared for easy preparation of data files. It is proposed to include online help for all the options/sun options at each stage of running the package.



7. Research Outcome of the Project:

A WINDOWS based Software package for flood estimation will be developed. The reasonable accurate estimation of floods by using the methodology and software would certainly be helpful in designing and the construction of economically as technically feasible structures. It is expected that the field engineers will find this package useful.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/01

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

2. **Project Team:**

Project Investigator	**:** Dr. R.J. Thayyen, Sci-E
Project Co-Investigators	**:** Dr. Farooq Azam, Inspire Faculty-NIH (Now IIT Indore)
	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

The winter and summer mass balance data of Phuche and Khardung glaciers were generated during the 2019. The year-end measurements were carried out in the month of September and data is being processed. Both the glaciers experienced extended snow fall in the months of May and July which resulted in the significantly less melting over the glacier during the reporting period. The data for estimating energy balance is also generated using two AWS on these glaciers and the data processing is in progress. The data retrieved from glacier ice temperature profiler suggest that the glacier is a cold glacier. Temperature lapse rate studies were carried out using the temperature measured over the glacier with that of two valley bottom stations which suggest that the localized effect of glacier on the temperature lapse rate is limited to early melt period and when the snow cover reduced to glacier elevations, temperature lapse rate gets higher, similar to the lower elevation station in the non-glacier zone. This suggest that the temperature regime of the glacier during the peak melt period is governed by the local valley –ridge process.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/02
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 'G', NIH, Roorkee
6. Dr. A. R. S. Kumar, Scientist 'F', 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 'C', 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 first important task in 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. 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.

Present Progress

All the hydro-meteorological data (IMD and CWC) for various stations in/around the Upper Ganga basin has been imported in HYMOS data processing systems and processed using various techniques. The spatial correlation among rainfall stations has been developed and stations within close vicinity, with good correlation (say, > 0.7), and with significant concurrent observations of rainfall have been identified for gap-filling of the missing data and for development of double-mass curves. Using surrounding stations with good correlation, spatial homogeneity tests have been conducted for all stations in the Upper Ganga Basin and outliers have been identified. A list of in the observed data at various stations has been compiled and provided to all sub-projects that are using the rainfall data for different purposes. Subsequently, gaps in the observed data have been filled using the spatial-filling-in technique and double mass curves have been prepared for all the stations. The double mass curves have been found to be deviated especially for the stations Nandkeshari, Uttarkashi, Badrinath, Narendranagar, Karanprayag. A view of the original and corrected double mass curves is shown in Figure – 1. After analysis and correction of data with double mass curve, the trend analysis is in progress for different stations.

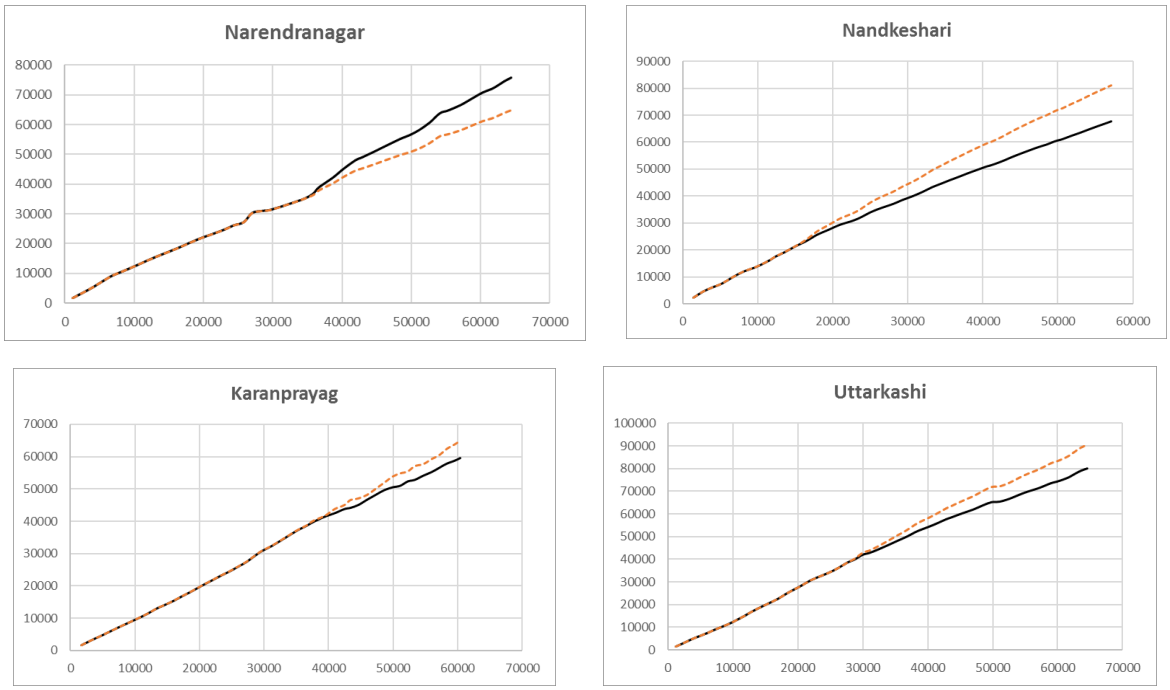


Figure – 1: Original and corrected double mass curves of a few rainfall stations

Project website is being continuously upgraded. Recently the webpage has been linked with the advanced We-GIS tool for display of snow cover information in the study basin since the year 2000. In the metadata section, options have been included for the visual display of data availability at a station. For example, the data availability of the Chaukhutai IMD rainfall station is depicted in Figure – 2. It helps in locating the gaps in the available data at a station. Data availability charts for IMD stations have been completed while the same for CWC stations are being incorporated.

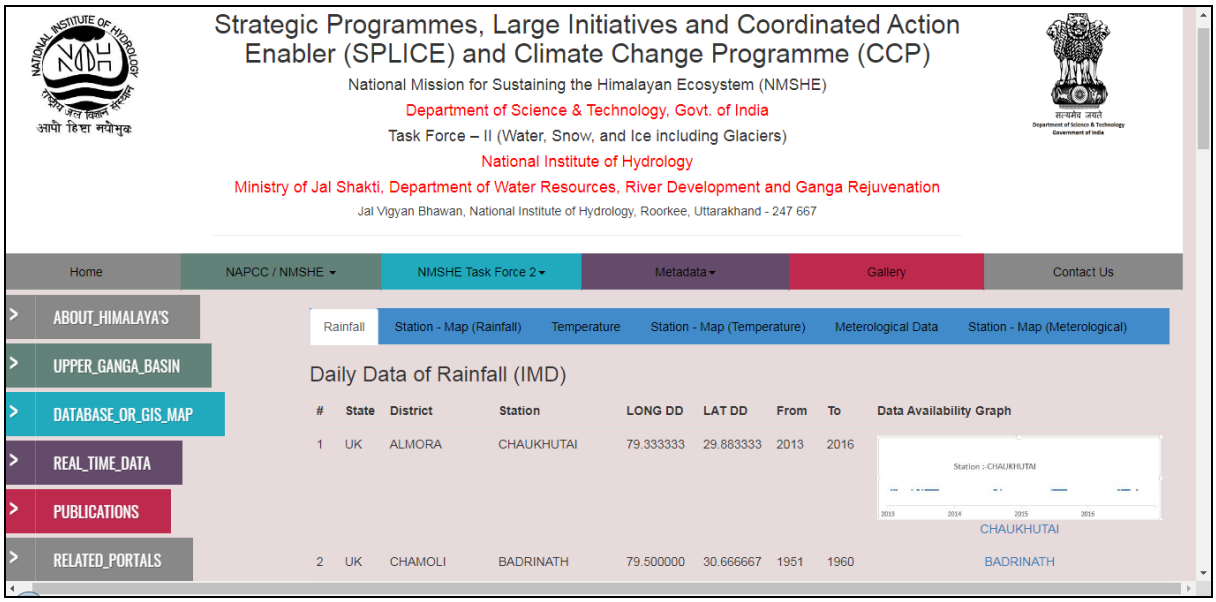


Figure – 2: A screenshot of the NMSHE website showing the data availability chart

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/03
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. "G" V.S. Jeyakanthan, Sc. "E" L.N. Thakural, Sc. "C"
c)	**Project Staff (JRF)**	Asish Bhandari, JRF Shravani Singha, JRF

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

Date of commencement of project: January, 2016
Duration of the project: 5 years

6. Statement of Problem

To study long-term snow cover extent variations, long-term and high temporal resolution snow cover maps are needed. MODIS data repository spans over nearly 17 years and highly suitable for hydrological studies. However, high temporal resolution data have coarser spatial resolution and introduces error due to mixed pixels. The data may be compared to better spatial resolution satellite data to assess its accuracy. The information generated may be further disseminated to stakeholders through web technology.

7. Present state-of-art

MODIS snow products, namely snow extent, snow fraction and grain size are available in public domain. Snow grain size has been utilized in modifying cloud mask and thus in post processing of the snow extent. Post processing algorithms also utilize filters and altitude masks. An web application developed by ICIMOD disseminates monthly snow statistics for basins in Hindu- Kush Himalaya.

8. Methodology

Satellite remote sensing imagery will be used for the extraction of snow extent and snow cover. Various techniques e.g. NDVI-NDSI regions for snow underneath forests, comparing multi spatial-resolution images for fraction snow cover determination etc. will be employed. Snow extent and its statistics will be published using Web GIS software such as Geoserver, Open layers, GeoExt etc. In addition, the available web services of spatial data e.g. Open Street Maps, Google maps etc. will also be utilized.

9. Location map/ study area

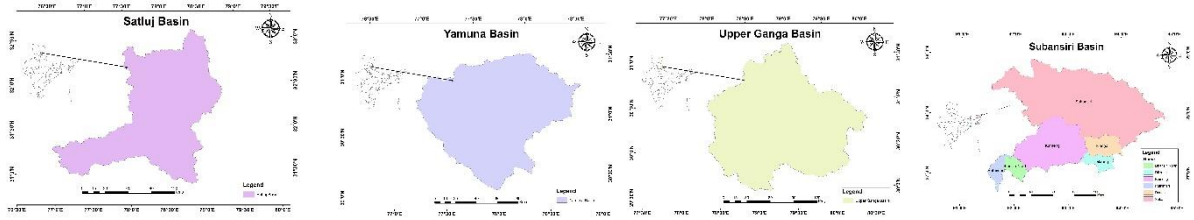


Fig. 1: Study basins: Satluj, Yamuna, Upper Ganga and Subansiri and adjoining basins.

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
2018-19	Snow extent methodology	Using a semi- automatic post processing procedure, implemented in R for altitude-based masking and temporal filter, post processing of MOD10A2 snow extent was done for Satluj, Yamuna and Subansiri basins. Eight-day median snow extent was estimated. Seasonal mean snow extent was estimated for gap filled time series.

Table 1: Snow cover trend and p-values

Basin	Oct-Nov	Dec-Jan	Oct-Jan	Feb-Mar	Mar-Jun
Satluj	-ve, 0.94			+ve, 0.62	+ve, 0.29
Yamuna	+ve,0.94			+ve,0.62	+ve,0.89
Upper Ganga	-ve, 0.94			-ve, 0.53	+ve, 0.62
Subansiri	-ve, 0.12	-ve, 0.14	-ve, 0.12	-ve, 0.94	

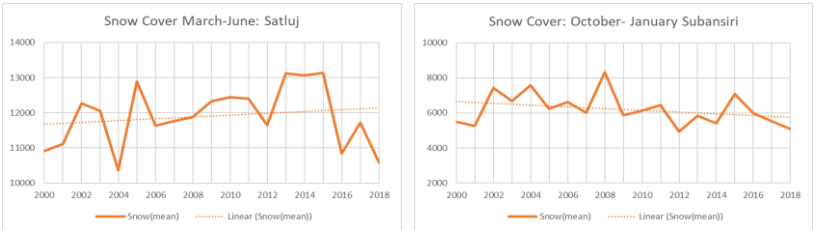
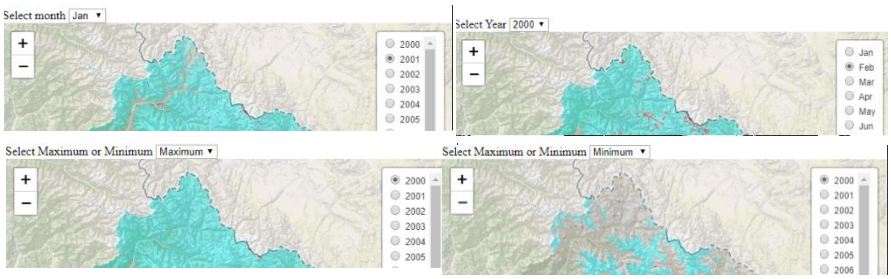


Fig. 2 Snow extent: Satluj (Mar-Jun), Subansiri and adjoining basins (Oct-Jan)

2018-19	Web GIS application	The web application was developed using leaflet javascript library for maximum, minimum and month wise for each year and year wise for each month, mid-February and mid-September for visualization of snow extent. A Terrain base map was also added.  Fig. 3 Snow extent web Application for Upper Ganga

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/04
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 'G', NIH, Roorkee - PI
2. Dr. A. K. Lohani, Scientist 'G', NIH, Roorkee – Co-PI
3. Dr. Sudhir Kumar, Scientist 'G', NIH, Roorkee
4. Dr. P. Thakur, Scientist 'D', IIRS, Dehradun

Project Staff (JRF) Mr. Amit Shukla, JRF

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 outburst.
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 outburst 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

This project includes four study basins: Sutlej, Beas, Chenab and Ganga. Image processing of these Glacier maps for all the basins have been carried out. The NDSI map and slope map have been prepared. Using these maps, GLIMS maps and Google maps, delineation of the glaciers for have been completed.

The inventory of glacial lakes in the basins i.e. Satluj, Beas, Upper Ganga and Chenab have been prepared. These lakes were further classified on the basis of area and altitude. The vulnerable lakes in the basins have been identified. Vulnerable lakes in the basins have been identified on the basis of area change, location and other conditions and shown in the figure1 Chenab basin.

The data base for hydrodynamic modelling for these lakes have been prepared. The simulation of GLOF for Chenab basin have been carried and for Beas basin under progress and the results will be presented during the meeting.

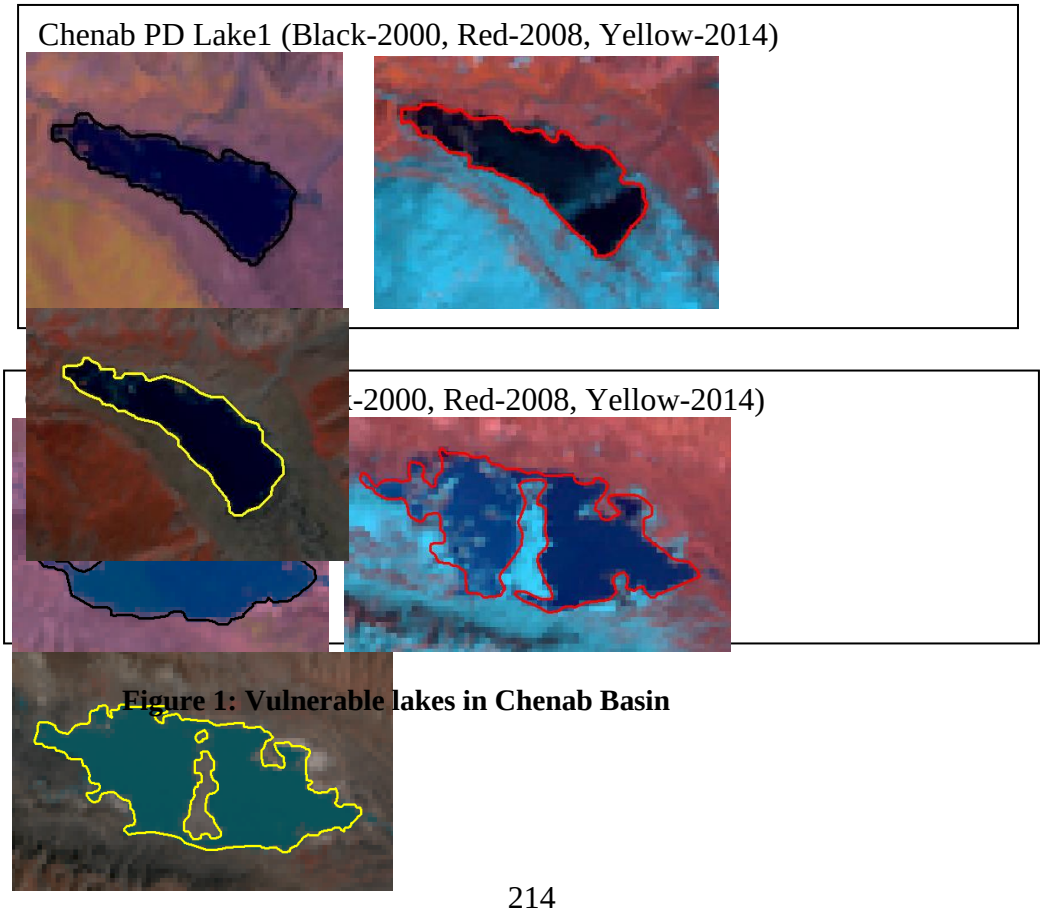


Figure 1: Vulnerable lakes in Chenab Basin

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/05
NMSHE STUDIES

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
    1. Dr. R. J. Thayyen, Scientist 'E', NIH, Roorkee - PI
    2. Dr. Sanjay K. Jain, Scientist 'G', NIH, Roorkee – Co-PI
    3. Dr. Sharad K. Jain, Director, NIH, Roorkee
    4. Dr. P. K. Mishra, Scientist 'C', NIH, Roorkee
    5. Dr. M. Arora, Scientist 'D', NIH, Roorkee
    6. *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

During the reporting period focus of the project was on runoff modelling at Maneri using the bias corrected temperature and precipitation data received from JNU collaborator. Initial simulation done for the period of 30 years (1990-2020) using SPHY hydrological model has been improved. In SPHY model HydroSheds SRTM DEM at 90 m spatial resolution is used for the generation of basin boundary, elevation information, slope and routing file generation. Randolf Glacier inventory 5.0 is used to demarcate the glacier cover area. Sentinal -2 multispectral remote sensing data has been used for the calculation (Kamble et al., 2013) of crop coefficients (Kc) for the individual land cover class. Which is further used to simulate potential evapotranspiration. Global soil maps from the Harmonized world soil database (HWSD) has been used to generate different root zone soil parameter's (Field Capacity, saturated content, permanent wilting point, wilting point & saturated hydraulic conductivity) and subzone physical soil parameters (field

capacity, saturated content & saturated hydraulic conductivity) for the study area. For the preliminary run, constant values have been taken for root layer thickness, sub layer thickness and ground water parameters as we don't have spatially distributed data. JNU-subproject has delivered bias corrected temperature and precipitation of RegCM4.5 RCM for 07 stations for which data was supplied to JNU. Future projections up to 2100 also been received. Now, the work is in progress to model the runoff using the bias corrected data.

Preliminary runs using the bias corrected data is also performed. Earlier results of the model run using REMO data has given snow contribution of 50%, Glacier - 14% followed by 30% rain and 2% base flow for 1990-2020 period. The model run using bias corrected RegCM4.5 CLM for historical period (1975-2005) has given snow contribution as 70%, Glacier-16%, Rain- 10% and base flow 4%. Significant change is noticed for snow and rain contributions. These values will be refined further by forcing temperature at higher elevations using the locally observed lapse rate (Currently 6.5 k/km is used) and topography controlled precipitation distribution. Once the historical period is calibrated and future runoff projections will be taken up.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/06
NMSHE STUDIES

1. **Thrust Area:** Himalayan Hydrology

2. **Project Team**

Project Investigator	**:**	Dr. Sharad K. Jain, Director
Co-Project Investigator	**:**	Dr. R. J. Thayyen, Scientist 'E' & TL
Project Co-Investigators	**:**	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. Surjeet Singh, Scientist 'E'
	:	Mr. M. K. Nema, Scientist 'C'
	:	Dr. P. K. Singh, Scientist 'D'
	:	Dr. P. K. Mishra, Scientist 'C'
	:	Mr. P. K. Agarwal, Scientist 'B'
	:	Dr. A. P. Dimri, Professor, JNU
	:	Dr. (Mrs.) Sangeeta Verma

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**

Complex Climate – Hydrology interaction in the mountains is due to closer and dynamic land-atmospheric exchange on account of orographic updraft and drainage winds. Indian Summer and Winter Monsoon 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 contribution to the anthropogenic forcing till date. There is a clear need 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 of the water cycle; starting from the seasonal atmospheric water budgeting, atmosphere-land surface interaction and feedback, surface water balance, soil moisture-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:

During the period roughness length for momentum (Z_{0m}) is estimated using wind speeds for a valley bottom and a mountain ridge site in a lesser Himalayan experimental catchment. Results indicated that Z_{0m} is comparatively higher at the valley bottom site (Nagini) in the range of (0.010 – 0.497) than the values observed (0 - 0.069) for the ridge site (Kumargaon). Seasonal variations are observed at both the stations indicating its higher value for high LAI in the leaf-on season and lower values for low LAI in the leaf-off season. At valley bottom site, the seasonal increase is higher during kharif cropping as compared to the rabi cropping whereas, at Kumargaon, this increase is visible only in the rainy season due to natural vegetation growth. The changing height of vegetation and consequently LAI in different seasons is the most important factor for seasonal variations in Z_{0m}. On diurnal basis, Z_{0m}varies differently in different season due to changing wind speed and direction. Heterogeneity of the terrain causing fluctuations in Z_{0m} is more evident at Kumargaon. Atmospheric stratification and instability is another factor responsible for diurnal variation of Z_{0m}.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/07
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 'C', NIH, Roorkee - PI
2. Dr. Renoj J. Thayyen, Scientist 'E', NIH, Roorkee Co-PI
3. Er. M. K. Nema, Scientist 'C', NIH, Roorkee
4. Dr. Pradeep Kumar, Scientist 'C', NIH, Roorkee
5. Swagatam Das (JRF)
6. Hemant Singh (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	
	I	II	I	II	I	II	I	II	I	II
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

- Following field survey at village level have been completed during 2017-18, 2018-19 & 2019-20:
  - 27 villages in the Henvel valley (Tehri Garhwal) during 26-30 December, 2017
  - 22 villages in the stretch between Uttarkashi to Harsil during 02-07 January, 2018.
  - 39 villages in the Chamoli district (Joshimath) during 13-22 April, 2018.
  - 42 villages in Pauri Garhwal region during 07-13 July, 2018.
  - 05 villages in Tehri Garhwal region during 13-15 August, 2018.
  - 39 villages and 131 Household level schedules in Rudraprayag district during 04-11 June, 2019
- Field visit for the Rudraprayag district completed.
- Reported extreme events during Monsoon (June-Oct) during 2019 identified and geotagged.
- IPCC based Livelihood Vulnerability Index (LVI) estimated using 7 major indicators (viz. Demographic, Water, Health, Livelihood, Social Network, Food, Climate and Natural disaster) and 25 sub-indicators. A comparative analysis is done on the adaptive capacity, sensitivity and exposure for three blocks (Augustmuni, Jakholi, Ukhimath) of Rudraprayag district.
- Household level surveys for the four districts (Uttarkashi, Chamoli, Tehri Garhwal, Pauri Garhwal) is under progress.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/08
NMHS STUDY

1. Title - Dynamics of Himalayan Ecosystem and its impact under changing climate scenario- Western Himalaya

2. Project team

National Team

Lead : Prof. A. P. Dimri, SES, Jawaharlal Nehru University, New Delhi, India
Co-Lead: Dr. Renoj J. Thayyen, National Institute of Hydrology, Roorkee, Uttarakhand, India

Institutional PI's

Dr. Subimal Ghosh (Indian Institute of Technology, Mumbai, Maharashtra, India)
Dr. Renoj J. 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. 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 (upto ~ 2100)
4. Identify ecological restoration strategies to adapt to future climatic scenarios
5. Communicate findings to stakeholders

4. 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 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))

5. Methodology (NIH)

Objective 1: NIH component of the project to install 50 AT/RH stations and 10 rainfall stations in the western Himalaya and develop data.

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.

6. 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.

7. Cost Estimate:

Total cost of the project:	Rs. 2.1 Crore
a. NIH	Rs. 58.76 Lakh
b. Source of funding:	NMHS-MoEF

8. Progress of the project

Under this project 43 air temperature/ Humidty (AT/RH) stations were installed along five cross profiles covering U.K and H.P such as 1) Dak Pathar – Rohru 2) Dak Pathar- Kharsali 3) Roorke-Jhala 4) Kotdwara – Phata 5) Kathgodam- Joshimath. 13 stand alone stations were installed in the western Himalaya including Ladakh and Kashmir. During the reporting period, AT-RH sites in the Ladakh region was visited for data downloading. Number of other stations also visited for data upgradaion. Collected data is processed and Lapse rate values of selected pairs were appended. Regional characteristics of temperature lapse rate is coninue to evolve with this new data set. Distint variations in the lapse rate of cold-arid regions of Kashmir and more wetter regions are reinforced with the new data collected this year. Disctinction between the lapse rates of local valley-ridge stations compared to ridge to ridge and regional valley-ridge stations are also observed. The lapse rate variations of various topoclimatic regimes are highlighted here. The summer lapse rates of the monsoon regime range between 6.6 to 5.5 K/km while for Cold-arid regime it vary between 7.7 to 9.6 K/km. Highest SELR is observed for the station pair Pandrass and Gumri as well as kargi/ Gumri ranging between 11.1 to 13.5 K/km. These stations liw on the northern slopes of the Great Himalayan range. In contrast, the southern slopes of the Great Himalayan range between Gagangor and Gumri SELR during the same period renage between 7.5 to 6.1 K/km showing the distinction between different topoclimatic region of the Himalaya. In the monsoon regime the SELR between the base station with the ridge stations are signigficantly differ from the that of the valley bottom stations. Similarly, local valley- ridge SELR is found to be different from regional SELR. The results are based on only once season and expected to improve with more data and seasons in future.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/11

1. Title of Project: Investigating water stress using hydro-meteorological and remote sensing data, Purpose Driven Study (PDS), National Hydrology Project (NHP)

2. Project team:

a) Principal Investigator:	Mr D.S. Rathore, Sc F
b) Project Co- investigators:	Dr. L.N. Thakural, Sc C
	Dr. Sanjay Kumar, Sc E
	Mr. R. K. Jaiswal, Sc D
	Dr. M.K. Jose, Sc D
	Dr. T. Chandramohan, Sc D
Partner Organization:	Water Resources Department, Rajasthan
Principal Investigator:	Sh Sanjay Agarwal, Deputy Director
Co- investigators:	Sh Shailesh Awasthi, Assistant Engineer

3. Statement of the Problem

Large part of states such as Maharashtra, Karnataka and Andhra Pradesh in Peninsular India are affected by drought condition frequently. Due to availability of surface irrigation, large areas in Andhra Pradesh and some areas in Maharashtra and Karnataka, the drought conditions are mitigated. Droughts and water stress conditions have socio- economic and environmental effects, necessitating scientific investigation of the conditions and mitigating it. Drought mitigation measures are moisture conservation, reduction in water demand and increase in supply.

4. Objectives

- Characterizing water stress using hydro meteorological, remotely sensed data and vadose zone modeling
- Analysis changes in water stress conditions due to drought response and mitigation measures
- Field level measurements of vadose zone moisture
- Forecasting and regionalizing drought indices
- Devising reservoir operating policy

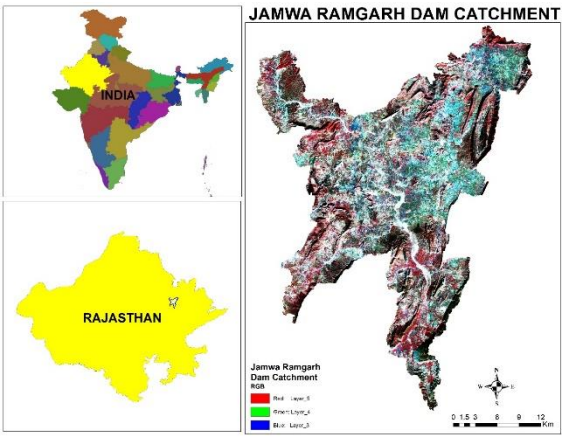
5. Present State-of-Art

Drought indices e.g. SPI, SODI, ADI, NADI utilize hydro-meteorological and NDVI, NDWI, VCI, TCI, SMADI, VTCI, VAI etc. utilize remotely sensed data. PCA, clustering and DIT techniques were used for regionalization of indices. Forecasting of the indices was done using ANN, SARIMA and ARMA techniques.

6. Methodology

Drought indices will be estimated using hydro-meteorological and remote sensing data. Field experiment will be done to study soil moisture profile and relate this information with drought indices. Water movement will be simulated in vadoze zone. Soil moisture condition will be simulated with varying cropping pattern. Regionalization and forecasting of the indices will be carried out.

7. Location map/ study area



Jamwa Ramgarh reservoir catchment is selected as study area. The dam is located on Banganga river. The study area falls in Jaipur district of Rajasthan. Area is located in East Rajasthan meteorological sub- division. Main aquifer system consists of alluvium. Quartzite, gneiss, schist and granite have localised occurrances. Catchment area is nearly 820 sq. km. The dam was built in 1903. The reservoir is dry since 2006. Mean annual rainfall is 492 mm with 36% COV. Normal annual rainy days are 110.

8. Approved action plan and time line

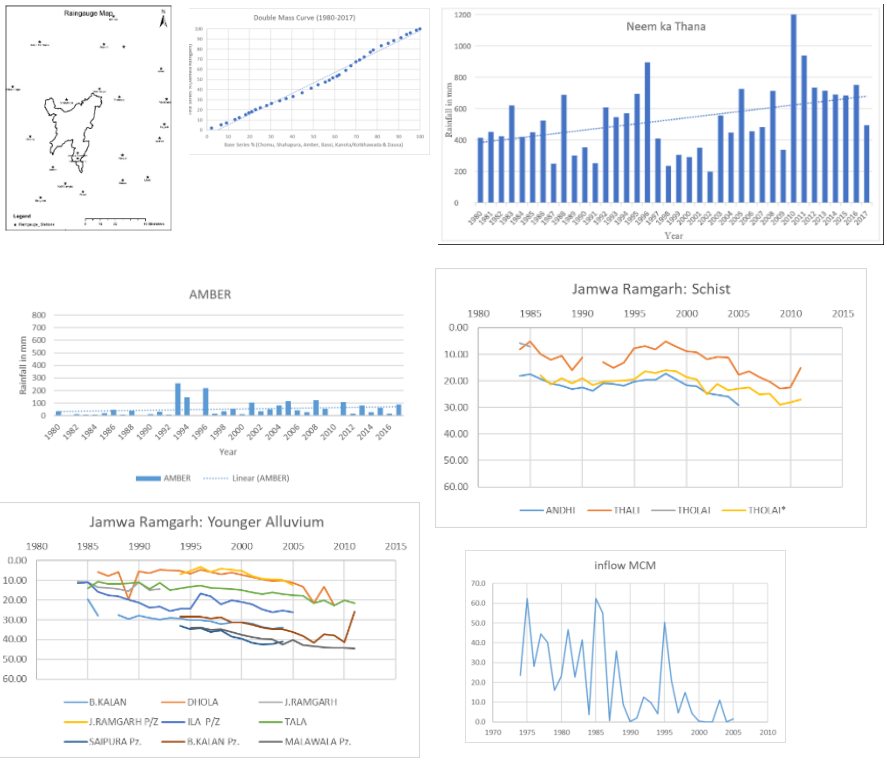
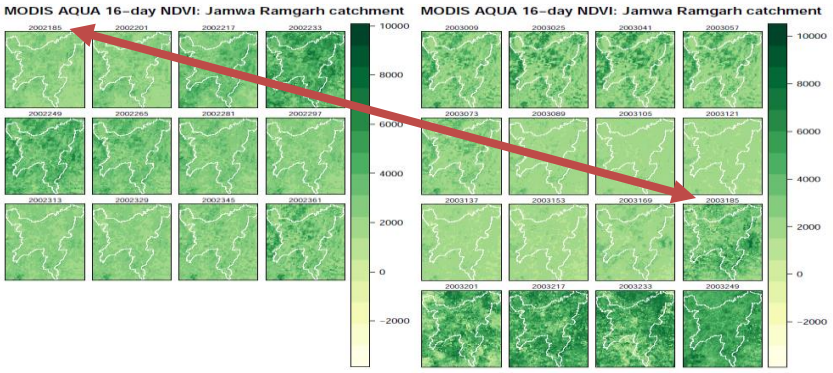
Activity	1st yr				2nd yr				3rd yr			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Data collection												
Satellite data procurement												
Field observation												
Data pre processing												
Computation of drought indices												
Regionalization of drought indices												
Forecasting												
Drought identification												
Unsaturated zone modeling												
Reservoir operation												
Scenario analysis												

9. Recommendations / suggestions in previous WG

None

10. Achievements

Year	Objectives	Achievements
2018-19	Data preprocessing	Data validation was carried out for daily/ yearly outliers, spatial homogeneity (daily) and double mass curve (Fig. 2b). Trend analysis was done for yearly and monthly data. Significant trend was observed for June rainfall at Amber and annual rainfall at Neem Ka Thana (both increasing) (Fig 2 c-d). Reduction is groundwater level (post monsoon) was of order of 10 m in 25 years in Younger alluvium and schist (Fig. 2 e-f). Inflow (Fig. 2 g) and storage in Ramgarh reservoir has decreased over time.

		 Fig. 2 a. Rainguge stations b. Double mass curve Jamwa Ramgarh c. Yearly rainfall (Neem Ka Thana) d. June rainfall Amber e. GW depth Schist (post monsoon) g. GW depth Alluvial (post monsoon) h. Inflow Jamwa Ramgarh
	Computation of Drought Indices	MOD13Q1 16-day NDVI time series for the study area was visualized using R-script (Fig. 3).  Fig. 3 MOD13Q1 16-day NDVI plots for years 2002 and 2003

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/12

1. Title of the Study: Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

2. Study Group **:** Dr Manohar Arora, Sc 'D'
Dr Sanjay Kumar Jain, Sc 'G'

3. Role of Team Members:

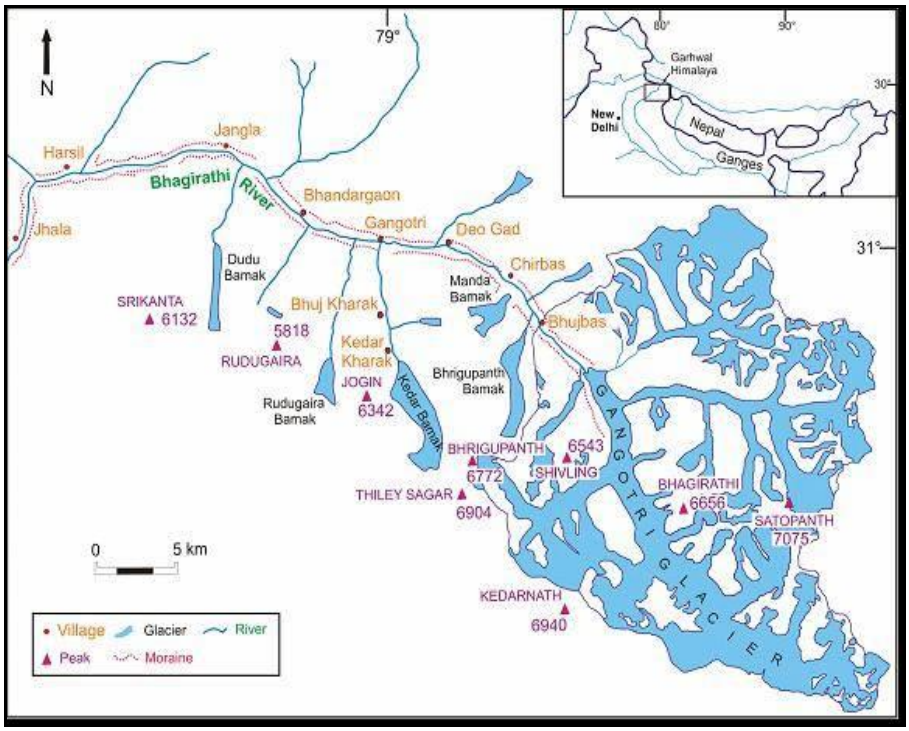
Dr Manohar Arora, Sc-D&PI: Conduction field investigations, analyzing data/information, report preparation and overall responsible for the study completion.

Dr Sanjay Kumar Jain, Sc-G & Co-PI: Guidance in development of methodology, modelling and structuring of report.

4. Type of Study **:** Internal. Project will be submitted to DST for funding.

Date of start **:** 01.04.2018
Scheduled date of completion: 31.03.2021.

5. Location Map:



6. 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.
- Seasonal characterization of the glacier melt.
- Estimation of suspended sediment yield from the Glacier.

- Modeling the catchment runoff variation under different climatic scenarios.

7. Action Plan

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

8. Objectives vis-à-vis Achivements:

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 collection and field investigations for the year 2019 commenced in the month of May 2019 and were carried out till 3rd October 2019.
To improve the hydrological model for simulating daily streamflow	The simulation of flow will be carried out after collection of three years of data.

9. Adopters of the results of the study and their feedback

The study is a sponsored study and the results will be disseminated by DST.

10. Lab facilities during the study

Analysis of suspended sediment samples will be carried out in Soil Lab.

11. Data generated in the study

Meteorological and hydrological data for the Gangotri Glacier.

12. Study Benefits/Impact

The meteorological and discharge data would be utilised in studying the characteristics of the Gangotri glacier under changing climate.

13. 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.

14. 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.

14. 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.

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/1

1. Title - Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya

2. Project team

NIH:
Dr. Sanjay K Jain, Dr. P. K. Singh, Dr. Manohar Arora, Dr. Renoj J. Thayyen, Dr. A K Lohani, Dr. Vishal Singh and Ms. Suman Gurjar

Partners:
Prof. A. P. Dimri (Jawaharlal Nehru University, New Delhi, India)
Dr. Yadav, JNU, New Delhi and Central Agricultural University (CAU), Ranipool, Sikkim

3. Project duration: 3 years (11/19-11/20)

4. Objectives

The proposed project will adopt an inter-disciplinary approach to address the following objectives, in particular for the Teesta basin within the eastern Himalayas:
The objectives of this study are:

1. Assessment of recent changes in snow, glacier, rainfall and its impact on the hydrology of the Teesta basin through Hydrologic modelling.
2. To understand the influence of glacier size, debris cover, topographic (i.e., altitude, aspect, and slope) and climatic variables on recent glacier changes?
3. Sediment transfer characteristics of Teesta River at selected sites and identification of major drivers.
4. Assessing climate change in the basin and future scenarios and resultant hydrological responses
5. To understand and simulate the magnitude of the GLOF hazard of glacial lakes formed due to glacier recession using MIKE-II breach modeling.
6. Identification of key change indicators for water resources of the region and their impact on local communities

5. Methodology (NIH)

In the present study, modelling of snow/glacier melt runoff, sediment sampling and modelling, climate change studies, impact of climate change and glacier lake outburst flood are proposed. The methodology for these is described in the following sections.

Snow/glacier melt runoff modelling
A number of models are available for snowmelt runoff modelling. In the proposal work, Snowmelt model (SNOWMOD) and VIC models will be used for estimation of stream flow in the basin.

Sediment yield monitoring and assessment
This study has been formulated to understand the suspended sediment dynamics and assess the sediment potential on spatial and temporal scales in Teesta basin and its selected tributaries during monsoon season, and its contribution to annual suspended sediment loads along with identification of critical areas of erosion and deposition.

Future climate change scenarios

For studying impact of climate change future scenarios are needed. Climate scenarios are sets of time series or statistical measures of climatic variables, such as temperature and precipitation, which define changes in climate. Many methods have been developed for generating climate scenarios for the assessment of hydrologic impacts of climate change, which include downscaled general circulation model (GCM) simulations. GCMs are used to generate projections of future climate change on a large spatial and temporal scale (several decades).

Impact of climate change

In order to provide an indication of the extent of impacts of climatic change on water resources, Stream flow represents an integrated response to hydrologic inputs on the drainage basin. The climate change impact assessment is carried out using the scenarios developed by climate models. The validated model will be used to generate the stream flows at the outlet for the current as well as future periods by using the downscaled precipitation and temperature data.

Glacial Lake Outburst Flood

The objective of GLOF study is defining the foot-prints of climatic change in Teesta Basin and analyzing the Glacial Lake database to identify the vulnerable lakes and their possibility of outburst under different causative modes.

6. Research Outcome from the project

- Snow and glacier extent and changes
- Snow and glacier melt contribution
- Glacial lake outburst flood
- Sediment status in the basin for enhancing watershed dependent ecosystem services
- Future climate change scenarios and water resources availability
- Identification of key change drivers and their impact on local communities

7. Cost Estimate:

Total cost of the project:	Rs. 1.43 Crore
a. NIH	Rs. 101.38 Lakh
b. Source of funding:	NMHS-MoEF

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/2

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
   a) Dr. R. J. Thayyen, Scientist 'E', PI-NIH
   b) *Prof. A. P. Dimri, PI-JNU*
   c) Dr. Sanjay K. Jain, Scientist 'G', NIH, Roorkee – Co-PI-NIH
3. **Title of the Project:** Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin
4. **Objectives:**
   1. Seasonal variations in Cryosphere mass over Indian Himalayan Region (IHR) and Hydrological linkage in the Upper Ganga basin
      a. Seasonal Snow loading and unloading estimation from GRACE and comparison with other RS products
      b. Seasonal mass fluctuation of glacier regime and regional mass balance assessment
      c. Seasonal soil moisture fluctuation in the basin with an emphasis to ISM (JJAS) and IWM (DJF)
      d. Inter-comparison between seasonal river runoff and basin scale mass anomaly from GRACE
5. **Present state-of-art**

The project is proposed to study the Upper Ganga basin up to Devprayag covering 18715 km^2 area having 2211 km^2 of glacier cover. Upper Ganga basin is a critical water resource for the country having nearly 950 glaciers and huge snow cover. This region plays an important role in keeping the Ganga "Aviral and Nirmal" and the response of the Ganga cryosphere under the changing climate is a crucial parameter in sustaining the health of river Ganga. Study of glacier mass change is often carried out on individual glaciers and hardly provide tangible input to the linkages between the glacier change and downstream hydrology (Thayyen and Gergan, 2010). Need of the hour is a tool to assess the regional response of glaciers and cryospheric system of the basin which cannot be surveyed or studied on the ground due to unassailable topography. The Gravity Recovery and Climate Experiment (GRACE) data could be a very useful tool in this regional scale analysis. Seasonal variations in the mass change over the basin will be analysed and linkages with regional hydrology will be established in the present study thereby overcoming a huge disadvantage of the present study models.

6. **Methodology**

First of all we will define snow season i.e. the time period from the start date (t_0) of snow accumulation to the breakup date (t_b) snowfall. The first snowfall precipitation event is determined when the daily average air temperature Ta is below 0°C and the mean Ta after this date remains negative. The breakup date of snowfall will be defined when the daily mean air temperature Ta rises above 0°C and the Ta after this date remains above zero. The net snow mass after the date of snow accumulated by snowfall, snow sublimation, blowing snow, etc., over the region (Wang et el., 2017). Total basin water storage (TWS_o) at start date of accumulation at t_0 and TWS_b at breakup date of accumulation t_b will be estimated by the GRACE TWS data. From winter peak (March) to summer low (October) cryospheric mass changes will be resulted in marked depletion in TWS detected by GRACE over the glacier area specific region. The TWS

change will be represented the integrated change of soil moisture, Snow water equivalent (SWE), and glacier mass change in the region. The remotely sensed data will be used such as MODIS snow cover product (SCA) (https://reverb.echo.nasa.gov/) and advance microwave observations (AMSR-E) SWE as calibration or validation of the GRACE data. These snow data (SCA and SWE) will be used to provide information regarding the distribution of snow in the basin. Moreover, the GRACE data will be used to represent the seasonal variation of TWS for the basin.

The information derived from snow season, amount of water storage change, and baseflow rate will be made to determine the snow mass change. Following equations will be used to calculate the Snow Water Equivalent (SWE)/Snow mass:

$$S_b = Q_{sum} + TWS_b - TWS_0$$

Where TWS_o and TWS_b are the total water storage change at t_0 of snow accumulation to the breakup snowfall date (t_b) in the snow season. The TWS_o represents the maximum amount of non-snow water in the basin during the snow season. It mainly consists of the surface water (e.g., in rivers and lakes), soil water, and groundwater, which will be discharged out of the basin in the snow season. The TWS_b represents the sum of snow mass accumulated during the snow season and the non-snow water left in the basin at time t_b. The total water discharge in the snow season, Q_{sum} can be calculated as:

$$Q_{sum} = \int_{t0}^{tb} Q_{base}(t)dt = TWS_0 - (TWS_0 - b)e^{-a(tb-to)} - b$$

Q_{base} is the winter baseflow rate component which is used in the peak river flows and floods estimation.

$$Q_{base}(t) = a(TWS_0 - b)e^{-at}$$

Where a in this first order differential equation represents the lump conductivity of the basin for water discharge, and b represents the threshold value of the change of non-snow water in the basin at which the basin discharge would be zero.

The snowmelt rate is estimated at a daily time step by the following temperature index model:

$$M(t) = \min[S(t), \alpha(T_a(t) - \beta)]$$

Where M(t) is the daily snowmelt rate, S(t) is the amount of snow mass available for melting on day t, β is a parameter representing the base temperature for snowmelt, and α is a parameter representing the snowmelt rate per unit of Ta above β. The S(t) is calculated as S(t-1)-M(t-1) with the initial value of S(0) = Sb. This assessment will be tested with the observed seasonal variations in the river flow.

7. Research Outcome from the project:

It will add on existing knowledge of remotely sensed information used for glacier and hydrological purposes over the Himalayan region. Since implementation of GRACE information is yet to be ascertained for glacier and hydrology over the Himalayan region, so a basin level studies integrated with the existing work/study going on can lead to better assessment. It will also be of added help to share the knowledge attained thus to share with State councils.

8. Cost Estimate:

Total cost of the project:	Rs.4639200/-
NIH	Rs. 2319600/-
JNU	Rs. 2319600/-
b. Source of funding:	NRDMS-DST

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/3

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
    a) Dr. R. J. Thayyen, Scientist 'E', PI-NIH
    b) Prof. A. P. Dimri, Co-PI-JNU
    c) Dr. G. Jeelani Co-PI Kashmir University
    d) Dr. V. Agnihotri,GBPNI

Collaborating Institutes:

a) National Institute of Hydrology (Lead)
b) Jawaharlal Nehru University, New Delhi, India (Co-Lead)
c) Kashmir University, Srinagar, Jammu and Kashmir, India-Member
d) G.B. Pant National Institute of Himalayan Environment &
    a. Sustainable Development, Kosi-Katarmal, Almora, UK, India- Member

3. **Title of the Project:** Permafrost mapping and characterisation of Ladakh Region

4. **Objectives:**

1. Modelling of permafrost extent in the Leh district of Ladakh.
2. Modelling of active layer thickness of Permafrost in the selected study sites
3. Regional climate modelling and fluxes over permafrost regions
4. Assessment of water quality and bio-geochemistry of permafrost horizon with special emphasis to DOC, DOM, DON and DIN in active layer.
5. Assessment of Ground ice melt contribution to Regional Water resources and estimate the sources of local, and transported moisture using isotope technique

5. **Present state-of-art**

Permafrost is unconsolidated sediment or bedrock that remain frozen for at least two consecutive years. Permafrost occurrence in the arctic and high mountain areas are well known and impact around 25% of the landmass of the northern hemisphere. Number of studies have shown permafrost thawing in the Northern Hemisphere during the past couple of decades. However, Permafrost studies are sparse in the Hindu Kush Himalaya (HKH) region in general and Indian Himalayan Region (IHR) in particular. Permafrost thaw and ground ice melt is an underground phenomenon, which is not visible and there by not appreciated or accounted for in the Himalaya. Hence, its extent and characteristics and implication are not known. Preliminary study in the Ladakh region indicate that the ground ice melt could be significant in the stream flowing in the region. Hence livelihood of the Cold-arid regions are susceptible to the permafrost thaw under a warming regime. Permafrost thaw also could lead to increased landslides and affect climate feedback. Infrastructure projects in the border areas, especially the road built by Border Roads Organisation (BRO) is highly susceptible by recurring damage by the seasonal freeze and thaw. Proposed project is aimed at generating actionable knowledge in the field of permafrost. A multi prone research plan is proposed. Soil temperature measurement and modelling of permafrost in the selected sites in the concerned districts will provide first indication of regional extent of permafrost under varying climate forcing. Active layer thickness and its progression is a key parameter for infrastructure development in the permafrost areas and this will be achieved by modelling. Possible large extent of permafrost in the cold-arid regions of IHR could influence the climate feedback in the area and the study of Surface flux based on Regional Climate Model will provide a much needed basic understanding on this issue. A detailed analysis of isotope and hydro-geochemistry will help in understanding the ground ice melt component in the stream flows and related water quality aspects. Further, study of DOC, DOM, DON and DIN released

by the thawing of permafrost soils will be helpful for understanding the biogeochemical cycles related to the permafrost activity. Overall, the study is aimed at providing a strong foundation for permafrost research in the IHR and key indicators for developing suitable adaptive strategies in terms of water availability and quality as well as infrastructure development in these areas. Project will also strive to impart training for developing manpower in this emerging sector.

6. Methodology

A) Modelling of Permafrost extent and active layer thickness: Permafrost extent can be estimated only through modelling exercise. Soil temperature is the key input data required for this purpose. Number of soil temperature sensors (30 Nos) will be stablished in selected plots across the Ladakh region. Relationship between Potential Incoming Solar Radiation (PISR) and Mean Annual Ground Surface Temperature (MAGST) will be established and spatial permafrost map will be generated using the GIS. Active layer thickness will be modelled by using "GEOtop" 1D model at select sites with MAGST data.

B) Surface flux studies based on Regional Climate Model to integrated assessment permafrost based on the regional climate model outputs, surface fluxes coupled with atmospheric forcing over the study of the region will be analyzed. Rationale over the region of cold desert with sub-surface processes will be defined with the help of model outputs and will be verified with the proposed observations. It should be noticed that over IHR no study thus so far is taken on coupling of atmospheric and surface processes leading to permafrost. Such forcing and process at first scale will be assessed to formulate a link with existing permafrost to late link with available water storage.

C) Estimation of Ground ice melt contribution and moisture source by isotopic method: Water samples of precipitation, snowmelt, glacier melt, groundwater, permafrost, streams will be collected across the study area for the hydrochemistry and stable water isotopic analysis. The samples will be collected in the frozen soil region by means of the excavation of the soil profile, and then the meltwater samples will be collected underneath the soil profile. The precipitation samples (event based) will be collected as rain, except in winter when the samples will be collected as fresh snow. Samples will be also collected from melting of snow packs, groundwater, glaciers, streams, permafrost during field campaigns. The samples will be collected in 50 ml high density polyethylene bottles and were kept in laboratory for proper labelling and coding. The stable isotope ratios of oxygen and hydrogen will be measured in a selected national Laboratory. The results of the stable isotopes will be reported in the standard δ-notation, and will be defined in relation to the Vienna Standard Mean Ocean Water. The End Member Mixing Analysis (EMMA) will be used to quantify the contributions of meltwater from snow, glacier and permafrost to runoff at the basin or catchment level.

D) Assessment of DOC, DOM, DON and DIN estimation in active layer and in permafrost horizon

Soil cores will be collected (using augur and ice corer) at different selected sites distributed across the Indian Himalayan region, cores will be cut in 15 cm thick sections, and deep active-layer and shallow permafrost sections will be thawed and leached. Leachates will be analysed for DOC, TDN, nitrate (NO_3^-), and ammonium (NH_4^+) concentrations. On and off site physico-chemical analysis of water and soil samples will also be carried out. The analysis will be carried out continuously at the same time throughout project duration for understanding the variations of targeted parameters. Data of permafrost leachates DOC, DON and DIN will be compared with that of active layer soil in contact with permafrost top layer. (The sample will be analysed for radioactive isotopes with the help of other Co-PI).

7. Research Outcome from the project:

- Permafrost extend maps of the study region
- Permafrost active layer thickness information at select sites

- Model development for permafrost processes
- Contribution from permafrost to regional water resources
- Regional climate model coupled with permafrost area and surface flux
- Quantification Dissolved Organic matter (DOM), DON and DIN in permafrost soil and meltwater and water quality implications

8. Cost Estimate: 1.97 Crore

Source of funding: NMHS-MoEF

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. A R Senthil Kumar	Scientist F
4	Er. Digamber Singh	Scientist C
5	Dr. (Mrs.) Jyoti Patil	Scientist C (LCU)
6	Sri. Rohit Sampatrao Sambare	Scientist B
7	Sri Subhash Kichlu	PRA
8	Sri Rajesh Agrawal	SRA
9	Sri N R Allaka	RA

Work Programme for the year 2019-20

SN	Title of Project/Study	Funding	Study Team	Duration	Status
			Internal Study		
1	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar (PI) J V Tyagi, S D Khobragade , Manohar Arora	Apr 2015-Mar 2018 (extended upto June 2019)	Completed
2	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	**NIH**: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka **CEH-UK**: Prof. Laurence Carvalho & Team	Apr 2018-Mar 2020	On-going
3	Bathymetric survey of identified ponds in the districts of Muzaffarnagar, Meerut, Ghaziabad and Baghpat (UP) for development of water management plan	NIH	Digambar Singh (PI), Omkar Singh, Rohit Sampatrao Sambare, N R Allaka	Apr 2018-Mar 2020	On-going
			Sponsored Projects		
1	Vulnerability assessment of identified watersheds in Neeranchal Project States	Shifted from NNWP to Plan	Jyoti P Patil (PI)	Jul 2017- Jun 2019	Completed
2	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	DST (under NMSHE)	A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel S. D. Khobragade P. C. Nayak, Manohar Arora	Mar 2016-Mar 2021	On-going
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts of UP	MoJS-sponsored project-Through INCSW	V C Goyal (PI) Omkar Singh, Digambar Singh, Rajesh Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka & Project staff	Apr 2017-Mar 2020	On-going
4	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS-sponsored project (through Plan Budget)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka & Project Staff	Jan. 2018-Dec. 2020	On-going
5	Development of water allocation plan for identified watersheds in	Shifted from NNWP to	A R Senthil kumar (PI) T R Nayak, Jyoti P	Apr 2018-Mar 2020	On-going

	Kanker district (Chhattisgarh)	Plan	Patil, Rohit Sampatrao Sambare, Rajesh Agarwal		
6	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI), Cost: Rs. 5.1 Crore	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sampatrao Sambare **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad	Apr 2019-Mar 2024	On-going

Proposed Trainings/Workshop/Activities:

S.No.	**Name of activity**	Funding	Team/Div.	Period	Venue
1	Inception cum-Need Assessment of IC-EcoWS Project	DST (GoI)	V.C. Goyal (PI) & NIH Team	24-25 June, 2019	NIH Roorkee
2	Networking Project on Rejuvenation of Ponds-Review Meeting	DST (GoI)	Dr. Jyoti Patil, Dr. T. Thomas	14-15 June, 2019	NIH Roorkee
3	National Workshop on Scientometrics	NIH	RMOD/LDOC	Feb 2020	NIH Roorkee

Expected Outreach Activities:

S.No.	**Name of activity**	Funding	Team/Div.	Period	Venue
1	Indian Science Congress	NIH	RMOD	Jan 2020	To be decided
2	India Water Week	NIH	RMOD	Sep/Oct. 2019	Delhi
3	India International Trade Fair	NIH	RMOD	Nov. 2019	Delhi
4	Any other Outreach activity on demand/assigned	-	RMOD		

List of proposed activities under INC-IHP during 2019-20

Meetings to be organised/ attended

1. Meeting of INC-IHP, during May/June 2019, after obtaining approval on re-constitution of committee from the Ministry
2. 24th session of the InterGovernmental Council (IGC) of the International Hydrological Programme of UNESCO, Paris, France
3. 27th meeting of the IHP Regional Steering Committee for Asia and the Pacific, to be held at Myanmar in 2019
4. Participation in Asian GWADI meeting
5. Participation of Indian nominees in various UNESCO meetings

Thematic Trainings:

1. Training course on 'Water Security Assessment' during July 2019 (Location: New Delhi/ Roorkee)
2. Training course on 'Water Education- Key for Water Security' during March 2020 (Location: New Delhi/ Roorkee)

Brainstorming sessions/ exhibitions during conferences/ summits

Sl. No.	INC-IHP proposed event	Conference/ Summit	Host Organisation	Location	Date
1.	Exhibition on R&D in Hydrology, Wastewater treatment	3rd World Water Summit 2019	Energy and Environment foundation	New Delhi	21-23 August, 2019
2.	Brainstorming session on Theme-V 'Ecohydrology- Engineering Harmony for a Sustainable World'	Water future Conference	Sustainable Water Future Programme, Indian Institute of Science, Bengaluru and Divecha Centre for Climate Change	Bengaluru	24-27 September, 2019
3.	Session on 'Enhancing sustainable groundwater resources management'	8th International Groundwater Conference on Sustainable Management of Soil-Water Resources	Department of Hydrology, Indian Institute of Technology, Roorkee	Roorkee	21-24 October, 2019
4.	Theme- Water-related Disasters and Hydrological Changes	International Conference on Soil and Water Resources Management for Climate Smart Agriculture, Global Food and Livelihood Security	Soil Conservation Society of India (SCSI), New Delhi	New Delhi	5-9 November, 2019
5.	Theme- Game-changing approaches and technologies	International Conference on Future Cities	Dept. of Architecture and Planning, Indian Institute of Technology, Roorkee	Roorkee	11-13 December, 2019
6.	Theme- Promoting innovative tools for safety of water supplies and controlling pollution	HYDRO-2019 (Hydraulics, Water Resources and Coastal Engineering)	Dept. Of Civil Engineering, Osmania University, Hyderabad	Hyderabad	18-20 December, 2019
7.	Theme- Water Education- Key for Water Security	Roorkee Water Conclave 2020	Indian Institute of Technology, Roorkee and National Institute of Hydrology, Roorkee	Roorkee	26-28 February, 2020
8.	Celebration of World Water Day		NIH, jointly with UNESCO New Delhi	New Delhi	22 March 2020

Study- 1 (Internal)

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 F, 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 (extended up to June 2019)

4. Whether externally funded or not: No

5. Objectives of the study:

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

6. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Pong reservoir.

7. Brief methodology:

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.

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.

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.

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.

8. Results achieved with progress/present status

The SWAT model is setup with the required input data to simulate the sediment yield from Beas Catchment up to Nadaun bridge (Pong reservoir). The input data such as DEM, LULC and soil type have been generated from different sources such as National Aeronautics and Space Administration (NASA), USA, Landsat 8 OLI, USGS and National Bureau of Soil Survey and Land Use Planning (NBSSLUP), India. Grid based meteorological data such as daily rainfall, minimum and maximum temperatures have been obtained from Indian Meteorological Department (IMD). The model is calibrated using the data of stream flow and sediment yield for the period from 1987 to 1995 and validated with data for the period from 1996 to 2005. The sensitive parameters for streamflow and sediment yield are optimized by SUFI2 algorithm (Sequential Uncertainty Fitting version 2). The simulated values of sediment yield are found to be in good agreement with the observed values. The performance of the model is evaluated on the basis of statistical parameters. The values of coefficient of determination (R^2) for streamflow and sediment yield are found to be 0.82 and 0.64 for calibration period and 0.76 and 0.61 for validation period. The scatter plots for streamflow during calibration and validation are given in figs. 1 and 2. The scatter plots for sediment yield during calibration and validation are given in figs. 3 and 4.

The statistical downscaling model (SDSM) is used to downscale the daily rainfall, minimum and maximum temperature from General Circulation Model (GCM) Coupled Model Intercomparison Project Phase 5 (CMIP5): Canadian Earth System Model, CanESM2. In SDSM, the multiple linear regression (MLR) technique is used to derive the statistical relationships between observed small-scale variables and larger GCM scale. The daily rainfall, minimum temperature and maximum temperature data of Indian Meteorological Department (IMD) (1961-2005) of the Nadaun Bridge, Himachal Pradesh is considered as input to the model. The MLR model has been calibrated and validated with the daily rainfall, minimum and maximum temperature for the period of 1961 to1995 and 1996 to 2005 respectively. National Centre for Environmental Prediction (NCEP) reanalysis data (historical) have been used as a predictor, which consists of 26 parameters. Significant predictors of rainfall, maximum and minimum temperature have been determined using the averaged IMD gridded data of rainfall, maximum and minimum temperature and the rainfall, maximum and minimum temperature from NCEP-NCAR reanalysis data for the period from 1961-2005 by SDSM tool. The significant predictors for rainfall, maximum and minimum temperature are given as follows:

Table 1 Significant predictors for rainfall, maximum and minimum temperature

Variable	Significant predictors
Rainfall	Mean sea level pressure (pa), total precipitation (mm), surface airflow strength (m/s), specific humidity at 500 hpa (%), surface specific humidity (%)
Maximum temperature	Mean sea level pressure (pa), wind direction at 500 hPa, airflow strength at 500 hPa (m/s), vorticity at 500 hPa, geopotential height at 500 hPa (m), mean temp (˚C)
Minimum temperature	Mean sea level pressure (pa), wind direction at 500 hPa, vorticity at 500 hPa, geopotential height at 500 hPa, surface specific humidity (%)

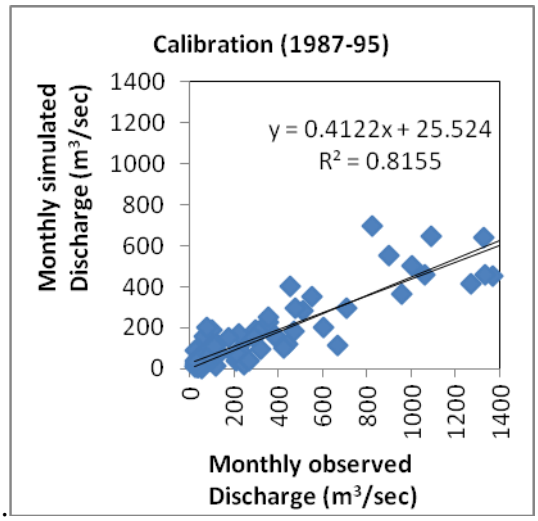


Fig. 1 Scatter plot of monthly discharge for calibration period from 1987-1995

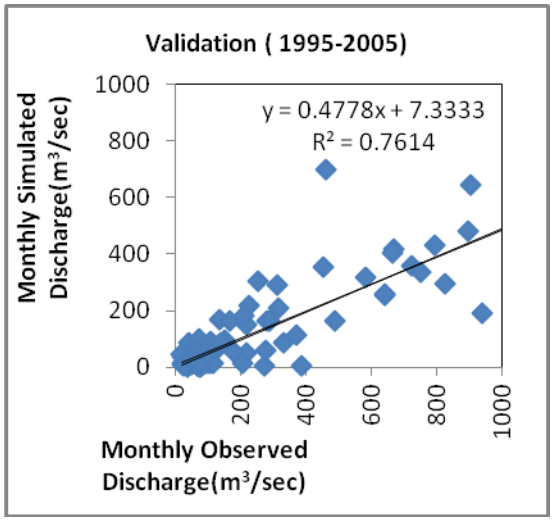


Fig. 2 Scatter plot of monthly discharge for validation period from 1996-2005

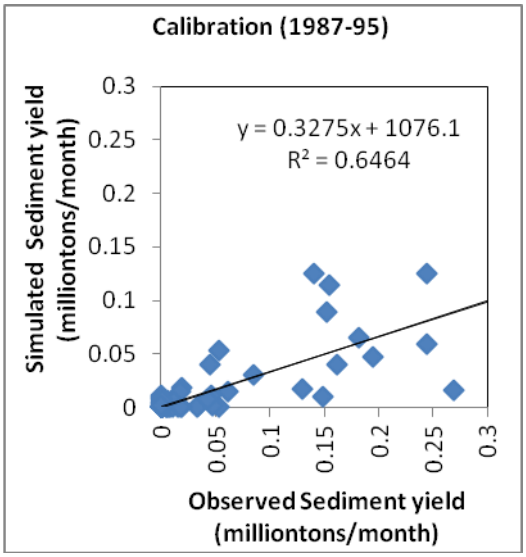


Fig. 3 Scatter plot of monthly sediment yield for calibration period from 1987-1995

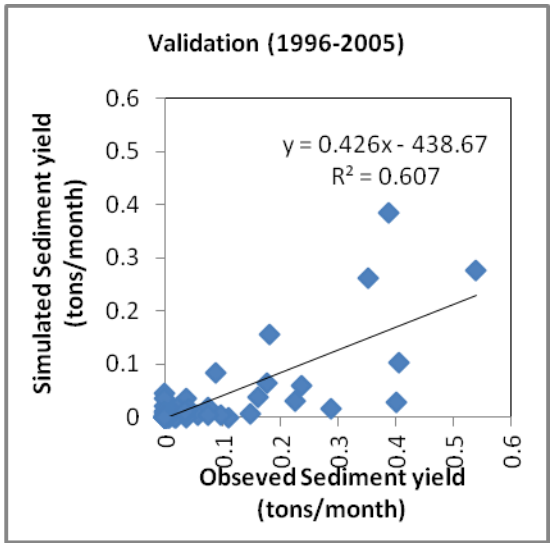


Fig. 4 Scatter plot of monthly sediment yield for validation period from 1996-20.

The calibration and validation of significant predictors of NCEP-NCAR data have been carried out by SDSM with averaged IMD gridded data. The coefficient of determination for the calibration and validation of significant predictors for rainfall are 0.98 and 0.97 respectively. The coefficient of determination for the calibration and validation of significant predictors for maximum temperature are 1.00 and 1.00 respectively. The coefficient of determination for the calibration and validation of significant predictors for minimum temperature are 1.00 and 1.00 respectively. The calibration and validation results for rainfall, maximum and minimum temperature. are given in figs 5 to 10.

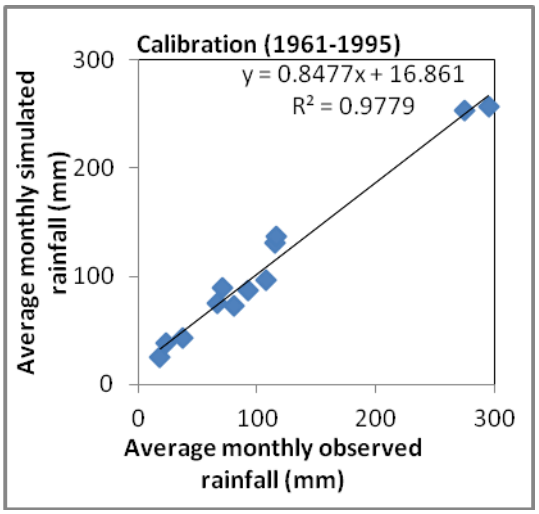


Fig. 5 Scatter plot of rainfall during calibration for 1961-1995

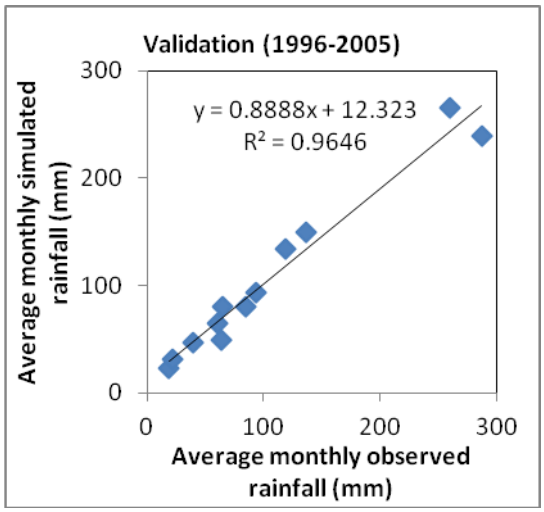


Fig. 6 Scatter plot of rainfall during validation for 1996-2005

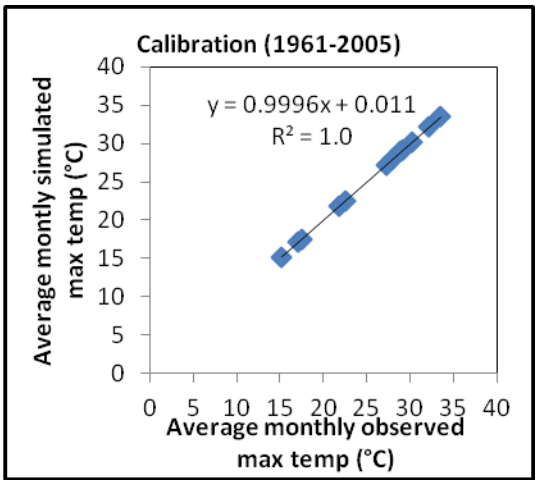


Fig. 7 Scatter plot of maximum temperature during calibration for 1961-1995

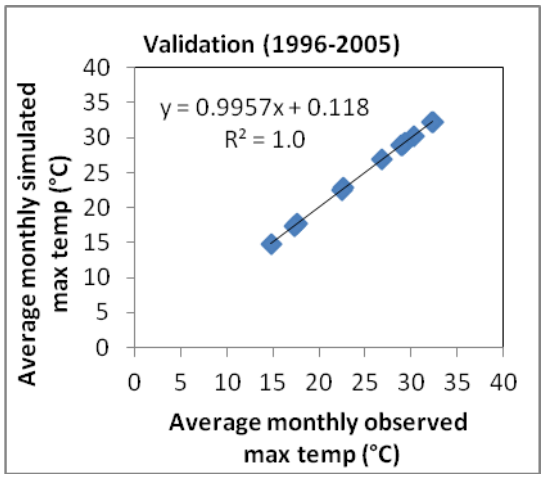


Fig. 8 Scatter plot of maximum temperature during validation for 1996-2005

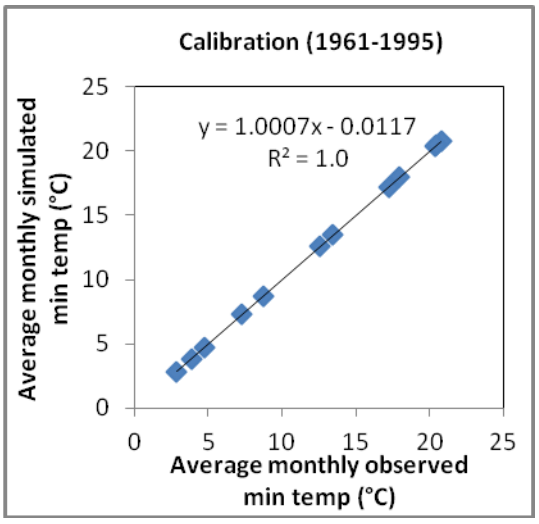


Fig. 9 Scatter plot of minimum temperature during calibration for 1961-1995

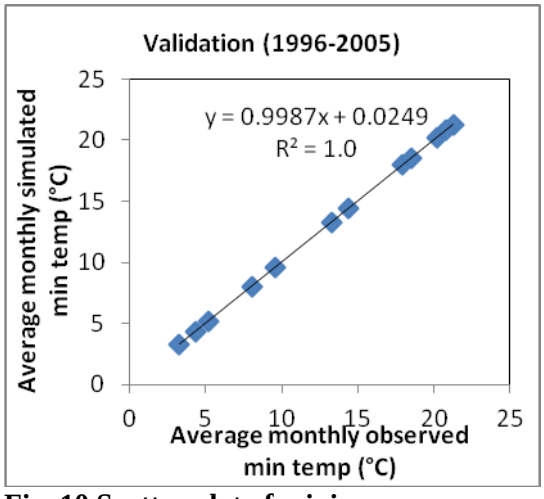


Fig. 10 Scatter plot of minimum temperature during validation for 1996-2005

Monthly rainfall, maximum and minimum temperature have been downscaled on the basis of future daily rainfall, maximum and minimum temperature by MLR model with the predictors from CanESM2 for the period from 2006 to 2100 under the RCP 2.6, RCP 4.5and RCP 8.5 emission scenarios. The downscaled rainfall, maximum and minimum temperature from CanESM2 for climate scenarios RCP 2.6, RCP 4.5 and RCP 8.5 with the significant predictors have been bias corrected by the method of probability of exceedence. The bias corrected rainfall for the climate scenarios RCP 2.6, RCP 4.5 and RCP 8.5 are given figs 11-13

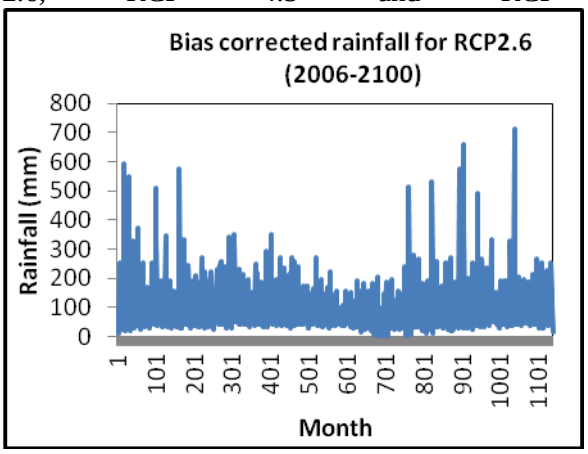


Fig 11 Bias corrected monthly rainfall for the scenario RCP 2.6 for 2006-2100

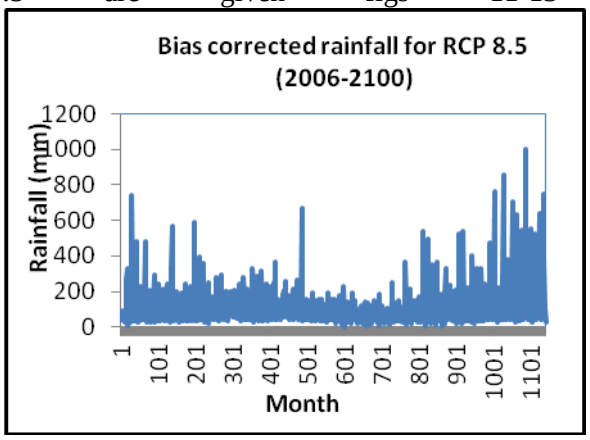


Fig 13 Bias corrected monthly rainfall for the scenario RCP 8.5 for 2006-2100

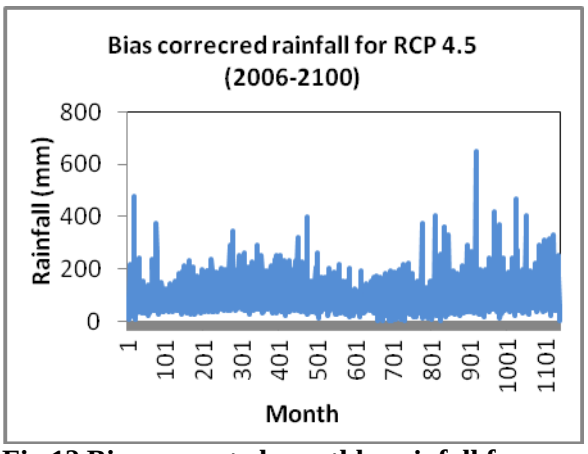


Fig 12 Bias corrected monthly rainfall for the scenario RCP 4.5 for 2006-2100

The monthly streamflow and sediment yield for the period from 2006 to 2100 have been projected using the monthly projected rainfall, minimum and maximum temperature under the RCP 2.6, RCP 4.5 and RCP 8.5 emission scenarios and the other meteorological data from SWAT website with the optimized parameters for streamflow and sediment yield obtained from SWAT-CUP using the hydrometeorological data for the period from 1987 to 2005. The projected streamflow and sediment yield for the period from 2006 to 2100 for the climate scenarios RCP2.6, RCP4.5 and RCP 8.5 are given in figs 14 and 15 respectively. The unit weight of deposited sediment in the reservoir is computed from particle size distribution of suspended sediment concentration and the method of reservoir operation by the procedure suggested by USBR, from the sediment volume observed by hydrographic survey and assuming porosity of uniformly distributed sediment in the reservoir. The consolidated unit weights of the sediment are computed by the equation proposed by Miller of USBR and frequency analysis of unit weights derived from particle size distribution. The consolidated unit weights computed by different methods are used to project the sediment volume and the life of the reservoir for the climate scenarios RCP 2.6, RCP 4.5 and RCP 8.5 for 2025, 2050, 2075 and 2100.

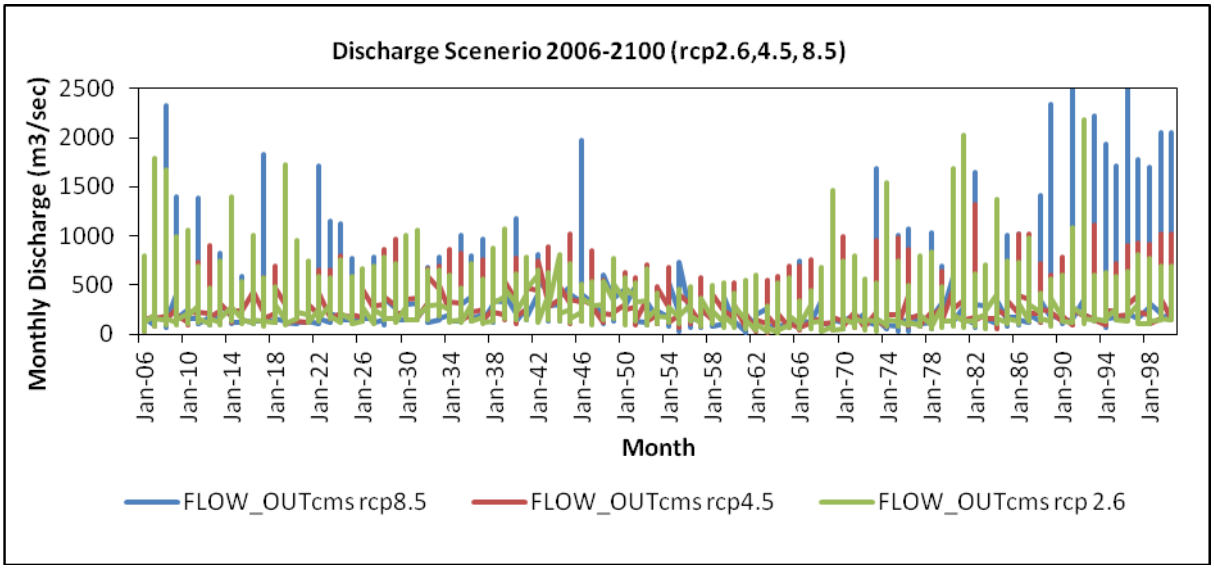


Fig. 14 Projected streamflow for the climate scenario RCP 2.6, RCP 4.5, RCP 8.5 for the period 2006-2100

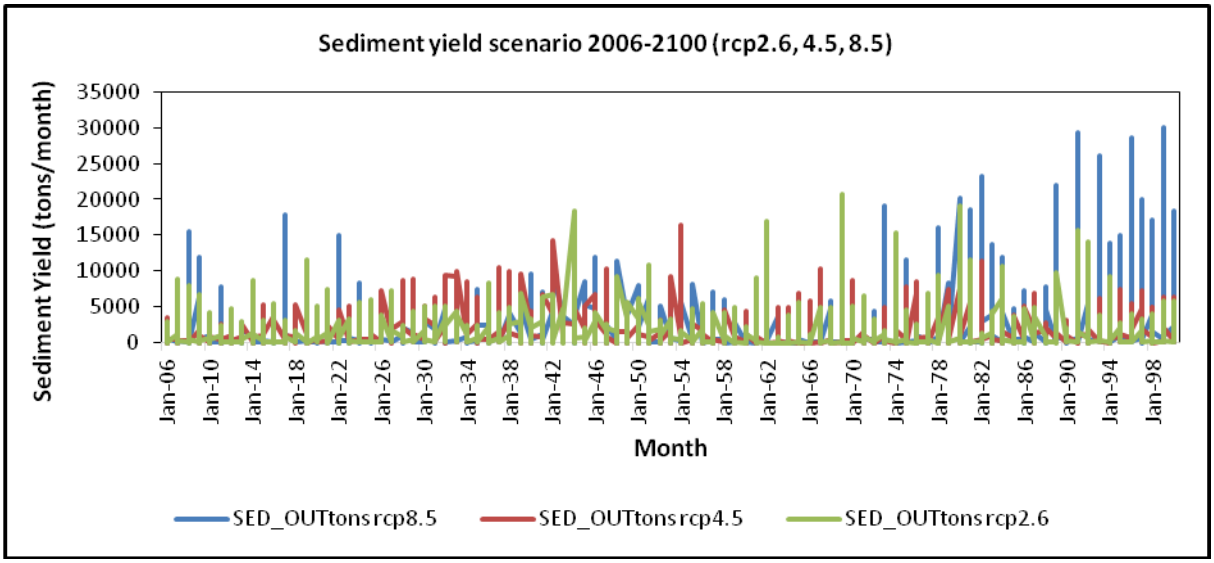


Fig. 15 Projected sediment yield for the climate scenario RCP 2.6, RCP 4.5, RCP 8.5 for the period 2006-2100

10. Date of completion: 30 June 2019

11 Timeline

Sl. No.	Work Element	2015-16		2016-17		2017-18		2018-19		2019-20	
		H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1	Literature Review										
2	Collection and processing of Hydro-meteorological data and purchase of satellite imagery and soil maps										
3	Data preparation for SWAT										
4	Simulation of Sediment yield by SWAT										
5	Downscaling of data from GCM Models										
6	Simulation of sediment yield with the data from future climatic scenarios										
7	Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield										
8	Preparation of interim report										
9	Preparation of final report										

Study- 2 (Internal)

1. Title of the Study: Conservation of ponds in Ibrahimpur-Masahi village and performance evaluation of natural treatment system.

2. Study Group:

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigators Dr. V. C. Goyal, Scientist G & Head (RMOD) Dr. Rajesh Singh, Scientist C, EHD Er. Digambar Singh, Scientist C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N.R. Allaka, RA
Partner Organization	Prof. Laurence Carvalho & Team, Centre for Ecology & Hydrology, Edinburgh, United Kingdom

3. Type of Study: Internally Funded (CEH-UK will cover the expenses towards O&M of CW, WQ Sampling & analysis of specific parameters of pond and wastewater, Installation & Maintenance of DO sensors, etc.).

4. Nature of Study: Applied

5. Date of start: April 2018

6. Scheduled date of completion: March 2020

7. Duration of the Study: 02 Years

8. Study Objectives:

- Water quality investigations of ponds, wastewater and groundwater
- Assessment of health of water body through ecological indicators
- Performance evaluation of CW based Natural Treatment System and re-use planning of treated wastewater
- Mass Awareness Activities and societal impact assessment of NTS

9. 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. In this context, the Institute has rejuvenated a pond (Village: Ibrahimpur Masahi, Tehsil-Bhagwanpur, Dist. Haridwar) by establishing CW based Natural Treatment System (NTS). The rejuvenated ponds with treated wastewater will be used for agricultural use and other livelihood activities such as fishery. The performance evaluation of this system is necessary to establish its feasibility and replicability in other village ponds receiving continuously input of domestic wastewater into the village ponds. Therefore, it proposed to monitor important water/wastewater quality parameters at two ponds, namely Ibrahimpur Masahi (receives village wastewater through constructed wetland) and Masahi Kala (control pond/reference pond: pond without any treatment system). The Centre for Ecology & Hydrology (CEH-Edinburgh, United Kingdom) is also associated in this study.

10. Approved Action Plan/Methodology:

In this study, the pond, wastewater, and groundwater (hand-pumps) quality will monitored per standard procedures (APHA 2012). Along with CEH-UK team, the health of the water body and possible its impact on society will also be assessed. Options for the use of treated wastewater will be explored. The water quality assessment for agriculture purposes (BIS-1987/2001; USDA 1954) and Fishery will be performed as per recommended procedures including development of WQ Indices. Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977).

11. Timeline:

S. N.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Review of literature								
2	Water quality and depth monitoring of pond, groundwater, and wastewater								
3	Data compilation & performance evaluation of NTS								
4	Assessment of health of water body								
5	Societal impact assessment								
6	Mass awareness activities								
7	Report Preparation								

12. Objectives and achievement during last twelve months:

Objectives	Achievements
Water quality and depth monitoring of pond, groundwater, and wastewater	• WQ Samples were collected in April (06 GW+01 PW+01WW), May (04 GW + 01 PW + 01 WW) and July (01 PW). • The organoleptic, major cations and major anions were analyzed. • Trace metal analysis of the samples completed. • The frequency of WQ sampling w.e.f. Nov. 2018 has been increased upto weekly/fortnightly level to check the performance of CW based NTS. • Total 78 samples have been collected weekly/fortnightly at Ibrahimpur Masahi (Grit Chamber inlet-01, GC outlet-01, CW outlet-0, pond water sample-01) and at Masahi Kala Pond (Wastewater Inlet-01, Masahi Kala Pond-01) and analyzed for critical parameters. • The plant density of Constructed Wetland is also been estimated periodically. • Productivity experiment was conducted in Nov. 2018. • The WQ samples were also collected by CEH-UK for specific parameters (viz. methane, biota, etc.) during Nov. 2018 for analyzing at CEH-UK. • *Fortnightly samples collected (1GC inlet, 1 GC outlet, 1 CW outlet, 1 pond water sample, 1 Masahi pond inlet & 1 Masahi pond water samples)* • *Parameters analyzed: pH, EC, DO, BOD, COD, Nitrate, Phosphate & ammonia and results compiled.* • *CEH-UK team collected water & WW samples for methane, plankton and benthic fauna from both the ponds and conducted social survey in the village during June, 2019.*

Mass Awareness/Outreach Activity	• Outreach activity conducted for villagers/Gram Panchayat Members and concerned local State Govt. officials at village Ibrahimpur Masahi (on dated (20/11/2018). • Transfer of CW-NTS to Gram Panchayat was done on 20.11.2018. The SOP for proper operation and maintenance of NTS was also provided to Gram Pradhan, Ibrahimpur Masahi.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	-

14. Analysis & Results:

Natural treatment system i.e. constructed wetland has been established in Ibrahimpur Masahi village. To check the efficiency of constructed wetland, water quality of the samples from the treatment units and pond at Ibrahimpur Masahi were analyzed weekly/fortnightly. In addition, the water quality of influent and pond at Masahi Kala village, without any interception, was also monitored as a reference/control pond. The samples were analyzed for indicator parameters like pH, EC, DO, BOD, COD, NO_3-N, PO_4 and NH_3-N. The pH of the Ibrahimpur Masahi pond was high as compared to the control pond. This is an indication of the lower organic input to the pond. The pond with high biodegradable organic load has low pH due to high CO_2 and organic acids due to decomposition of the organic matter. The DO that is a critical parameter for aquatic life is also observed improved in case of Ibrahimpur Masahi pond. The average DO value in Ibrahimpur pond was 2.32±0.67 mg/l with minimum value 0.8 mg/l whereas in Masahi Kala pond the average value was 0.74±0.50 mg/l with minimum value non detectable. The average BOD value in Ibrahimpur pond was 34.4±8.8 mg/l in comparison to 130.0±26.0 mg/l in the control pond at Masahi, clearly indicating the positive impact of the constructed wetland. Further, outreach activity was conducted in the month of November Ibrahimpur–Masahi Village and the constructed wetland was handed over to village Gram-panchayat.

After 48th WG meeting, fortnightly sample collection of Ibrahimpur-Masahi pond was started to check the performance evaluation of constructed wetland (CW). Wastewater, CW inlet, CW outlet and pond water has been collected. Different parameters like pH, EC, DO, BOD, COD, nitrate, phosphate and ammonia in Water Quality Laboratory, NIH, Roorkee. Detail of water samples collected and various parameters analyzed in laboratory given in Table 1

Table 1: Detail of samples collected from Ibrahimpur-Masahi ponds

Month	Date	Number of Samples	Parameter Analyzed in WQ Laboratory
November, 2018	2/11/2018	6	pH, EC (µS/cm), DO (mg/l), BOD (mg/l), COD (mg/l), TC (MPN/100ml), EC (MPN/100ml, Nitrate (mg/l), Phosphate (mg/l),Ammonia (mg/l), Methane, etc.
	14/11/2018	6	Same as above
	20/11/2018	6	-
	28/11/2018	6	-
December, 2018	12/12/2018	6	-
	27/12/2018	6	-
January, 2019	15/01/2019	6	-
	30/01/2019	6	-
February,2019	13/02/2019	6	-
	28/02/2019	6	-
March, 2019	13/03/2019	6	-
	27/03/2019	6	-
April, 2019	24/04/2019	6	-

May, 2019	09/05/2019	6	-
	23/05/2019	6	-
June, 2019	04/06/2019	6	Field visit by NIH & CEH-UK team at both pond sites
July, 2019	22/07/2019	6	-
Sept., 2019	13/09/2019	6	-
October, 2019	10/10/2019	6	-

The latest results of study showed that pH of the pond samples ranged from 7.22 to 8.96 and EC of pond samples varied from 1280 to 2410µS/cm. Dissolve oxygen (DO) of pond Ibrahimpur ranged from 0 to 18 mg/l and in Masahi pond Dissolved oxygen found Zero. Biochemical oxygen demand in GC inlet ranged from 60 to 400 mg/l and in pond Ibrahimpur BOD value ranged from 17 to 200 mg/l. Total coliform in pond Ibrahimpur was low as compare to Masahi pond. Nitrate value in pond Ibrahimpur varied from 2 to 17 mg/l and pond Masahi nitrate was 5 to 20 mg/l. Phosphate values in pond Ibrahimpur ranged from 0.2 to 14 mg/l and in Masahi pond phosphate concentration was 5.4 to 10.8 mg/l. Ammonia value in pond Ibrahimpur ranged from 0.25 to 13.14 mg/l and in Masahi Pond ammonia value ranged between 0.75 to 27.75 mg/l. The results are plotted in (Fig. 1 to 9).

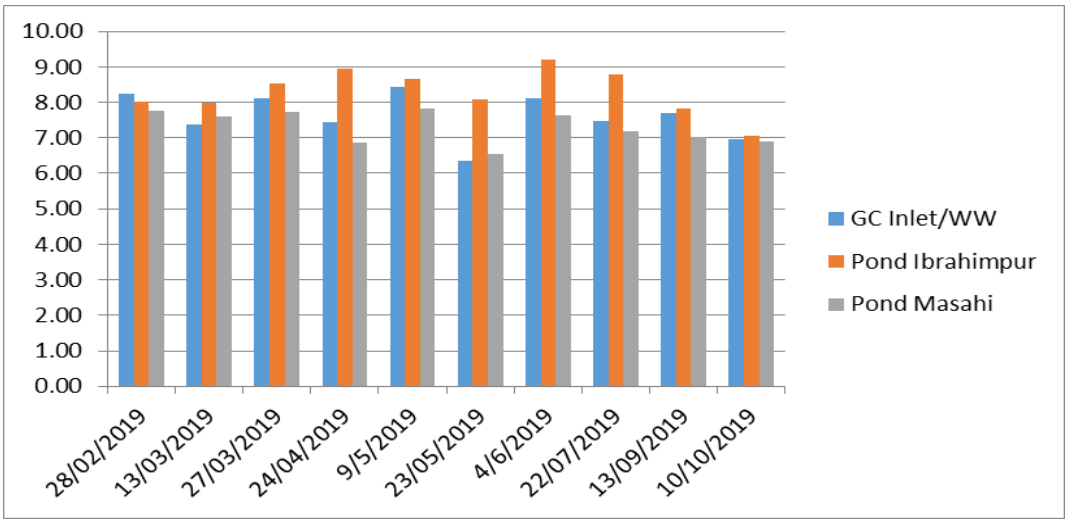


Fig. 1: pH Variation in Ponds at Ibrahimpur Masahi & Masahi Kala

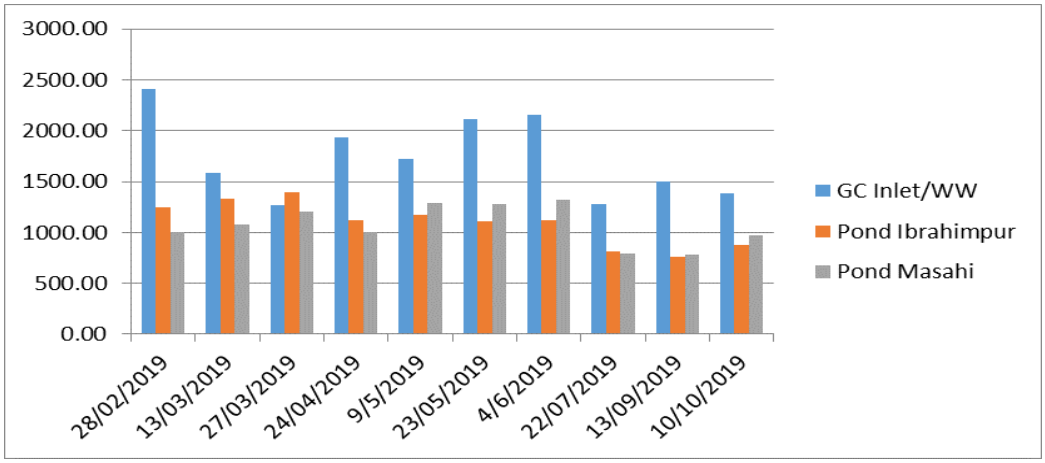


Fig.2 : EC Variation in Ponds at Ibrahimpur Masahi & Masahi Kala

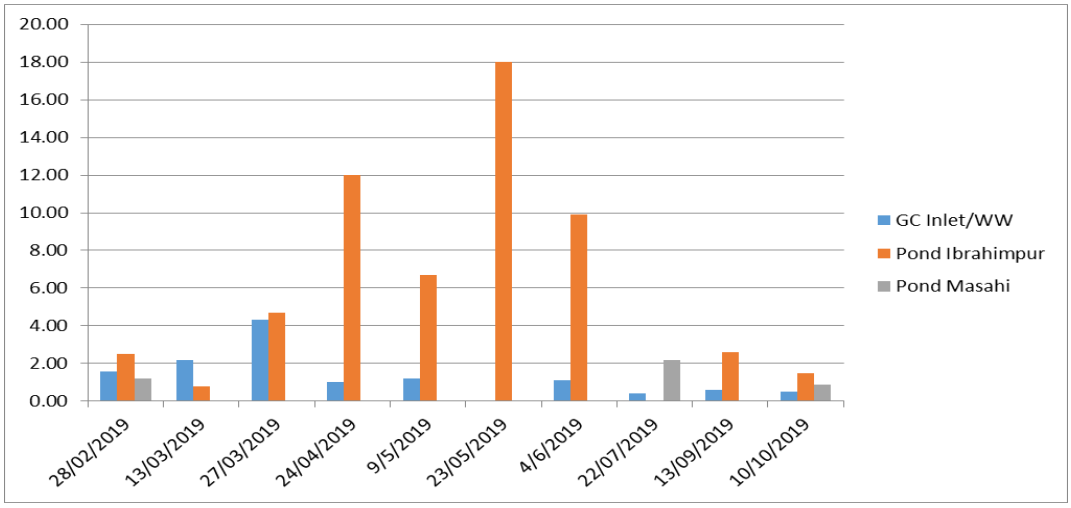


Fig. 3 : Conc. of DO in Ponds at Ibrahimpur Masahi & Masahi Kala

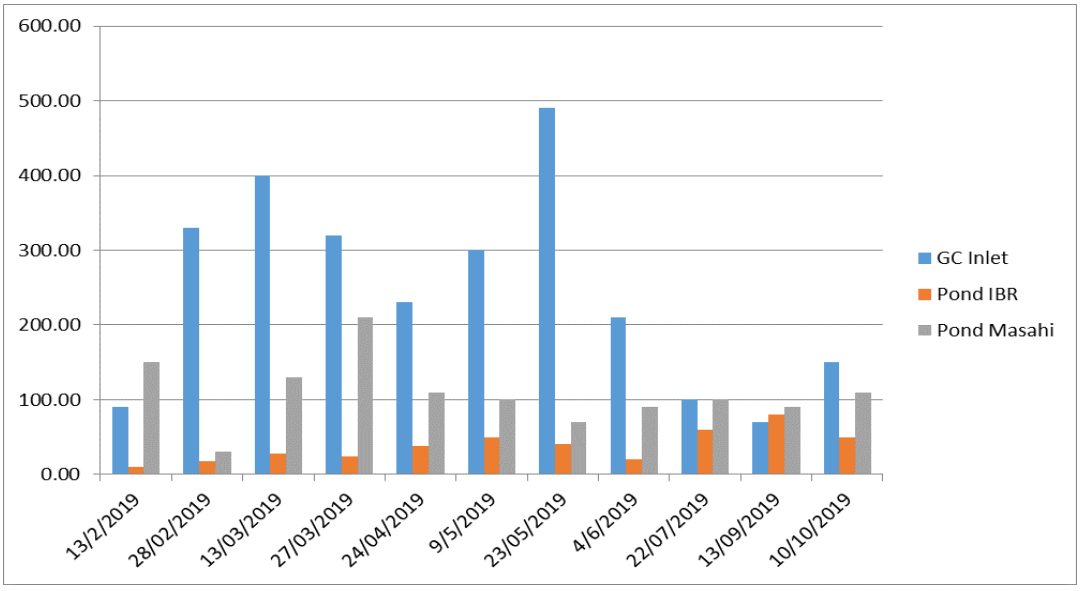


Fig. 4: Conc. of BOD in Ponds at Ibrahimpur Masahi & Masahi Kala

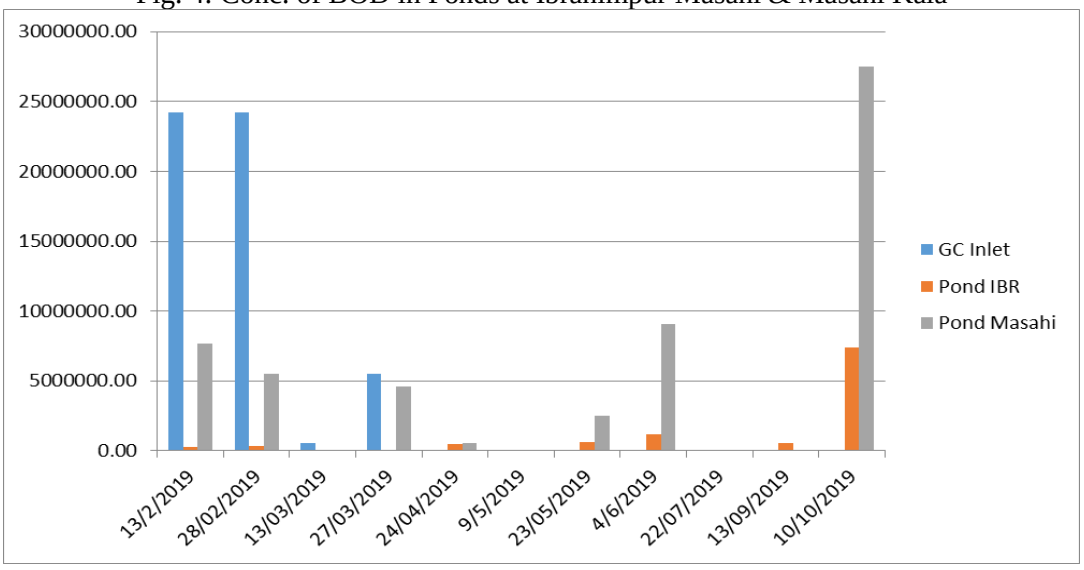


Fig. 5: Conc. of Total Coliforms in Ponds at Ibrahimpur Masahi & Masahi Kala

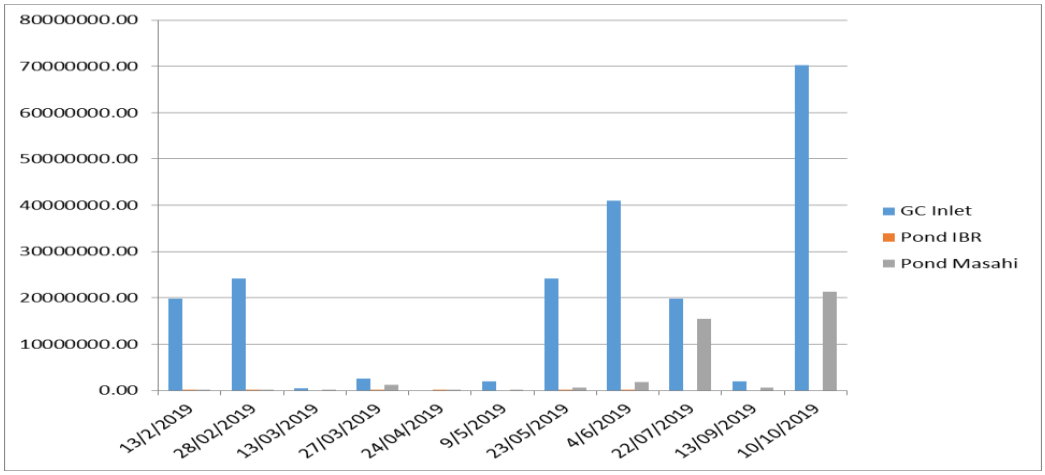


Fig.6 : Conc. of E.Coli in Ponds at Ibrahimpur Masahi & Masahi Kala

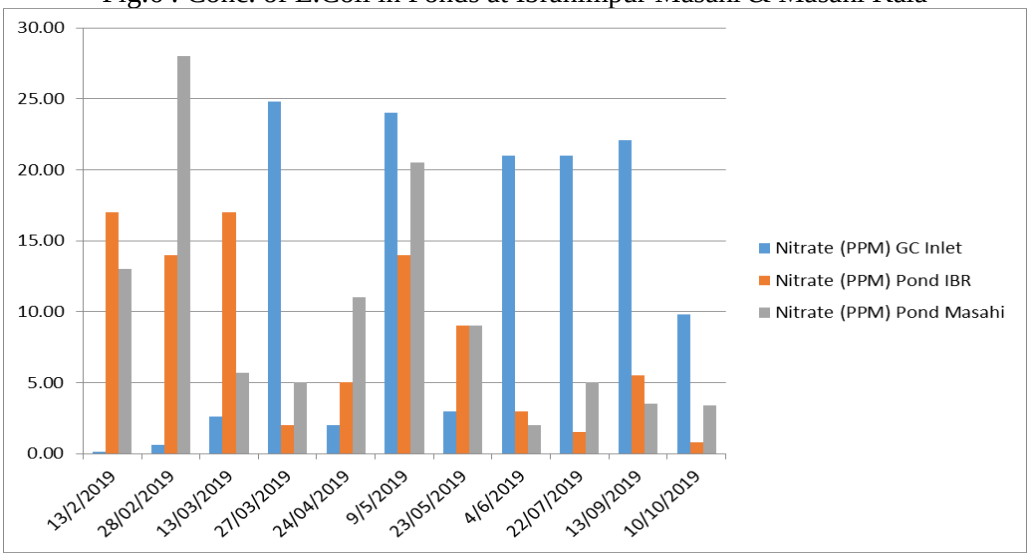


Fig. 7 : Conc. of Nitrate in Ponds at Ibrahimpur Masahi & Masahi Kala

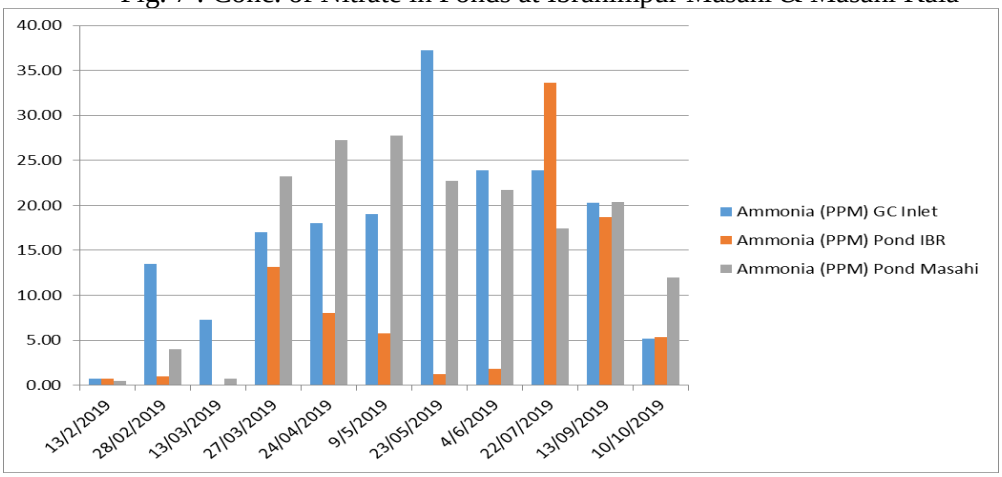


Fig. 8: Conc. of Ammonia in Ponds at Ibrahimpur Masahi & Masahi Kala

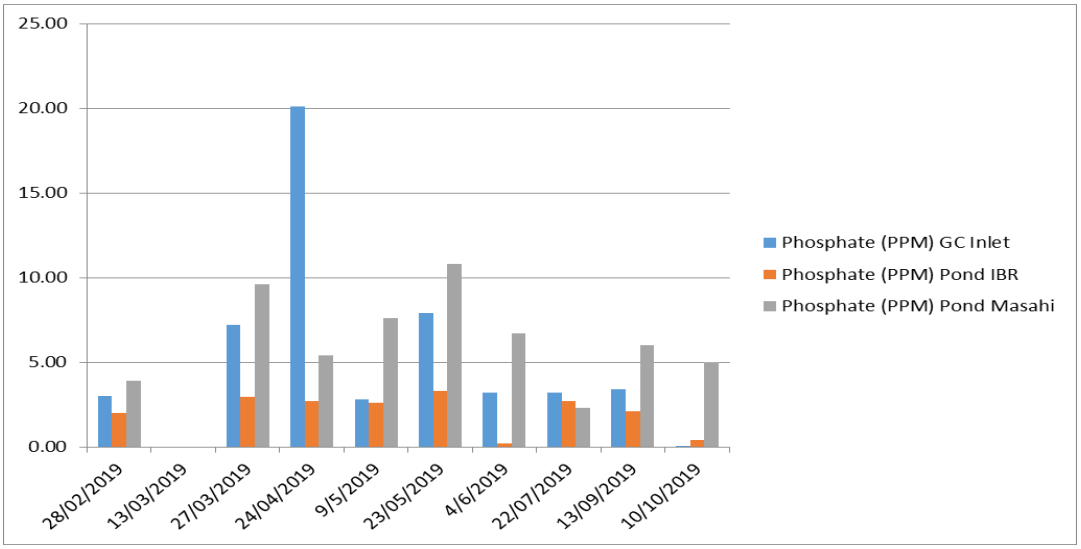


Fig.9 : Conc. of Phosphate in Ponds at Ibrahimpur Masahi & Masahi Kala

15. **End Users / Beneficiaries of the Study:** Villagers & Stakeholders

16. **Deliverables:** Performance Evaluation Report of CW-NTS, Societal impact of rejuvenated water body, Eutrophication Trends of Ponds.

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** WQL, GWHD (NIH)/ IIC (IITR)

19. **Data procured or generated during the study:** Pond and groundwater quality and groundwater level data.

20. **Study Benefits / Impacts:** The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond and also enhance the groundwater water quality of the area. This study will address the issues related to contamination of village ponds and the outcomes from the study can be utilized by the policy makers for addressing the issues in other villages.

21. **Involvement of end users/beneficiaries:** Villagers and Gram panchayats
22. **Specific linkage with Institution and /or end users / beneficiaries**: Gram panchayats

23. **Shortcoming/Difficulties:** Societal issues

24. **Future Plan:** As per approved action plan

Study- 3 (Internal)

1. Title of the study: Bathymetric survey of identified ponds in the districts of Muzaffarnagar, Meerut, Ghaziabad and Baghpat (UP) for development of water management plan

2. Study Group:
Digambar Singh, Sc C,
Er. Omkar Singh, Sc F,
Er. Rohit Sampatrao Sambare, Sc. B
Shri N R Allaka, RA,

3. Date of start: 1, April 2018

4. Duration of the study: 2 Years

5. Whether externally funded or not: No

6. Objectives of the Study:

- Bathymetric survey of identified village ponds in Muzaffarnagr, Meerut, Baghpat and Ghaziabad Districts
- Estimation of water storage capacity and Elevation Area Capacity Curves of identified ponds for development of water management plan

7. Statement of the problem

In our country, most of the traditional water harvesting structures (viz. ponds) are disappearing/shrinking due to encroachment, siltation, dumping of solid and liquid waste (sewage) entry from the villages into the adjacent ponds. Consequently, pond water is no longer useful to the society due to poor water quality and higher levels of eutrophication, which ultimately affects the livelihood of the peoples. The ponds located in the Western Uttar Pradesh are also suffering from various hydrological problems and need appropriate intervention for rejuvenating on priority basis. Morphometric data are of fundamental importance in most limnological and hydrological projects. Bathymetric map of a water body (pond/lake) is source of most morphometric data. It is constructed from hydrographic surveys conducted with echo-sounding equipment/eco-boat. For scientific purposes, in hydrological, limnological and sedimentological contexts, it is of primary interest to have a bathymetric map illustrating the general morphology of the water body. Therefore assessment of availability of water from surface water bodies is very important to sustain irrigation, fisheries and other water needs as well as to provide security to farmers.

This study aims to estimate the quantity and quality of available water in the selected water bodies to know the present status and plan a strategy for the future by carrying out bathymetric survey and water quality investigations.

8. Brief methodology:

Remote/Pedal boat (using sonding weight) will be used for bathymetric survey.
The Echo Boat is a hand portable remote controlled catamaran platform developed for bathymetric survey applications. The light weight, wide profile and water tight connection provide stability, ruggedness and portability.

9. Study area

The study area covers 22 ponds in Western UP covering Muzaffarnagar, Meerut, Baghpat and Ghaziabad Districts. The details of identified ponds are given below:

Locations of Identified Village Ponds in Muzaffarnagar and Meerut Dist.

Sr. No.	Village	Village ID	Block & District	Global Location	Pond Khasra No.
1	Bhora Kalan	MN - 1	Shahpur, M.Nagar	29.390714°; 77.446661°	168
2	Bhora Khurd Pond No. 1	MN - 2	Shahpur, M.Nagar	29.396421°; 77.466515°	440
3	Mohammadpur Madan, Pond No. 2	MN - 3	Baghra, M.Nagar	29.444523°; 77.468680°	226
4	Biral	MN - 4	Budhana, M.Nagar	29.247980°; 77.353848°	640
5	Pavli Khas	ME - 1	Daurala, Meerut	29.068355°; 77.686094°	973/1
6	Itawa Pond No. 02 (Near Masjid)	MN - 5	Budhana, M. Nagar	29.224812°; 77.467710°	195
7	Bhora Khurd Pond No. 2	MN - 6	Shahpur, M.Nagar	29.398626°; 77.467483°	405
8	Siwaya Jamalullapur	ME - 2	Daurala, Meerut	29.088818°; 77.708742°	513
9	Roni Hazipur	MN - 7	Charthwal, M.Nagar	29.543380°; 77.493092°	486
10	Antwara	MN - 8	Khatauli, M.Nagar	29.312605°; 77.787791°	540
11	Munnawarpur Kalan	MN - 9	Khatauli, M.Nagar	29.387868°; 77.742046°	291
12	Itawa Pond No. 01 (Bademandir Wala)	MN - 10	Budhana, M. Nagar	29.226693°; 77.465664°	212

Locations of Identified Village Ponds in Baghpat, Meerut and Ghaziabad Dist.

Sr. No.	Location ID	District	Village	Pond Name	Khasra No.	Latitude	Longitude
1	BG - 1	Baghpat	**Dhikana**	Pattidahaewan Pond	223	N 29°05’00.21”	E 77°13’15.21”
2	BG - 2	Baghpat	**Basoli**	Brahamanwala Pond	474	N 29°10’35.00”	E 77°15’33.00”
3	GZ - 1	Ghaziabad	**Saidpur**	Chauthipatti (Mata Mandirwala Pond)	1008	N 28°51’50.13”	E 77°38’40.40”
4.	MT - 1	Meerut	**Ikari**	Bindawalla Pond	---	N 29°05’49.00”	E 77°34’47.04”
5	BG - 3	Baghpat	**Palri**	Tyagiwala Pond near Shiv Temple	834	N 29°10’30.15”	E 77°24’24.72”
6	BG -4	Baghpat	**Budhera**	Pacchalapatti Pond	1003 & 1025	N 29°01’43.62”	E 77°18’35.83”
7	BG - 5	Baghpat	**Pilana**	Guhali Pond	791	N 28°56’16.73”	E 77°22’20.76”
8	GZ - 2	Ghaziabad	**Khindora**	Devetawaala Pond	417	N 29°00’14.12”	E 77°22’13.03”
9	BG - 6	Baghpat	**Dagarpur**	Pallay mohella Near Dairy (BadaTalab)	207	N 28°48’01.76”	E 77°20’28.06”
10	MT - 2	Meerut	**Rasulpur Zahid**	Chhapedawala Pond	1217	N 29°02’11.88”	E 77°28’15.66”

10. Action plan and timeline

Sl. No.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Literature review								
2	Training & Testing of Eco-boat								
3	Bathymetric Survey of the ponds								
4	Computation of the volume of the ponds & Elevation-Area-Capacity Curves								
5	Report writing								

11. Data requirements

(a) Bathymetric survey data of ponds will be generated at each pond sites.

12. Progress/present status

i) Literature review related to Bathymetric Survey and estimation of capacity of ponds for development of water management plan

ii) Testing of eco boat with M/s Pan India Ltd. has been carried out during Oct. 2019 at NIH and nearby ponds for data acquisition through e-boat.

iii) Bathymetric survey by eco boat is proposed & to be carried out during Q3/Q4 2019-2020.

13. Deliverables:

i) Bathymetric map of the ponds
ii) Elevation-Area-Capacity curve
iii) Research papers

14. Adopters of the results of the study: Local Administration and Concerned Gram Panchayats.

Sponsored Project- 1

1. **Title of the Study:** Vulnerability assessment of identified watersheds in Chhatisgarh

2. **Study group:**

   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

This is completed study. The objectives, brief methodology and results of the study were presented during 48th WGM. There were no specific comments from working group members.

The report of the study is submitted to the institute.

Sponsored Project- 2

1. Title of the study: Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact

2. Study Group:

Dr. A. R. Senthil kumar Sc F, NIH, Roorkee
Dr. J. V. Tyagi, Scientist 'G', NIH, Roorkee
Dr. M. K. Goel, Scientist 'G', NIH, Roorkee
Dr. S. D. Khobragade, Scientist 'F', NIH, Roorkee
Dr. P. C. Nayak, Scientist 'D', Deltaic Regional Centre, NIH, Kakinada
Dr. Manohar Arora, Scientist 'D', NIH, Roorkee

Project staff: Sh. Sandeep Chourasia, JRF, Sh. Bhajanlal, PA

Date of start: 1 January 2016

3. Duration of the study: 5 Years

4. Whether externally funded or not: DST

5. Objectives of the study:

a. To model stream flow/snow melt runoff in Bhagirathi Basin up to Tehri dam.
b. To model sediment yield at Tehri dam.
c. To investigate the impact of likely future changes in climate on stream flow and sediment yield up to Tehri dam using future climate scenarios.
d. To assess impact of afforestation/deforestation on sediment yield in the basin.
e. To assess the operation policy of the Tehri dam in light of the climate change impact.

6. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Tehri reservoir. The study on impact of afforestation/deforestation on sediment yield in the basin is also important for effective watershed management.

7. Brief methodology:

Sediment yield model

The sediment yield up to Tehri 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.

Streamflow simulation

The streamflow up to Tehri reservoir is modeled by SNOWMOD with the input data of elevation, rainfall, aspect, temperature and snow cover area. The performance of SWAT is compared with SNOWMOD in simulating the discharge.

Climate Scenarios

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

Computation of streamflow and sediment yield under different scenarios

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

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.

The impact of afforestation/deforestation on sediment yield is analyzed by the simulation of sediment yield using SWAT by increasing/decreasing the LULC.

The rule curves for operating the reservoir are modified by considering the revised elevation-area-capacity curve in light of increased/increased sediment yield.

8. Results achieved with progress/present status:

The sediment yield at Tehri reservoir is modelled by Soil and Water Assessment Tool (SWAT). The inputs such as DEM, LULC and Soil map for running the ARCSWAT 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), Indian Council of Agricultural Research, Harmonized World Soil Database (HWSD) International Institute for Applied Systems Analysis **(**IIASA) and National Remote Sensing Centre (NRSC). The daily rainfall, maximum temperature, minimum temperature, Solar radiation, wind speed, relative humidity have been obtained from IMD and SWAT.tamu website**.** Initially**,** the discharge and sediment yield at Tehri dam has been simulated using the input data from IMD and SWAT.tamu website by taking the parameters randomly with SWAT. The parameters for discharge and sediment yield have been optimized in SWAT-CUP using SUFI-2 algorithm.

The daily rainfall values at Mukhim, Tehri, Bhatwari, Dunda, Maximum and Minimum temperature at Mukhim, relative humidity and wind speed at Mukhim have been obtained from IMD. The daily discharge (1994 to 2007) and sediment yield (1994 to 2001) have been obtained from THDC, Rishikesh and are given as follows:

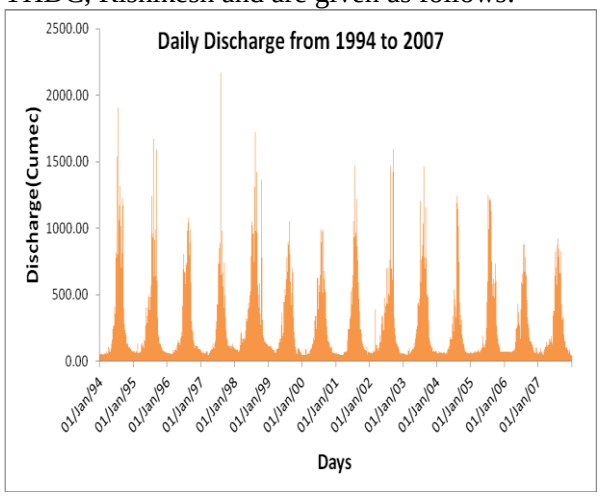


Fig.1 Daily discharge at Tehri dam from 1994 to 2007

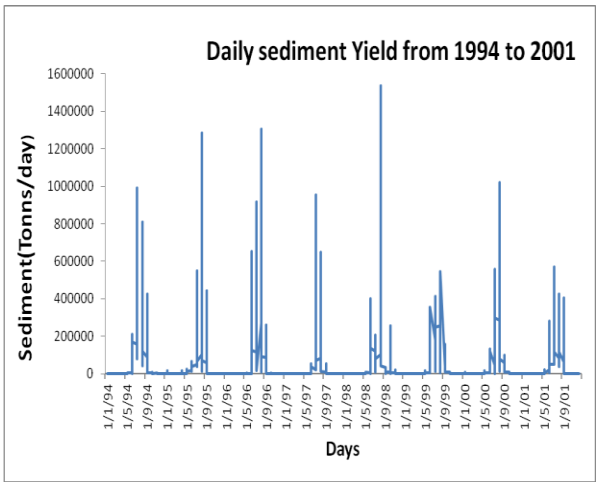


Fig.2 Daily sediment yield at Tehri dam from 1994 to 2001

The parameters of the SWAT have been calibrated for discharge and sediment yield by considering the data from IMD and THDC, Rishikesh. Sensitivity analysis of the parameters for both discharge and sediment yield has been carried in SWAT-CUP using SUFI2 and the rankings is given in flowing table 1. The best eight sensitive parameters for sediment yield have been considered for optimization. The lower, upper limits and the best fitted values of the parameters are given table 2.

Table 1 Sensitivity analysis of parameters for sediment yield

S.No	**Parameters name**	**P-value**	**t-stat**	**Rank**
1	USLE_P.mgt	0.00002	-45.058	1
2	USLE_K.sol	0.00005	-15.59	2
3	SPEXP.bsn	0.00032	2.17	3
4	SPCON.bsn	0.00042	0.301	4
5	CH_COV2.rte	0.05126	1.16	5
6	CH_COV1.rte	0.01625	1.15	6
7	ADJ_PKR .bsn	0.21561	2.15	7
8	PRF BSN.bsn	0.415369	-0.414	8

Table 2. Lower limit, upper limit, best fitted values of parameters

Parameter	Details	Lower Limit	Upper Limit	Best Fitted Value
SPCON.bsn	Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing.	0.0001	0.01	0.004
SPEXP.bsn	Exponent parameter for calculating sediment reentrained in channel sediment routing	1	1.5	1.132
CH_COV1.rte	Channel erodability factor	0	0.2	0.0030
CH_COV2.rte	Channel cover factor	0	0.2	0.076
USLE_P.mgt	USLE equation support practice factor	0.1	1	0.02
USLE_K.sol	USLU soil factor	-0.2	0.2	0.432
ADJ_PKR .bsn	Peak rate adjustment factor for sediment routing in sub basin (tributary channels)	0.5	2	1.32
PRF.bsn	Peak rate adjustment factor for sediment routing in the main channel	0.5	1	0.71
PRF.bsn	Peak rate adjustment factor for sediment routing in the main channel	0.5	1	0.71

The graphical comparison of the observed and simulated discharge and sediment yield at Tehri dam are given as follows:

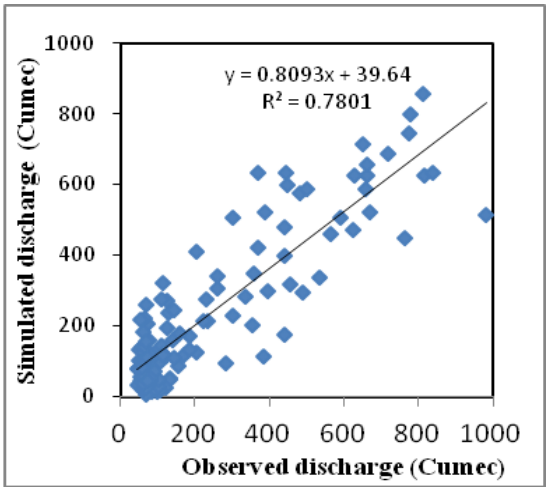


Fig. 3 Scatter plot for monthly discharge for calibration period from 1996 to 2005

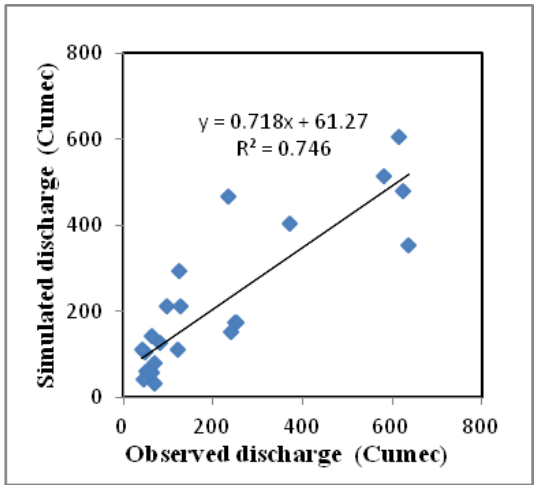


Fig 4. Scatter plot for monthly discharge for validation period from 2006 to 2007

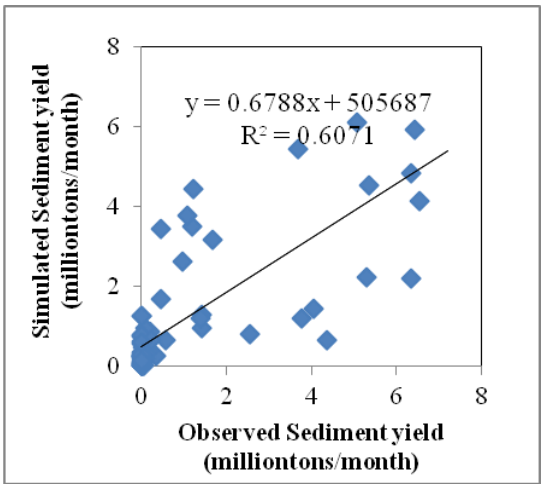


Fig. 5 Scatter plot for monthly sediment yield for calibration period from 1996 to 1999

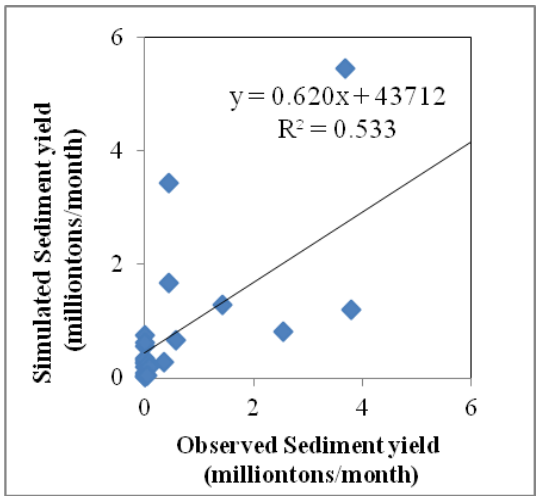


Fig. 6 Scatter plot for monthly sediment yield for validation eriod from 2000 to 2001

SNOWMOD data preparation

SNOWMOD requires daily rainfall data, temperature and snow covered area to simulate the runoff components from sources such as snow, rain and subsurface flow. The whole area is divided into 10 elevation zone and is given table 3.

Table 3 Zone wise area of the Bhagirathi basin

Zone	Elevation(M)	Area(km^2)	Percentage
1	<700	0.0603	0.001
2	700-1400	534.3911743	7.543
3	1400-2100	1240.68689	17.513
4	2100-2800	951.2783813	13.428
5	2800-3500	644.7393188	9.101
6	3500-4200	642.9959717	9.076
7	4200-4900	1113.010254	15.711
8	4900-5600	1540.567749	21.746
9	5600-6300	568.8143921	8.029
10	>6300	48.7629013	0.688

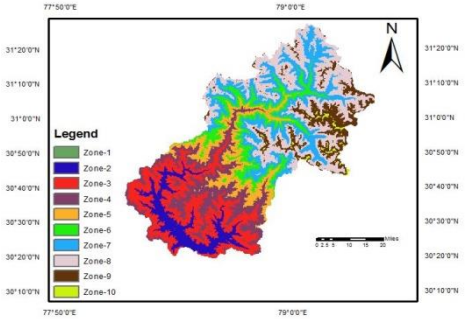


Fig. 7 Zone wise Digital elevation model of the Bhagirathi basin

The 8-day maximum snow cover data from MODIS 8-day snow cover product (MOD10A2) with spatial resolution of 500 m have been used to map and monitor SCA for the period from 2001 to 2007. In Himalayan basin the snow accumulation in Himalayas is generally from November to March, while snowmelt is from April to September. The average snow covered area at the start of ablation season is 59.74%, when the accumulation of snow is started in September, the average snow covered area at the end of ablation season is 28.67%. A comparison of the percentage snow cover for different years as extracted from image classification for ablation period (March-September) is given in table 4.

Table 4 Percentage snow covered for different years

Month	Snow Covered Area (%)						
	2001	2002	2003	2004	2005	2006	2007
March	59.19	63.08	60.91	53.90	61.12	56.97	63.04
April	57.12	56.88	56.26	47.63	55.92	49.67	50.36
May	45.48	48.10	34.90	32.52	37.83	33.35	37.88
June	31.06	39.20	33.29	29.27	39.97	18.71	20.82
July	29.77	24.58	29.95	25.88	37.19	29.69	27.05
August	32.45	33.93	34.21	27.17	28.36	19.21	17.01
September	23.98	36.38	27.12	33.75	38.98	17.10	23.36

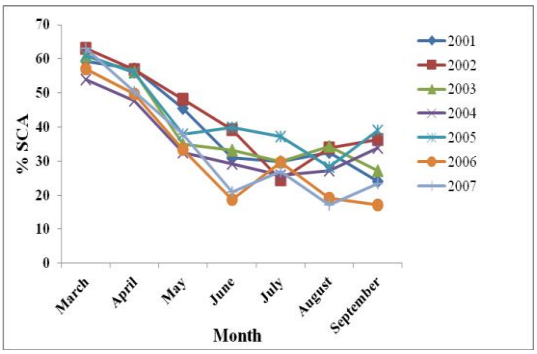


Fig 8. Snow depletion curves for years (2001-2007)

9. Outcome of the study

The output of the study will give an idea of increased sediment yield and streamflow from the future climatic scenarios to the state department officials for managing the various demands based on the available the storage in the reservoir on priority basis. The impact of afforestation/deforestation on sediment yield will be used for planning cropping pattern to reduce the sediment yield

10. Expected date of completion: 31 January 2021

11. Timeline

Activity	2016-17		2017-18		2018-19		2019-20		2020-21	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
Collection and processing of Hydrometeorological data and purchase of satellite imagery										
Data preparation for SNOWMOD and SWAT										
Simulation of streamflow by SNOWMOD										
Simulation of Sediment yield by SWAT										
Downscaling of data from GCM Models										
Simulation of streamflow and sediment yield with the data from future climatic scenarios										
Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield										
Analysis of the reservoir performance with the revised elevation-area-capacity table and projected streamflow										
Writing of the final report										
Training workshop										

Sponsored Project-3

1. Title of the Study: Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts of UP

2. Study Group:

Lead Organization	**Project Investigator** Dr. V. C. Goyal, Sc. G &Head, RMOD
	Co-Investigators Er. Omkar Singh, Scientist F, RMOD Dr. Rajesh Singh, Scientist C, EHD Er. Digambar Singh, Scientist C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N. R. Allaka, RA Dr. N. G. Shrivastava, Senior Expert Dr. Nihal Singh, Research Scientist Dr. Kalzang Mathus, Research Associate Sh. Sandeep Yadav, Research Associate Sh. Subhash Vyas, Project Assistant
Civil Work Execution Agency	NPCC Limited (A GoI Enterprise), Noida

3. Type of Study: INCSW (MoWR, RD & GR) Sponsored Pond Project

4. Budget: Rs 8.3 Crores

5. Nature of Study: Applied Research

6. Date of start& duration: April 2017(3 Years)

7. Scheduled date of completion: March2020

8. Study Objectives:

- Assessment of water situation in the identified villages and carry out water budgeting exercise with the respective Gram Panchayats.
- Rejuvenation of identified village ponds through installation of appropriate Natural Treatment Systems.
- Carry out awareness generation and capacity building of the local villagers.

9. 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.

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. The location map of identified village ponds is given in Fig. 1.

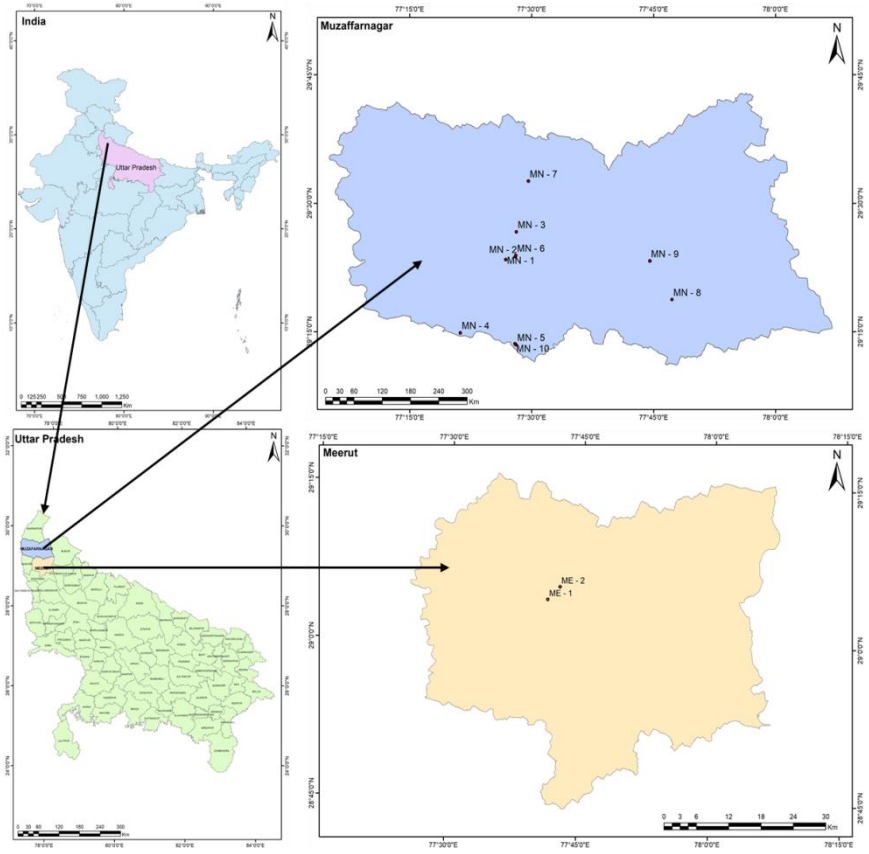


Fig. 1: Location map of identified village ponds in Muzaffarnagar & Meerut Dist.

10. Approved Action Plan/Methodology:

After field measurement of the dimensions of the ponds, DPRs were 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 (Floating Wetland) will be established in the limited no. of identified pond/s for treatment of the wastewater entering into these ponds. In order to ensure effectiveness of NTS, Screen Chamber, Grit Chamber and Sedimentation chamber will be provided at the identified locations of Inlet of waste water to the pond. Side walls/embankments of the ponds will be strengthened.

11. Timeline:

S. N.	Work Element/ Milestone	2017-18				2018-19				2019-20			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Data collection (baseline data of village/community) for existing ponds and identification of suitable												

	natural treatment s stem												
2	Carry out water budgeting / reuse exercise/LULC mapping around pond area for respective GPs												
3	Groundwater level measurement around ponds												
4	Water/wastewater sample collection and analyses												
5	Execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)												
6	Nursery development *(plant species for floating wetland)* at NIH, Roorkee												
7	Performance evaluation of Natural Treatment System												
8	Trophic State Analysis and Primary Production Capacity												
9	Capacity building/Mass Awareness & preparation of SOP for O&M of treatment system												
10	Submission of reports												

12. Achievements:

Objectives	**Achievements**
Rejuvenation of ponds by execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)-through NPCC/any Govt. Agency	• The ponds for the study were identified with the help of people representatives. • MoU was signed with the gram panchayats of the ponds to be undertaken for the study. • The consent from respective gram panchayats for undertaking the research work was undertaken. • MoU was signed with NPCC Ltd., Noida for execution of civil works and awarded work of 12 ponds. • *Rejuvenation work has been completed in all identified ponds* • *Floating wetland established in Munnawarpur Kalan village pond as per revised scope of work.*
Nursery development *(plant species for floating wetland)* at NIH, Roorkee	• The nursery for developing aquatic plant saplings has been established. • Approx. 5000 Reed Plant and 1500 Canna plant saplings has been raised and are ready for transportation to the site. • Demonstration setup for pilot scale NTS system is under progress. • *Nursery development work completed.* • *Nursery plants transported to the site/s for establishing Floating Wetland at identified pond site (Munawwarpur Kalan).*
Assessment of water/wastewater/ groundwater quality and	• Water quality data analyzed, compiled and the trophic status of ponds computed for pre rejuvenation stage. • Fieldwork for collection of sludge and soil samples completed for nine

sludge/soil characterization	ponds and the analysis of the same is under progress. • Infiltration test for the excavated pond bed carried out for nine ponds. • *Ground water samples and ground water level measured during the month of April & May 2019.* • *Total 33 samples collected and analysed for physico-chemical, microbiological & heavy metal anlaysis in the laboratory is completed.* • *Results compiled and interpretation of results is in progress.* • *Infiltration of 12 ponds completed and results compiled.* • *Soil samples collected from Agri. Lands around pond were analysed using PUSA kit and soil health card prepared.* • *Sludge samples collected from pond beds and analysis has been completed for trace metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg)* • *Water quality index of ground water samples completed.*

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	-

Village	PROGRESS OF R&D WORK		

14. Analysis & Results:

The civil work related to the rejuvenation of the ponds has been completed by the NPCC. Natural treatment system (Floating wetland) has been established in pond at Munnawarpur Kalan. The status/ progress of the civil works by NPCC is given below in Table 1:

Table 1: Status of rejuvenation of ponds in Muzaffarnagar and Meerut

Date: 01/10/19

RENOVATION & OTHER CONSTRUCTION WORK OF POND
STATUS OF WORK UPTO SEPTEMBER- 2019

S.No	Name of Pond and Village		Dewatering	Removal of Sludge	Periphery Drain work	Sedimention Tank	Screening Chamber at Inlet	Compaction of embankment & periphery	Floating Wetland Work	Depth of Pond (NGL)	Depth of Pond (Sludge)
A	Muzffarnagar & Meerrut (PACKAGE-1)										
1	Mohamadpur Madan-2	Baghra	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	4.87m	3.93m
2	Bhora Kalan	Shahpur	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	6.05m	4.46m
3	Bhora khurd-1	Shahpur	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	5.84m	4.12m
4	Bhora khurd-2	Shahpur	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	6.3m	4.58m
5	Itawa-1	Budhana	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	2.92m	2.43m
6	Itawa-2	Budhana	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	5.89m	5.89m
7	Biral	Budhana	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	2.45m	1.52
8	Munnawarpur Kalan	khatauli	Completed	Completed	Completed	Complete	Not required	Completed	Completed	4.32m	2.71m
9	Roni Hazipur	Charthawal	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	3.49m	1.8m
10	Antwara	Khatauli	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	3.75m	3.2m
11	Pavli khas	Pavlikhas	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	5.47m	4.16m
12	Siwaya	Shiwaya	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	4.11m	3.1m

Project Manager
NPCC Ltd.
Meerut Unit

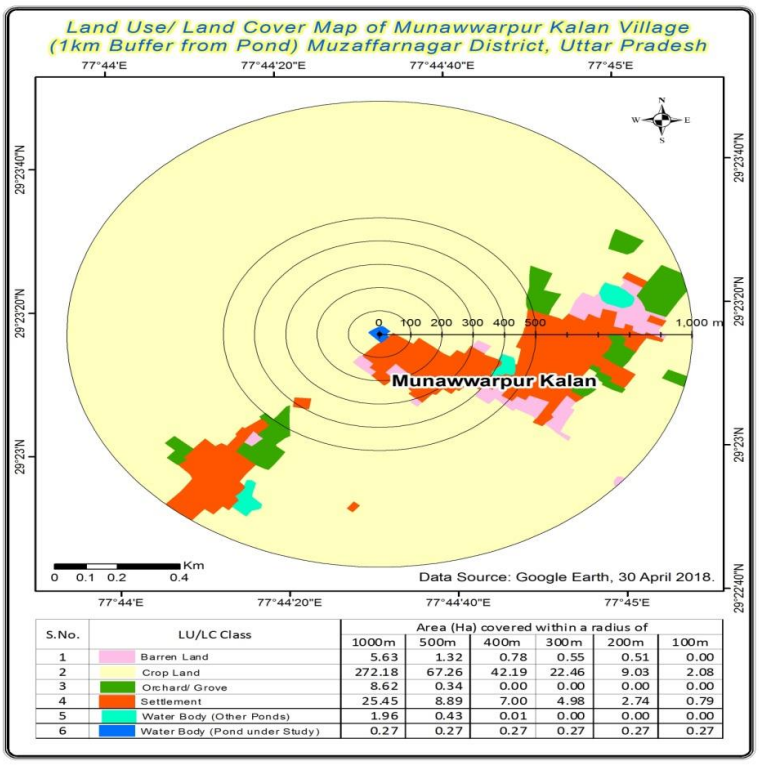
Name	Sludge Sampling	Soil Sampling		Infiltration Test	Ground Water Level Measurement	Ground Water Sampling	Agri. soil Sampling	Analysis of GW Samples	Analysis of Soil Samples
		Disturbed	Un-disturbed						
MUZAFFARNAGAR DISTRICT									
Mohammadpur Madan - 2	23/4/2019	water available in pond	water available in pond	water available in pond	23/4/2019	23/4/2019	23/4/2019	✔	In progress
Bhora Kalan	17/10/2018	17/10/2018	17/10/2018	4/12/2018	4/12/2018	4/12/2018	17/10/2018	✔	In progress
Bhora khurd-1	11/1/2019	11/1/2019	25/4/2019	25/4/2019	25/4/2019	25/4/2019	11/1/2019	✔	In progress
Bhora khurd-2	11/1/2019	11/1/2019	11/1/2019	11/1/2019	25/4/2019	25/4/2019	11/1/2019	✔	In progress
Itawa-1	9/1/2019	9/1/2019	9/1/2019	9/1/2019	24/5/2019	24/5/2019	9/1/2019	✔	In progress
Itawa-2	8/1/2019	8/1/2019	8/1/2019	8/1/2019	24/5/2019	24/5/2019	8/1/2019	✔	In progress
Biral	3/1/2019	3/1/2019	3/1/2019	3/1/2019	22/5/2019	22/5/2019	3/1/2019	✔	In progress
Munnawarpur Kalan	17/10/2018	17/10/2018	17/10/2018	17/10/2018	15/5/2019	15/5/2019	17/10/2018	✔	In progress
Roni Hazipur	24/4/2019	24/4/2019	24/4/2019	24/4/2019	24/4/2019	24/4/2019	24/4/2019	✔	In progress
Antwara	7/1/2019	7/1/2019	7/1/2019	7/1/2019	15/5/2019	15/5/2019	7/1/2019	✔	In progress
MEERUT DISTRICT									
Siwaya	15/10/2018	15/10/2018	15/10/2018	15/10/2018	23/5/2019	23/5/2019	23/5/2019	✔	In progress
Pavli Khas	18/3/2019	18/3/2019	18/3/2019	18/3/2019	24/5/2019	24/5/2019	18/3/2019	✔	In progress

Various field investigations (viz. infiltration tests, soil & sludge sampling, WQ, GWL) were carried out in the month of April & May 2019 at identified pond sites and detail of it given in Table 2. Total 33 ground water samples were collected and analyzed in laboratory for various parameters. pH of samples ranged from 6.3 to 7.9 in all the ground water samples. EC values ranged from 489 to 1744 µs/cm. The conductivity of water is affected by the suspended impurities and also depends upon the amount of ions in the water.TDS Ranged from 387 to 1205 mg/l. The TDS content represents the total

amount of inorganic substances, mainly salt, in the water. Turbidity in samples varied from 0.6 to 74.5 NTU. The determination of ORP is advisable in water that contains a relatively high concentration of a redox-active species e.g., organic carbon, the salts of many metals (Fe^{2+}, Mn^{2+}) and strong oxidising (chlorine, oxygen) and reducing (sulphite ion) agents. TH of samples ranged from 152 to 841 mg/l. All the samples were within the limit. Calcium ions make major contribution to the hardness of water. Total alkalinity ranged from 110 to 507 mg/l. Calcium concentration varied from 32.66 to 222.37 mg/l. Magnesium conc. ranged from 8.64 to 39.14 mg/l. Sodium concentration ranged from 12.2 to 66.54 mg/l and potassium value varied from 4.02 to 195 mg/l. Sulfate ranged from 2.55 to 108 mg/l. A common source of sulfate and Ca in groundwater is gypsum(CaSO4·2H2O). Nitrate concentration ranged from 0 to 90 mg/l in ground water samples.

Table 2: Field Investigations at Identified Ponds in Muzaffarnagr and Meerut Dist.

Bacteriological analysis for total coliform and E.coli was performed using coli-alert method and total coliform results showed satisfactory for all the samples collected but in Mohammadpur Madan-01 (14.6 MPN/100 ml), Ronihazipur-01 (25.9MPN/100ml), Bhora khurd-02 (1732.9 MPN/100 ml), Munawarpur Kalan-03 (1 MPN/100ml), Munawarpur Kalan -04 (248.9 MPN/100ml), Munawarpur Kalan-05 (1 MPN/100ml) Antwara-02 (>2419.6 MPN/100ml), Antwara-04 (218 MPN/100ml) total coliform were present. E .coli were found in Bhora khurd-02, Antwara-02 & Antwara-04 samples. Heavy metal results of ground water samples showed high concentration of aluminum in Mohammadpur Madan-01 & Mohammadpur Madan-02 samples as per BIS 2012. Cd, Cr, Mn, Ni, Pb and Zn concentration in all the samples showed within the limit. Iron (Fe) concentration found high in all the ground water samples as per BIS 2012 standards i.e. 0.3 mg/l. PUSA kit test for samples has been completed and based on this soil health card has been prepared for different crops. The LULC maps of the area around pond surroundings (upto 1 km) were prepared for reuse planning of the treated pond water (Fig.2). The progress against R&D related activities in this project is summarized in Table as given below:



S.No.	LU/LC Class	Area (Ha) covered within a radius of					
		1000m	500m	400m	300m	200m	100m
1	Barren Land	5.63	1.32	0.78	0.55	0.51	0.00
2	Crop Land	272.18	67.26	42.19	22.46	9.03	2.08
3	Orchard/ Grove	8.62	0.34	0.00	0.00	0.00	0.00
4	Settlement	25.45	8.89	7.00	4.98	2.74	0.79
5	Water Body (Other Ponds)	1.96	0.43	0.01	0.00	0.00	0.00
6	Water Body (Pond under Study)	0.27	0.27	0.27	0.27	0.27	0.27

Fig. 2: LULC map of Munawarpur Kalan

15. **End Users / Beneficiaries of the Study:** Villagers and Stakeholders

16. **Deliverables:** Rejuvenated village ponds, Estimated potential of fish production for the Gram Panchayats, Standard Operating Procedures (SOP) for O&M of treatment system in village ponds, Technical report(s) and publications.

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** WQL, S&W Lab, GWHD (NIH)/ IIC (IITR)

19. **Data procured or generated during the study:** Groundwater quality, Pond water Quality, Village wastewater quality, Trophic Status Index of pond, Pond productivity test, Groundwater level, Infiltration rate at pond bed, Permeability, Leachability of trace metals and nutrients in the sludge

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond and also enhance the groundwater water quality of the area. This study will also help in replication of the technology in other village ponds of other districts of the country.

21. **Involvement of end users/beneficiaries:** Villagers & Gram Panchayats

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:** NA

24. **Future Plan:** As per approved action plan

Sponsored Project-4 (Sponsored by MoJS-through Plan Fund)

1. Title of the Study: Rejuvenation of Village Ponds in Identified Villages of Baghpat, Ghaziabad and Meerut Districts of Uttar Pradesh

2. Study Group:

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigator Dr. Rajesh Singh, Sc. C, EHD Dr. V. C. Goyal, Sc. G, RMOD Er. Digambar Singh, Sc. C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N. R. Allaka, RA Dr. N. G. Shrivastava, Senior Expert Dr. Nihal Singh, Research Scientist Dr. Kalzang Mathus, Research Associate Sh. Sandeep Yadav, Research Associate Sh. Subhash Vyas, Project Assistant
Civil Work Execution Agency	NPCC Limited (A GoI Enterprise), Noida

3. Type of Study: Invited study by MoWR, RD & GR,

4. Budget: Rs. 856.94 Lakh

5. Nature of Study: Applied Research

6. Date of start & duration: Jan. 2018 (3 Years)

7. Scheduled date of completion: Dec. 2020

8. Study Objectives:

a. Rejuvenation of identified village ponds by carrying out de-weeding, de-silting and associated civil works for development of Natural Treatment System (NTS) in the ponds for their rejuvenation.
b. Establishment of appropriate phyto-remediation based Natural Treatment System (NTS) technology for treatment of wastewater entering into these ponds,
c. Performance evaluation of the NTS based rejuvenated ponds and assessment of treated wastewater for irrigation and fishery by monitoring relevant water & wastewater quality parameters, groundwater levels, etc.
d. Capacity building and Mass Awareness Activities.

9. Statement of the Problem:

With the availability of millions of village ponds and local drains, there exists a vast potential of recycling and reuse of wastewater through simple retrofitting techniques. Such decentralized treatment of these small water bodies is an emerging need for their restoration and preservation, leading to multiple benefits of disaster resiliency, groundwater recharging, environment

regeneration and livelihood generation at the local watershed level. The Ministry of WR, RD & GR (GoI) directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Bagpat, Ghaziabad and Meerut (Fig. 1).

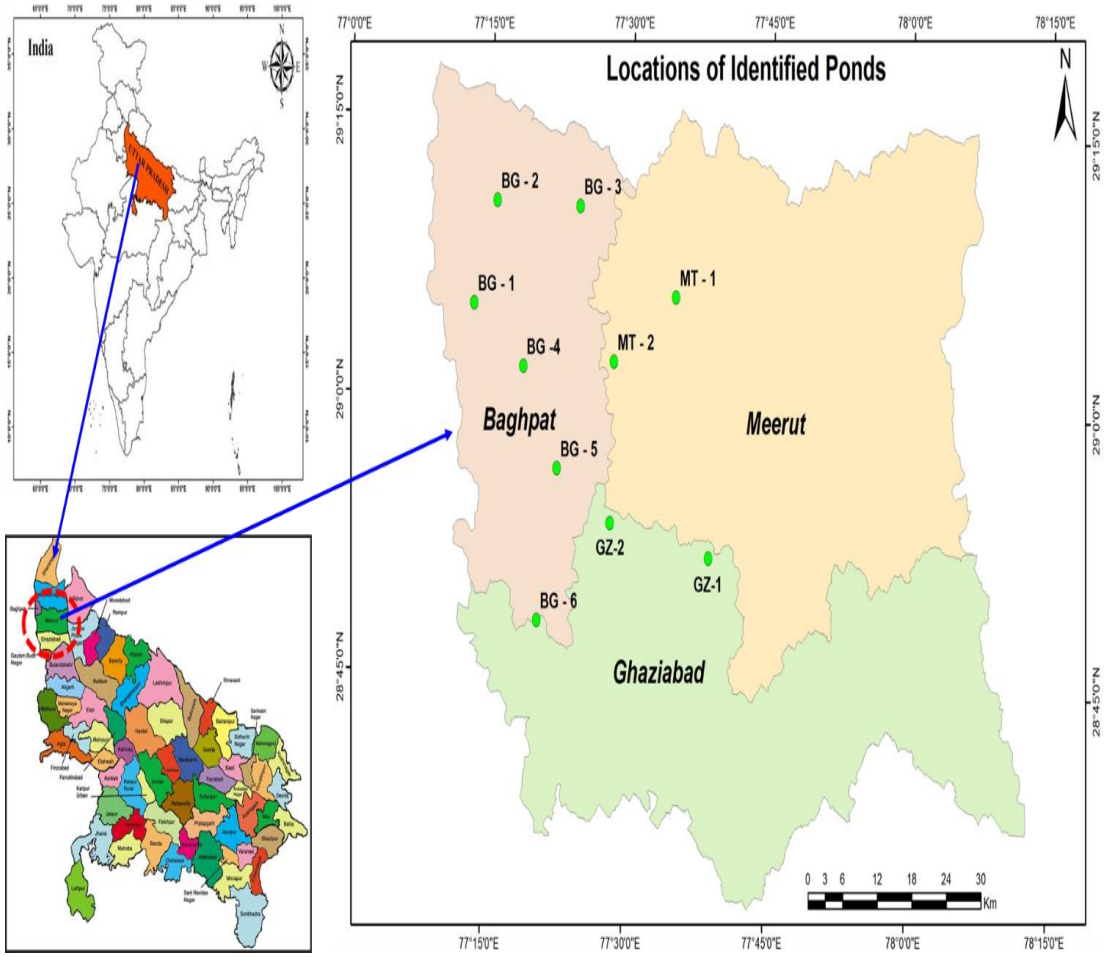


Fig.1 : Location map of identified village ponds in Baghpat, Ghaziabad & Meerut Dist.

At present, the wastewater generated from most of the villages in the country is discharged into the village ponds and leads to eutrophication of these ponds and growth of blue green algae, making the water toxic and unfit for the consumption, even by animals. Moreover, the organic laden water in the pond during recharge to the aquifer transports organics into the aquifer material enhancing the undesirable anaerobic microbial action on the aquifer media resulting in the dissolution of toxic metals like arsenic etc. into the groundwater. The polluted water resources lead to dramatic human cost. Keeping in view of the above issues related to contamination of water resources and wastewater management in the villages, the ministry directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Bagpat, Ghaziabad and Meerut. Accordingly, the research proposal has been formulated which will address the problem related to deteriorating health of village ponds and the declining groundwater levels as well as quality in the villages of western UP on a pilot scale, the results from which can be replicated in other villages of the country.

10. Approved Action Plan/Methodology:

- Reconnaissance survey of identified village ponds for data collection along with sampling and analysis of wastewater input to the pond
- Designing and erection of suitable natural treatment system (CWT) for carbon and nutrient removal.
- Technology demonstration and performance (technical/chemical) evaluation
- Health Assessment of Water Body
- Reuse of Treated Water & Sludge
- Hygienic and health impact assessment
- Technical guidelines for design and technology application
- Mass Awareness/capacity building

11. Timeline:

Sr. No.	Activities	YEAR 1				YEAR 2				YEAR 3			
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
1	Identification of study site												
2	Site survey, sampling and analysis of samples												
3	Detailed engineering design												
4	Construction of CW based treatment plants												
5	System optimization												
6	Technology demonstration and performance evaluation												
7	Health Assessment of Water Body												
8	Reuse planning of Treated Pond Water												
9	Hygienic and health impact assessment												
10	Mass awareness/Capacity building												
11	Technical report												

12. Objectives and achievement during last twelve months:

Objectives	**Achievements**
Identification of study site	• The ponds for the study were identified based with the help of people representatives.
Site survey, sampling and analysis of samples	• A field survey of the experimental sites were conducted in the month of May 2018 and 63 samples from ponds, inlet water to ponds, and groundwater were collected. • Trace metal analysis of the samples were completed and results compiled. • Pond bed soil (disturbed and undisturbed), sludge and agricultural soil sample collected from Palri and Ikari village and analysis is in progress in soil laboratory. • Infiltration rate test conducted in Palri and Ikari. • For leachability test, 9 samples were collected from Palri, Ikari and Dagarpur villages and sample preparation for analysis of heavy metals is in process. • Nutrient analysis of samples is in process using PUSA kit. • *Ground water samples and ground water level measured during the month of April & May 2019.* • *Ground water level also measured.* • *Total 33 samples collected and analysed for physico-chemical, microbiological & heavy metal analysis in the laboratory is completed.* • *Results compiled and interpretation of results is in progress.* • *Infiltration of 4 ponds completed and results compiled.* • *Soil samples collected from Agri. Lands around ponds which have been analysed using PUSA kit and prepared soil health cards.* • *Sludge samples collected from pond beds and analysis has been completed for trace metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg)*
Construction of CW based NTS	• Rejuvenation work has been completed for the 9 identified ponds. • *Floating wetlands established in Basoli and Ikari village ponds as per revised scope of work.*
Nursery development for aquatic plants at NIH, Roorkee	• The nursery for developing aquatic plant saplings has been established. • Approx. 5000 Reed Plant and 1000 Canna plant saplings has been raised and are ready for transportation to the site. • Nursery development work completed. • *Nursery plants transported to the site/s for establishing Floating Wetland at identified pond site (Basoli & Ikari)*

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	-

14. Analysis & Results:

The civil work related to the rejuvenation of the ponds has been completed by the NPCC. Natural treatment system (Floating wetland) has been established in pond at Basoli and Ikari as per revised scope of work. The status/ progress of the civil works by NPCC is given below in Table 1:

Table 1: Status of rejuvenation of ponds in Baghpat, Ghaziabad and Meerut

Date: 01/10/19

RENOVATION & OTHER CONSTRUCTION WORK OF POND

STATUS OF WORK UPTO SEPTEMBER- 2019

S.No	Name of Pond and Village		Dewatering	Removal of Sludge	Periphery Drain work	Sedimention Tank	Screening Chamber at Inlet	Compaction of embankment & periphery	Floating Wetland Work	Depth of Pond (NGL)	Depth of Pond (Sludge)
B	Baghpat & Ghaziabad (PACKAGE-2)										
1	Budhara	Pacchalapatti	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	2.37m	2.07m
2	Pilana	Guhali	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	4.28m	4.03m
3	Basoli	Brahamanwala	Completed	Completed	Completed	Complete	Not required	Completed	Completed	3.56m	2.63m
4	Dagarpur	Pallaymohalla	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	3.97m	2.89m
5	Dikana	Pattidahaewan	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	3.35m	2.83m
6	Paldi	Tyagiwala	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	4.7m	3.23m
7	Khiondora	Devtawala	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	2.88m	2.36m
8	Ikari	Bindawalla	Completed	Completed	Completed	Complete	Complete	Completed		3.8m	1.88m
9	Saidpur	Chauthipatti	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	4.52m	3.7m

P.M

Project Manager
NPCC Ltd.
Meerut Unit

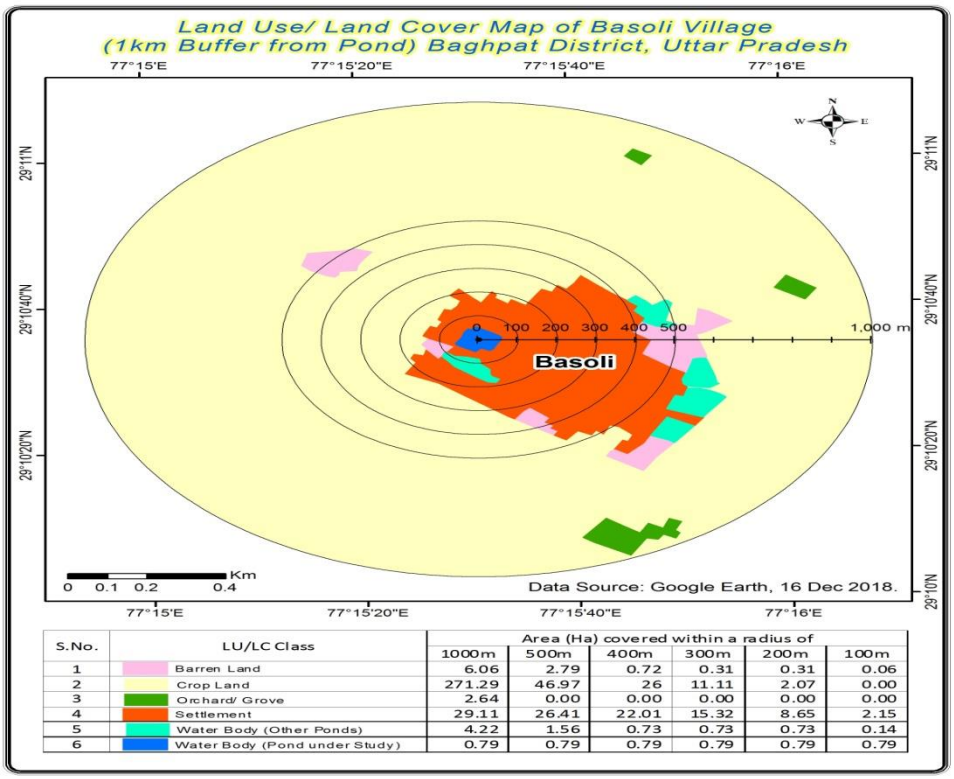
Field investigation was carried out in the month of April & May 2019 and detail of it given in Table 2. Total 33 ground water samples were collected and analyzed for various physico–chemical analysis. Results of the study showed that pH and EC of samples ranged from 6.1 to 8 and 473 to 1596 µs/cm. TDS of ground water samples were within the limit. Turbidity ranged from 1.13 to 166 NTU. Total alkalinity varied from 227.3 to 507 mg/l. Total Hardness varied from 160.75 to 579.11 mg/l except for Pilana (HP-03) samples value was high above the limit as per BIS 2012 (600 mg/l). Magnesium value of Pilana (HP-03) was above the limit and calcium in all sample was within the limit. Total alkalinity was well within the limit. Sodium and potassium ranged from 25 to 159 mg/l and 3.89 to 42 mg/l.

Nitrate values in Ikari (HP-03) and Pilana (HP-03) found to be high above the limit (45 mg/l). Sulphate in ground water samples were within the limit.

Bacteriological test were conducted using coli-alert method. The samples were incubated for 48 hours and the presence of total coliforms was observed by the change in colour. Bacteriological result of the groundwater samples shows high pathogenic contamination. Out of 33 samples 15 samples found presence of total coliform and 5 samples contaminated with E.coli bacteria. Ideally, total coliforms should not be present in drinking water and their presence makes it unfit for human consumption. Presence of coliforms indicates contamination of water due to organic material. The trace metals such as As, Cd, Co, Cu, Cr, Pb, Fe, Zn, Mn were analyzed and results showed Fe concentration in ground water samples were found to be high as per BIS 2012. On the basis of PUSA kit results soil health card prepared. The LULC maps of the area around pond surroundings (upto 1 km) were prepared for reuse planning of the treated pond water (Fig.2).

Table 2: Field Investigations at Identified Ponds in Baghpat, Ghaziabad and Meerut Dist.

Village	Progress of R&D WORK								
	Sludge sampling	Soil sampling		Infiltration Test	Ground Water Level Measurement	Ground Water Sampling	Agri. Land-soil sampling	Analysis of GW Samples	Analysis of soil samples
		Disturbed	Un-disturbed						
BAGHPAT									
Budhera	15-03-19	15-03-2019	15-03-2019	15-03-2019	21-05-2019	21-05-2019	15-03-2019	✔	In progress
Pilana	18-03-2019	-			20-05-2019	20-05-2019	15-03-2019	✔	In progress
Basoli	14-03-2019	14-03-2019	14-03-2019	14-03-2019	23-04-2019	23-04-2019	14-03-2019	✔	In progress
Dagarpur	04-02-2019	-			20-05-2019	20-05-2019	04-02-2019	✔	In progress
Dhikana	19-03-2019	-			16-05-2019	16-05-2019	19-03-2019	✔	In progress
Paldi	15-10-2018	15-10-2018	15-10-2018	15-10-2018	14-05-2019	14-05-2019	04-02-2019	✔	In progress
MEERUT									
Ikari	10-01-2019	10-01-2019	-	10-01-2019	14-05-2019	14-05-2019	10-01-2019	✔	In progress
GHAZIABAD									
Saidpur	29-04-2019	-			29-04-2019	29-04-2019	29-04-2019	✔	In progress
Khindora	28-04-2019	-			28-04-2019	28-04-2019	28-04-2019	✔	In progress



S.No.	LU/LC Class	Area (Ha) covered within a radius of					
		1000m	500m	400m	300m	200m	100m
1	Barren Land	6.06	2.79	0.72	0.31	0.31	0.06
2	Crop Land	271.29	46.97	26	11.11	2.07	0.00
3	Orchard/ Grove	2.64	0.00	0.00	0.00	0.00	0.00
4	Settlement	29.11	26.41	22.01	15.32	8.65	2.15
5	Water Body (Other Ponds)	4.22	1.56	0.73	0.73	0.73	0.14
6	Water Body (Pond under Study)	0.79	0.79	0.79	0.79	0.79	0.79

Figure 2: LULC Map of Basoli

15. **End Users / Beneficiaries of the Study:** Villagers and Stakeholders

16. **Deliverables:** Technical reports, SOP & research publications

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** WQL, S&W Lab, GWHD (NIH)/ IIC (IITR)

19. **Data procured or generated during the study:** Groundwater level, Groundwater quality, Pond water Quality, Trophic Status Index, Pond productivity test and Village wastewater quality.

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond, enhance the groundwater water quality of the area, and increase the income of Gram Panchayats through Pisciculture. This study will also help in replication of the technology in other village ponds of various districts, where there is scarcity of freshwater is found.

21. **Involvement of end users/beneficiaries:** Villagers & Gram Panchayats

22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes

23. **Shortcoming/Difficulties:** NA

24. **Future Plan:** As per approved action plan

Sponsored Project-5

2. Title of the Study:

Development of water allocation plan for identified watersheds in Kanker district (Chhattisgarh)

3. Study group:

Dr A. R. Senthilkumar, Sc "F" RMOD
Dr. T R Nayak, Sc "F", RC, Bhopal
Dr. Jyoti P Patil, Sc "C", RMOD
Sh. Rohit Sambare, Sc "B", RMOD
Sh. Rajesh Agarwal, SRA, RMOD

4. Date of start: April 2018

5. Duration of the study: 2 Years

6. Whether externally funded or not: No

7. Objectives:

a. To model the different components of hydrological process.
b. To evolve water allocation plan for various uses by scenario analysis.

8. Statement of the problem

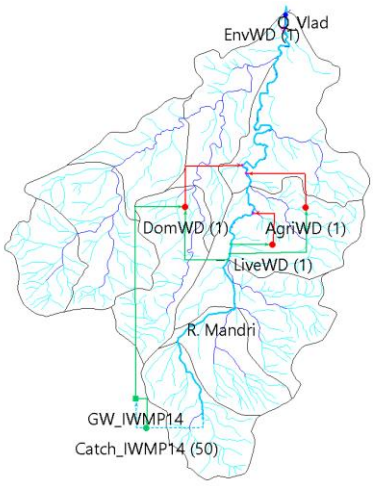
The demand for water from agricultural, industrial and domestic uses is continuously increasing due to the development in their respective sectors. The fixed availability and uncertainty over the occurrence of water increases the complexity of allocation of water to the competing demands from various sectors. It is imperative to evolve management plans for the allocation of water in efficient way to achieve optimum crop yield without compromising the demands for domestic and industrial uses. Allocation of limited water resources among agricultural, domestic and industrial uses requires the integration of supply, demand, water quality and ecological considerations. The Conventional supply-oriented simulation models are not always adequate for exploring the full range of management options for water allocation. Water Evaluation And Planning (WEAP) tool integrates all tools in a robust way for integrated water resources planning.

9. Methodology

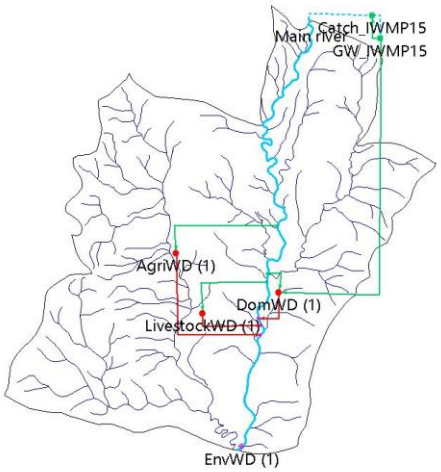
The water allocation plan among different uses in micro watersheds in Chhattisgarh is evolved by setting up of WEAP tool. The inputs to WEAP tool such as water demand from various sectors, priority of the demand, catchment details, hydrologic conditions and inflows, catchment hydrology (river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc), supply preference (operating rules/policy), return flows, minimum flow requirements, economic variables such as cost water transmission etc are prepared from the data obtained from various sources such as irrigation department, IMD, CWC, census department. The hydrological processes occurring in the catchment will be modeled and will be compared with the measured discharge time series. After the proper calibration of the model, the demand sites will be added into a model framework and different scenarios will be generated to assess the gaps in the water demand and supply and water availability at different locations and at the different period. The different water allocation plan will be evolved based on the scenario analysis to achieve optimum crop yield.

10. Results achieved with progress/present status:

The WEAP model has been setup for micro watersheds IWMP14, IWMP15 and IWMP16 using the climate data such as rainfall from IMD data, reference evapotranspiration for crops, population data and livestock details, area under different crops, priority for supply from DPR, crop coefficient, etc. The runoff computation is done using the simplified coefficient. The schematic diagram of the model setup for IWMP 14 and 15 are given as follows:



Schematic diagram for IWMP 14



Schematic diagram for IWMP 15

The catchment area of IWMP 14 and IWMP15 are 66.73 and 46.56 sq.km. respectively. The details of crop, its area and water requirement for each crop for IWMP 15 are given as follows:

Sl. No	Type of crop	Area in m^2	Annual water use rate in m^3
1	Gram_Kharif	3500	60
2	Kulthi_Kharif	9200	60
3	Maize_Kharif	6750	55
4	Paddy_kharif	227786	125
5	Urad_Kahrif	2270	55
6	Gram_Rabi	6500	34
7	Kulthi_Rabi	2000	60
8	Peas_Rabi	4000	35
9	Sunflower_Rabi	260	35

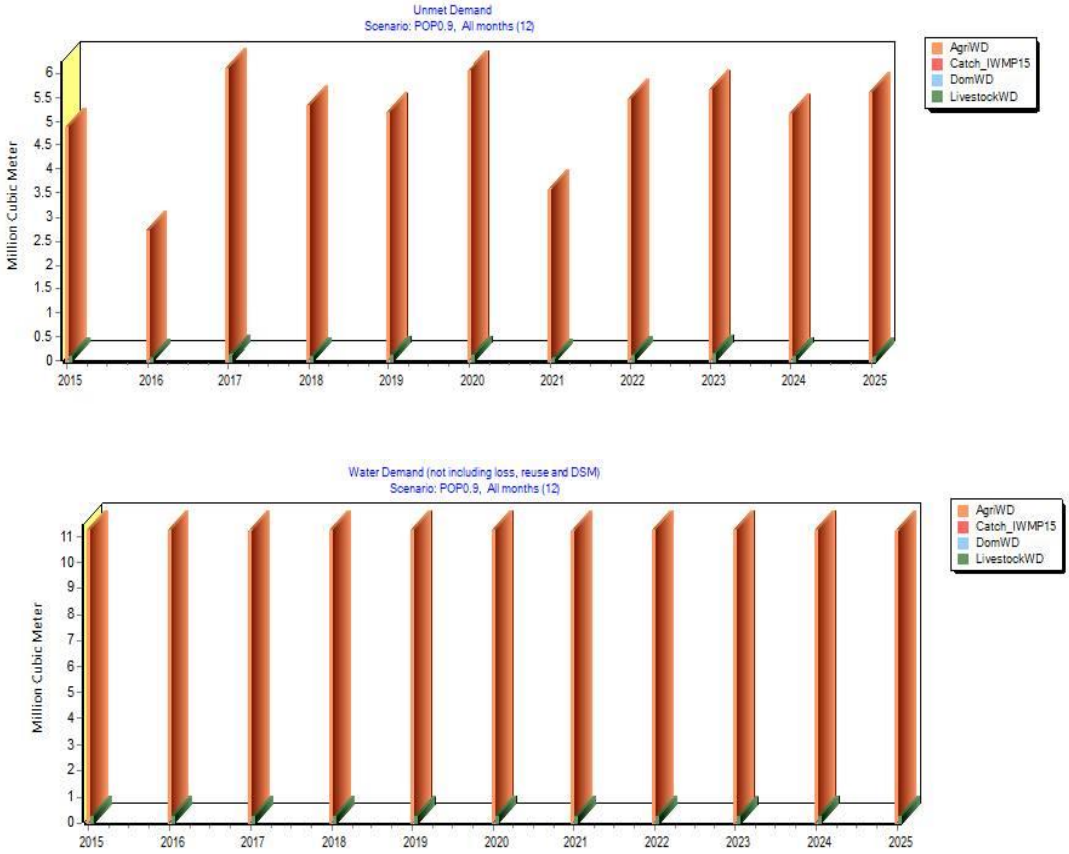
The details of livestock and its water requirement are given as follows:

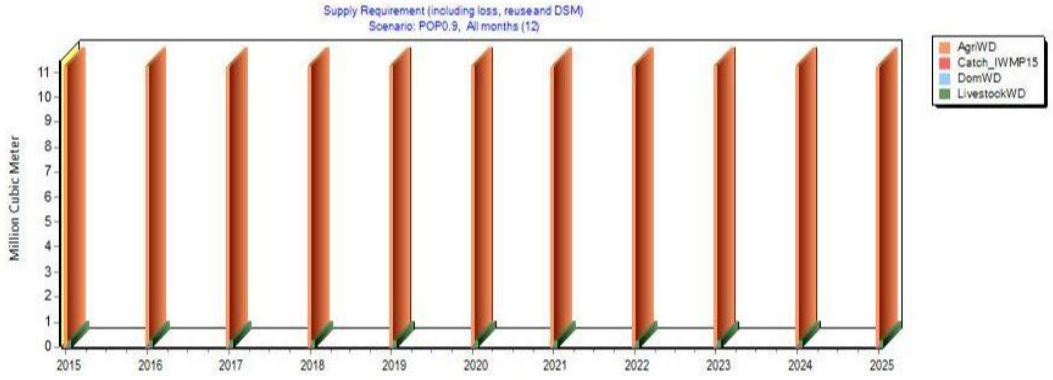
Sl. No	Type of livestock	Population	Annual water use rate in m^3
1	Buffaloes	134	56.575
2	CB cows	516	73

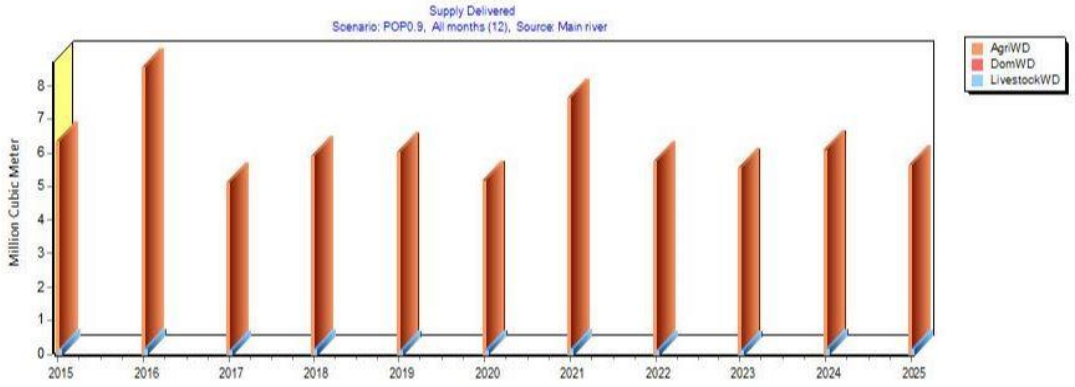
3	Draft animal	1694	91.25
4	Goat	1094	3.65
5	Indigenous Cows	427	49.275
6	Sheep	35	3.65

The population for base period (2015) of 7639 is considered for current scenario in the model and the reference period is 2016-2025. The population based on 1991, 2001 and 2011 census are 4117, 5787 and 7294 from IWMP15 DPR and the growth rate from 1991 to 2001 and 2001 to 2011 are 4.03% and 2.53% respectively. The projected population growth rate for Chhattisgarh based the report of technical group on population protestations constitute by the National Commission on Population (Census of India 2001) for the periods 2001-05, 2006-201, 2011-15, 2016-20 and 2021-2025 are 1.6%, 1.5%, 1.3%, 1.1% an d 0.9% respectively. So projected population growth rates from 0.9 % to 1.3% are considered for carrying out scenario analysis and the results for the scenario for population growth of 1.1% are given as follows:

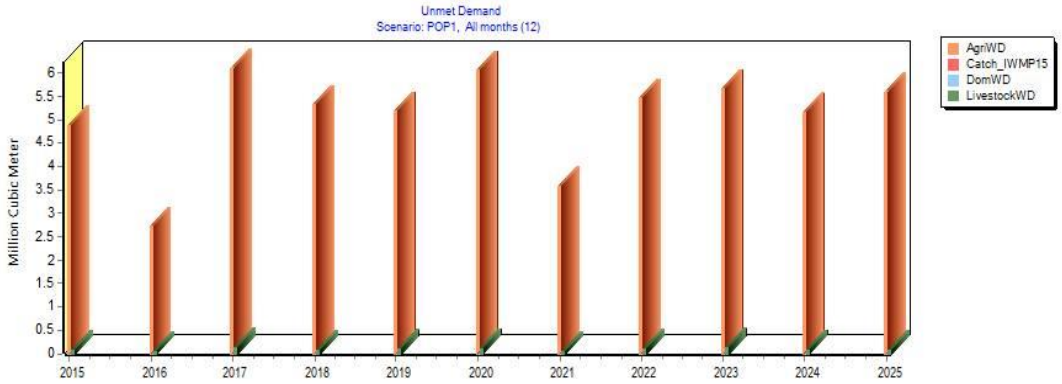
Scenario of population growth rate at 0.9% per annum

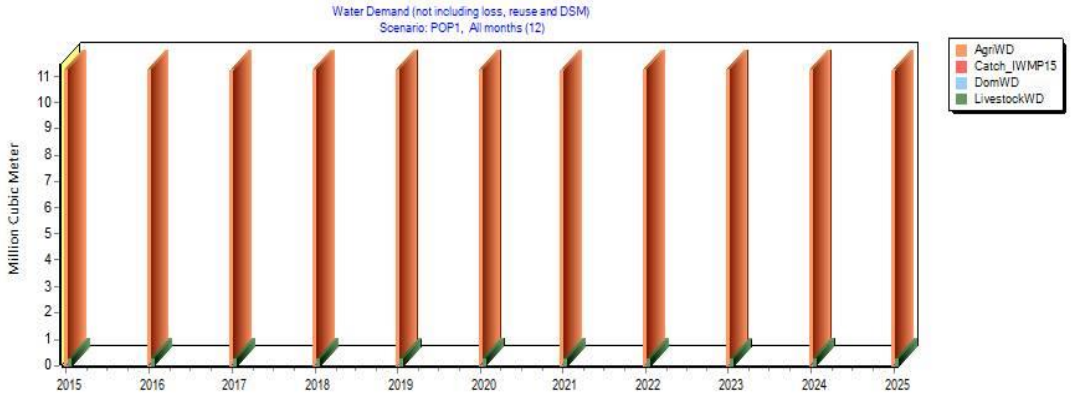


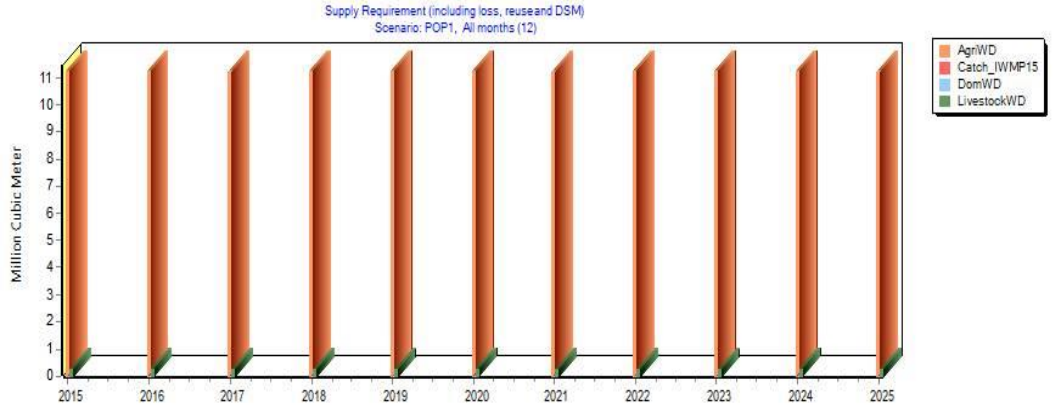


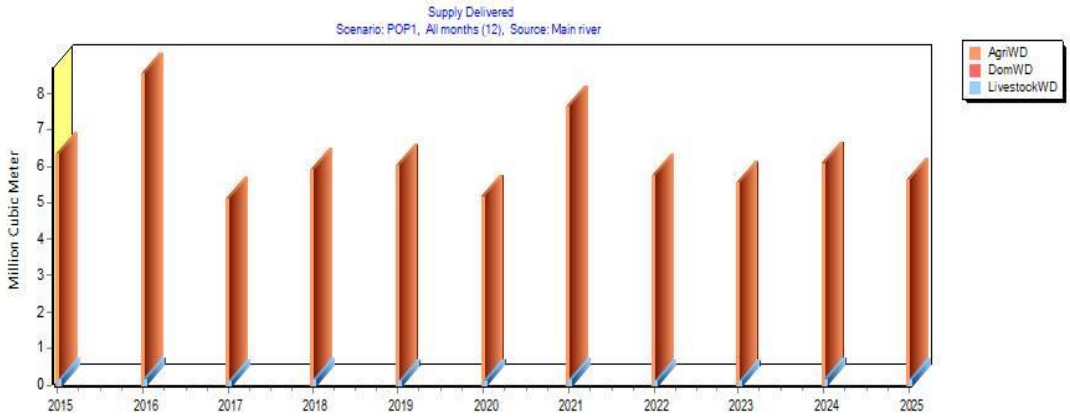


Scenario of population growth rate at 1% per annum

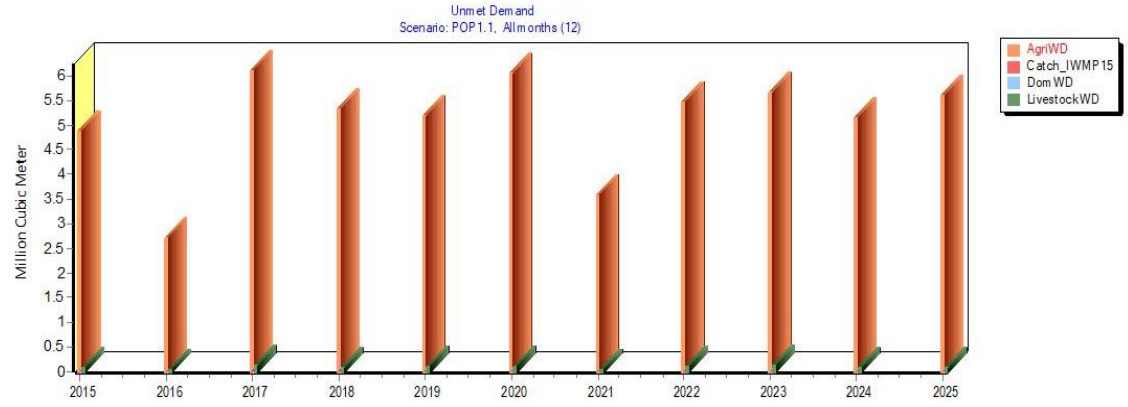


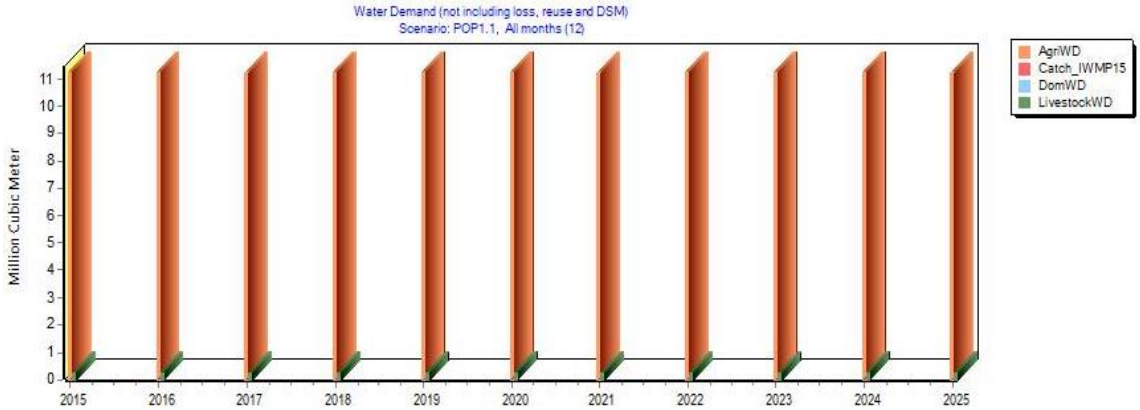


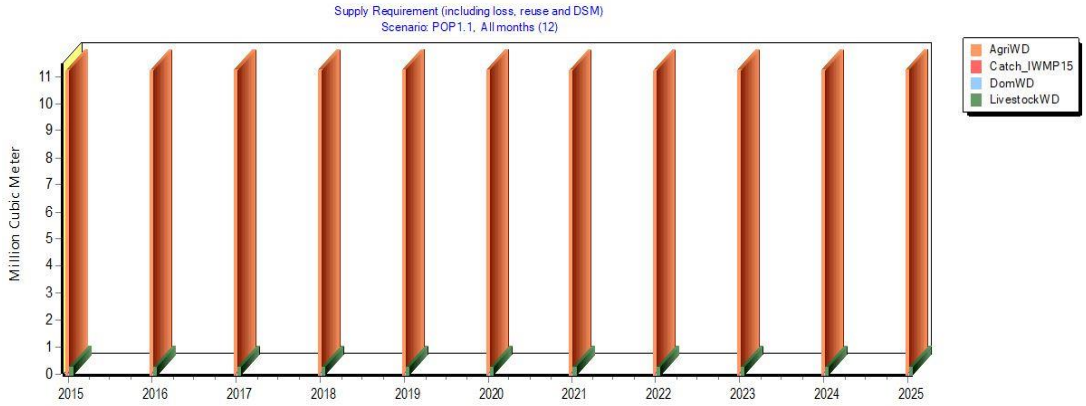


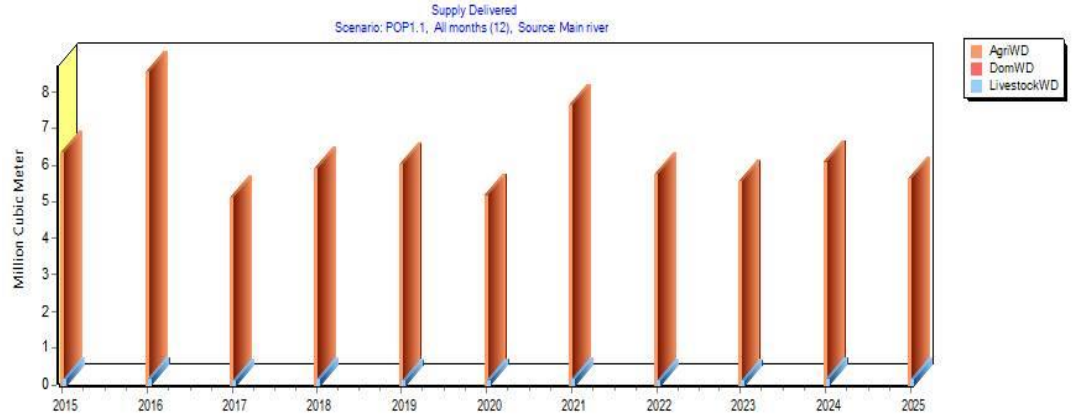


Scenario of population growth rate at 1.1% per annum

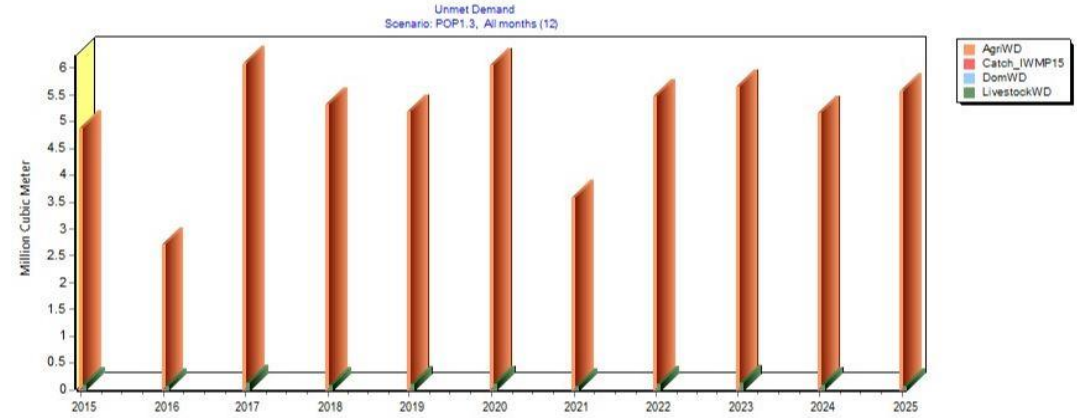


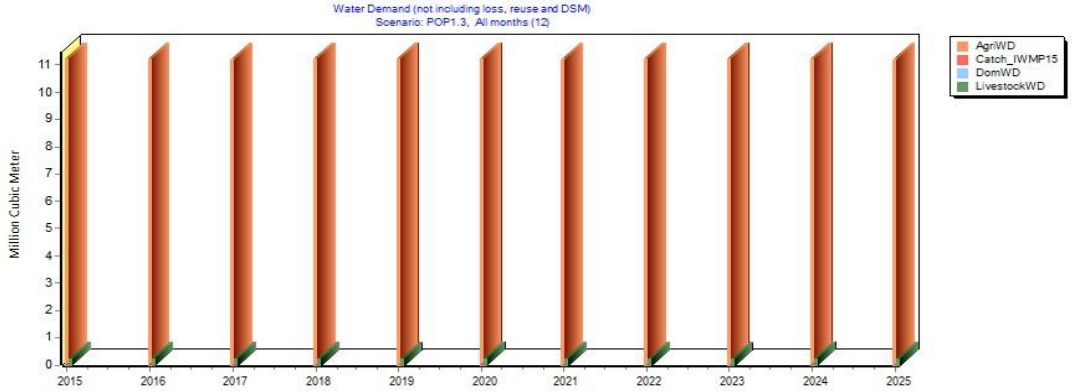


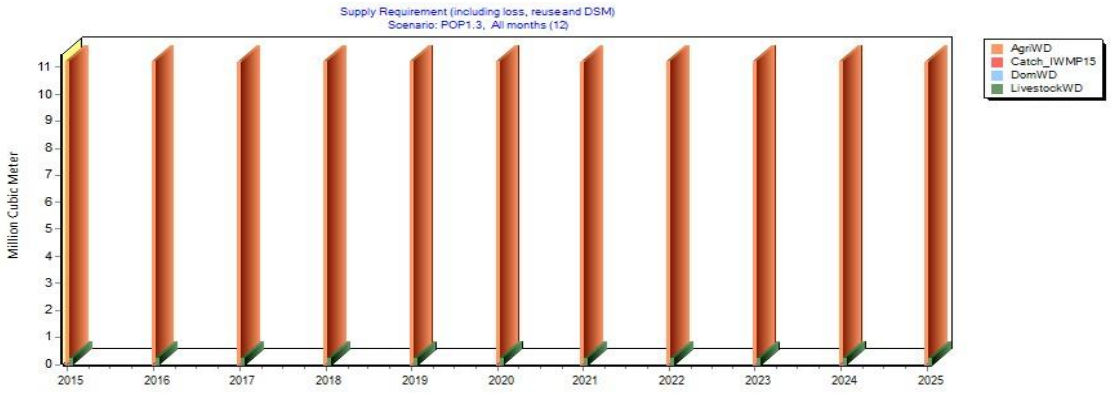


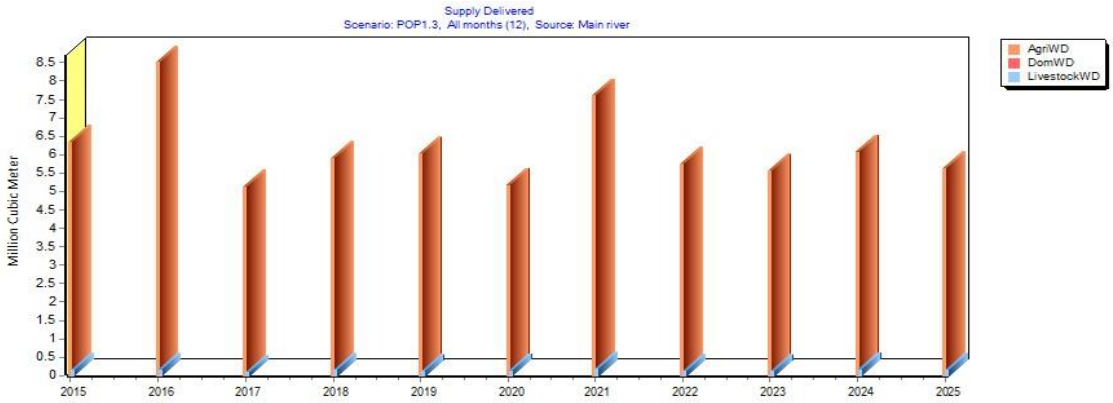


Scenario of population growth rate at 1.3% per annum









The other scenario analysis for water supply for very dry, dry, normal, wet, very wet are being worked in combination with projected population growth.

11. Research outcome from the study

Expected date of completion**: 31 March 2020**

12. Timeline

Sl. No.	Work Element	2018-19				2019-20			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Literature review								
2	Collection of hydro meteorological data, satellite images, thematic maps etc.								
3	Compilation and verification of hydro-meteorological data, baseline survey data, census data and other qualitative data								
4	Preparation of input data for WEAP model								

5	Simulation of components of hydrological processes using SWAT model								
6	Water allocation plan for different uses by scenario analysis by WEAP model								
7	Report writing								

Sponsored Project-6

SN	Title of Project/Study	Funding	Study Team	Duration
1	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI), Cost: Rs. 5.1 Crore	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad	Apr 2019-Mar 2024

The project **'Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)'** is funded by Department of Science & Technology (DST), Government of India. The National Institute of Hydrology (NIH) Roorkee is the leading institute for implementation of this project, in collaboration with the project partners from Indian Institute of Technology Bombay (IITB), Malaviya National Institute of Technology (MNIT), Jaipur and Institute of Rural Management Anand (IRMA), Ahmedabad.

Following activities have been completed/ in progress under the projects:

1. **Inception cum Need Assessment Workshop**

   The first Inception cum Need Assessment Workshop for the project, held from 8-9 August 2019, was organized by National Institute of Hydrology (NIH) Roorkee, in collaboration with the project partners. A total of 50 participants from 17 organisations took part in the workshop, including two representatives from the Department of Science and Technology (DST) (Annexure-2). The workshop was structured in a way to spend more time on brainstorming the ideas and discussing the gaps and need associated with the Natural Treatment System (NTS) technologies in India. As anticipated, the workshop was highly participative owing to the several interactive sessions between the stakeholders with a range of experience and expertise (i.e., administrative authorities, research institutes, universities, water utilities, NGOs, and Gram Panchayat). The successful completion of the event enlightened the future actions plan for the IC-EcoWS project.

2. **Project flyer**

   During the inception workshop, the emphasis was given to publish a project flyer, for distribution in various events, for wider publicity and awareness among the stakeholders. Accordingly, project flyer has been published

3. **Webpage of the project**

   The webpage of the project is prepared and hosted on NIH website http://nihroorkee.gov.in/major-projects/ic-ecows

4. **Social media pages**

   Facebook and twitter pages of the project are created.

5. **Procurement of the equipment:** In progress

Activities under INC-IHP during 2019-20

Meetings to be organised/ attended

1. 7th meeting of the IHP Regional Steering Committee for Asia and the Pacific, to be held at Myanmar in 2019

Thematic Trainings:

2. Training course on 'Water Security Assessment for Nation Building' during July 2019 at NIH, Roorkee

Brainstorming sessions

Sl. No.	INC-IHP proposed event	Conference/ Summit	Host Organisation	Location	Date
1.	Brainstorming session on Theme-V 'Ecohydrology-Engineering Harmony for a Sustainable World'	Water future Conference	Sustainable Water Future Programme, Indian Institute of Science, Bengaluru and Divecha Centre for Climate Change	Bengaluru	24-27 September, 2019

Other Activities:

- RMOD participated in the IWW exhibition held during September 24-28, 2019 at Vigyan Bhavan/IGNCA, New Delhi.

- RMOD participated in exhibition "Destination Uttarakhand-2019", during July 18-20, 2019 in Dehradun organized by UCOST (Gov. of Uttrakhand).